Review of the draft long-term water resource assessment for southern Victoria

Review Panel report

November 2019

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EPA response to its expert panel review of the Long-Term Water Resources Assessment (LTWRA) for southern Victoria

The 2004 'White Paper: Securing of Water Future together' set the framework for Victoria's future water security, including the requirement for the development of Sustainable Water Strategies (SWSs) to deliver stable and sustainable allocation of water to all users. It also specified that the status of the resource base and waterway health, and whether either is suffering a decline, be assessed at regular 15–year intervals.

The Department of Environment, Land, Water and Planning (DELWP) have released draft reports on the first assessment of long-term water resources in southern Victoria. Environment Protection Authority Victoria (EPA) commissioned a review of the draft assessment reports conducted by an independent expert panel (the Panel). The Panel's review is contained in this report as well as EPA's response to their review. The Panel generally agreed with the conclusions drawn in DELWP's assessments (as well as the data and methods of analysis underpinning them) but notes some areas where improvements could be made in future assessments.

Review process and scope

As required under Clause 22L of the *Water Act 1989* (the Act), DELWP is required to conduct a Long-Term Water Resources Assessment (LTWRA) to 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.

Clause 22N of the Act also specifies that the LTWRA must be reviewed (the Review) by the EPA. The Review must consider:

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

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

(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.

This LTWRA does not cover the whole state and only includes the southern draining basins. The northern basins, all in the Murray-Darling Basin, are to be assessed in 2025 when the Murray-Darling Basin Plan is reviewed. This is the first time the LTWRA has been conducted and reviewed.

EPA conducted the Review through engaging a highly qualified and independent panel of experts in the fields of hydrology, groundwater, ecology and statistics, who also have a good understanding of the water allocation framework in Victoria. Due to the novelty and complexity of the work being undertaken by DELWP for the LTWRA, EPA and the Panel met, questioned and briefed DELWP as the work progressed. Through these meetings with DELWP, the Panel sought to clarify and identify areas of concern to inform EPA's Review.

This report outlines EPA's response to the review of the LTWRA for southern Victoria, in accordance with the requirements Clause 22N of the Act.

Summary of EPA's review

Overall, EPA's review found in relation to the aspects assessed under clause 22N of the Act:

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 assessment are supported by the methodology and data. EPA notes that data constraints have impacted the ability to make conclusive findings about waterway health, and that, given these constraints, the inconclusive finding is appropriate.

Some further detailed feedback on specific aspects of the review is summarised below.

Surface water availability

The LTWRA found that the current (1975-present) long-term surface water availability across the 18 river basins in southern Victoria has declined by between 4 and 21 per cent compared to when it was last estimated for the SWSs.

EPA endorses the methodology used by DELWP in assessing surface water availability and supported the conclusions reached in the draft LTWRA.

Groundwater availability

Long-term decline in groundwater was determined in three different aquifer systems. Approximately 16 Groundwater Management Areas were identified that have groundwater extraction and declining water levels that intersect with waterways and wetlands across southern Victoria.

EPA endorses the methodology used by DELWP in assessing groundwater availability and supported the conclusions reached in the draft LTWRA.

Water Sharing

Water availability for the environment has declined in all basins except the Otway Coast. The percentage decline varied from 4 to 28 per cent and was mainly due to declines in above-cap water. Water availability for consumptive uses has declined in most of southern Victoria, with the percentage decline varying from 1 to 13 per cent. The LTWRA established a 1 per cent change in the proportion of water for the environment and for consumption as the threshold for a 'disproportionate' change.

The LTWRA found that the decline in water availability has not been shared equally. Since the SWSs were developed, in many basins, less water is available for the environment as a proportion of all available water.

EPA endorses the approach of the LTWRA and finds that the conclusions reached in the draft LTWRA are supported by the methodology and data

It is noted that the independent Panel made one recommendation regarding the assessment of Water Sharing that is not supported by EPA. DELWP used a three-step approach to determine water sharing under three scenarios. The Panel concluded that the LTWRA should be based on Step B (which includes changes due to climate since the SWS was determined) rather than Step C (which includes changes in water sharing arrangements since the SWS was determined) (refer Figure 32 of the LTWRA Overview Report).

EPA supports the use of Step C in the LTWRA as it represents the existing water sharing arrangements, incorporating changes since the SWSs were determined. EPA notes that the Act is not clear on this element of the assessment. It is also noted that changes in water availability due to a changing climate is critical for setting a new baseline to clearly understand impacts to different uses, which is clearly expressed in Step B.

Waterway health

The LTWRA found that, due to limited available data relating to waterway health, it was not possible to conclude from the river basin-scale or regional-scale analyses that waterway health in the three southern Victorian SWS regions have deteriorated for reasons related to flow over the assessment period.

Best available data

The Panel was of the view that the waterway health data used was generally the best data available, with the following limitations (S7.11.3 in the Review):

- pH and total nitrogen data were not used
- water quality data between 1975 and 1990 was available but not used. EPA notes that there are quality concerns with this data.
- the absence of Melbourne Water's macroinvertebrate data

- many sites were excluded which had macroinvertebrate data below a minimum threshold of site visits
- fish data was very limited, with only suitable data for two rivers (Moorabool and Glenelg) and that only from 2005.

EPA concludes that the waterway health data used in the LTWRA was generally the best available and considers that it is reasonable that the LWTRA excluded some water quality data due to data quality concerns.

Methodology

The Panel expressed concerns about the use of a segmented regression statistical method and the time periods adopted for assessment (S7.7.3.1.1). The Panel considered that this overly complicated the interpretation of the results and that an assessment over a single time-period would have made interpretation more straightforward. The Panel expressed a view that, if other statistical methods and better data had been used, a greater number of significant trends in these indicators may have been found, together with an improved indication of those trends that were flow related (S7.8.3). However, the Panel were not able to conclude that the application of other approaches would have shown a deterioration in waterway health over the period 1990-2018.

EPA recognises the large amount of work and effort that went into the statistical analysis of waterway health. EPA notes that the SWSs were established at different times and close to or during the Millennium Drought, and that disentangling these effects is challenging given the data available. In many cases, monitoring programs began before the enactment of the LTWRA and so were not specifically designed for such an analysis. EPA can see merit in the breaking up of time periods for the assessment, which was an attempt to disentangle the influence of the Millennium Drought and incorporate time periods following the implementation of the SWSs.

EPA supports the rationale of the LTWRA statistical approach, but notes that the approach used has resulted in conclusions that are difficult to interpret. However it is noted that no other statistical approach would necessarily have shown a deterioration in waterway health.

Conclusions supported by methodology and data

The Panel raised concerns that the biological or ecological importance of trends in waterway health were not considered when assessing whether a deterioration occurred (S7.5.3.1.1). EPA agrees that it would have been more informative to better link trends in waterway health to biologically and ecologically significant changes, such as by assessment against objectives in SEPP (Waters).

EPA considers that the inconclusive findings of a deterioration in waterway health related to flow was primarily due to limited data and that choice of statistical methods was also a significant contributor to this.

EPA supports that overall conclusions of the LTWRA in relation to waterway health, which were inconclusive.

EPA overall findings

EPA accepts the findings of the Long-Term Waterway Resource Assessment for southern Victoria.

The Review report contains many recommendations for improvements in future assessments. EPA considers that the most important future improvements to the assessment process could include:

1. More 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.
2. A broader review of appropriate statistical methods for future LTWRAs.

In accordance with the requirements of Clause 22N of the Act, EPA provides this Review to the Minister for Water and will make the review report available on EPA's website.

Review of the draft Long-Term Water Resource Assessment for Southern Victoria – Review Panel Report

Executive summary

This report covers the findings of a Review Panel (the Panel) established by EPA to review Victoria's first long-term water resource assessment (LTWRA). The Victorian *Water Act 1989*, as amended in 2005, requires that LTWRAs are undertaken every 15 years to ensure that the water-sharing arrangements specified in the sustainable water strategies (SWSs) are kept up to date.

This first LTWRA covers southern Victoria, with 18 river basins organised into three SWSs (Central, Gippsland and Western regions).

Broadly, the LTWRA is required (*Water Act 1989*, section 22L) to determine if the long-term availability of surface water or groundwater has declined, and if any decline has fallen disproportionately on the share between the environment and consumptive uses. It also seeks to determine whether there have been any changes in waterway health due to changes in the flow regime.

The Panel met with the Department of Environment, Land, Water and Planning (DELWP) project team seven times in the period between August 2018 and October 2019. It was decided that the complexity of the LTWRA made it preferable for the Panel to review work progressively rather than wait for the formal review period to commence.

The details of the LTWRA have been published in an Overview Report and a Basin by basin results report. Five technical reports and several additional specialist reports have also been made available to the Panel.

Long-term availability of surface water

The change in surface water availability for each river basin was determined by comparing the average (mean) annual water availability estimated at the time the relevant SWS was established (using historical gauging records and hydrological modelling), with the mean annual water availability calculated over the period 1975–present as the period representative of the current climate. These pre-SWS estimates were updated with better data and models than were available when the initial estimates were made.

The LTWRA found that the current (1975–present) long-term surface water availability across the 18 river basins in southern Victoria has declined by between 4 and 21 per cent compared to when it was last estimated for the SWSs.

The Panel endorses this methodology and finds that the conclusions reached in the draft LTWRA are supported by the methodology and data.

Long-term availability of groundwater

When the SWSs were established they did not establish a benchmark for long-term availability of groundwater. The LTWRA adopted the period 1975–1997 as the pre-SWS benchmark and the period 1997–2016 as the post-SWS period. The year 1997 was chosen since groundwater Permissible Volumetric Caps (PVCs) were introduced in Groundwater Management Areas (GMAs) in Victoria in the period 1997 to 2000. All GMAs and unincorporated areas within southern Victoria were assessed.

Declines in the long-term groundwater availability were estimated as changes greater than 0.1 metre in the median groundwater levels in the benchmark period compared with the assessment period (1997–2016). Long-term decline in groundwater was determined in three different aquifer systems (watertable (unconfined aquifer), middle aquifer, lower aquifer). A significant decline was assumed as greater than 2 metres.

Groundwater levels in watertables have declined throughout southern Victoria, mostly less than 1 metre. In some areas groundwater has declined more than 2 metres. Several mid-level and lower-level aquifers have also declined by more than 1 metre.

The LTWRA also assessed the possible impact of licensed groundwater extraction on surface water availability in waterways. This assessment was focused on possible impacts on baseflow in waterways. The areas identified were those with: a long-term decline of >0.1 metres; licensed groundwater extraction in the area of decline; and a decline that is likely to be connected to waterways. Impacts on groundwater-dependent ecosystems (for example, wetlands) were also assessed.

Approximately 10 GMAs were identified that have groundwater extraction and declining water levels which intersect with waterways and wetlands across southern Victoria.

The Panel endorses the LTWRA finding that groundwater levels have declined in some areas, and notes that the conclusion that long-term groundwater 'availability' has declined across southern Victoria is not strictly true as level changes are a surrogate only for groundwater 'availability' changes. The Panel also endorses the finding that licensed groundwater extractions are only a minor contributor to changes in mean annual surface water availability.

The Panel notes the groundwater assessment did not consider the impact of other factors, such as climate changes, that also contribute to changes in groundwater inflows to surface waters and considers that the influence of changes in groundwater contributions to river baseflow during low flow periods will be more significant than during mean flow periods.

Sharing of changes in water availability

The LTWRA is required to identify whether any decline in surface water availability has fallen disproportionately on water for the environment or on water for consumptive uses. Importantly, the LTWRA assessment defined water for the environment as the Environmental Water Reserve (EWR) – the legally recognised volume of water set aside for the environment – plus above-cap water for river basins in which this water was not included within the EWR.

The LTWRA found that:

- the average annual water availability for the environment has declined in all basins except the Otway Coast with the percentage decline varying from 4 to 28 per cent, mainly due to declines in above cap water
- water availability for consumptive uses has declined in most of southern Victoria, with percentage decline varying from 1 to 13 per cent
- to assess whether a disproportionate change due to climate has occurred, the LTWRA compared the water available for the environment and for consumptive uses at the time of the SWS (Step A) with that available under the current climate (1975–2017) (Step B). The LTWRA established a 1 per cent change in the proportion of water for the environment and for consumption as the threshold for a 'disproportionate' change
- the LTWRA also calculated the water available for the environment and for consumptive uses under the current climate (1975–2017) and accounting for changes made as a result of the introduction of the SWSs (Step C). This information was not used in assessing 'disproportionate' changes
- 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 SWSs were developed. The following river basins exceeded the 1 per cent threshold: Yarra (7 per cent), Werribee (5 per cent), Moorabool (4 per cent), Thomson (3 per cent) and Barwon (2 per cent). The Latrobe and Maribyrnong river basins were assessed to be at 1 per cent
- the Panel endorses this methodology (using Step B compared with Step A) and finds that the conclusions reached in the draft LTWRA are generally supported by the methodology and data, and recommends that the declines in water availability for the Latrobe and Maribyrnong river basins also be considered as disproportionate.

Changes in waterway health

The *Water Act 1989* requires an LTWRA to determine whether there has been any deterioration in waterway health for reasons related to flow. The LTWRA defined waterways as including regulated and unregulated rivers, their associated estuaries and floodplains (including floodplain forests and wetlands) and non-riverine wetlands.

Waterway health is generally defined as comprising particular ecological characteristics (such as the presence, abundance and diversity of species, habitat condition and extent, feeding and breeding opportunities) and water quality. For the LTWRA, a subset of six water quality and two biodiversity (macroinvertebrates and fish) indicators of waterway health was selected. There was insufficient data for other biodiversity indicators or indicators of ecosystem function (such as processing of nutrients or production of overall biomass).

Because of a lack of biodiversity data before 1990, the period 1990–2018 was selected as the ‘current’ assessment period. This period was split into three time periods for the statistical assessment: 1990–2005; 2006–2010; and 2011–2018, ostensibly to account for the effect of the Millennium drought (2000–2010). The Panel is not convinced that the splitting of the time period for this analysis into three time periods was either necessary or helpful for the analysis.

Linear segmented (or ‘broken stick’) regression models were used to test the significance of trends in the indicator variables at the river basin scale, with the three time periods and with changes in flow, while a Bayesian hierarchical model was used to test whether the trends and flow causality analyses differed at different spatial scales, namely river basins, SWS region and southern Victoria. While the statistical approach used in the LTWRA is not incorrect, the Panel had several detailed technical comments on the choice of the statistical analysis methods.

Unfortunately, it has not been possible to conclude from the river basin-scale or regional-scale analyses that waterway health in the three southern Victorian SWS regions have deteriorated for reasons related to flow over the assessment period.

The Panel has concerns with the statistical analysis methods used and the use of the three time period for the statistical analysis. The Panel, is also convinced that other less complicated statistical models may have produced more meaningful results. However, it is not possible for the Panel to conclude that the application of other approaches including improved data would have shown a deterioration in waterway health within southern Victoria’s river basins over the period 1990–2018.

Contents

1 Introduction

The Victorian *Water Act 1989* specifies how the state's surface water and groundwater is managed and shared between users (environment, irrigators, industry, towns and cities). This is done through four sustainable water strategies,[1] which 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, irrigators and industry) and the environment across a region.

To ensure these water-sharing arrangements are kept up to date, the *Water Act 1989* requires that long-term water resource assessments (LTWRAs) are undertaken every 15 years.

The draft LTWRA was provided to EPA for review on 23 September 2019 and was made available for consultation on 30 September 2019. It covers southern Victoria's 18 river basins.

Broadly, the LTWRA aims to determine if the long-term water availability has declined and if there have been changes in how water has been shared between the environment and consumptive uses. It also seeks to determine whether there have been any changes in the health of our waterways due to changes in the flow regime. The findings from an LTWRA are used to review water-sharing arrangements in a sustainable water strategy.

1.1 *Water Act 1989* requirements

Section 22L of the *Water Act 1989* lists LTWRA requirements as:

> 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; and
>
> *(b)* there has been any deterioration in waterway health for reasons related to flow.

Section 22N of the Water Act 1989 requires the EPA to review the LTWRA. It is:

> (1) The Minister must cause the draft assessment to be submitted to the Environment Protection Authority for a review of—
>
> *(a)* the methods and criteria adopted to carry out the assessment; and
>
> *(b)* any other matter required by the Minister.
>
> (2) In reviewing the draft assessment the Environment Protection Authority must review—
>
> (a) the methodology adopted to carry out the draft assessment; and
>
> (b) whether or not the data used in the draft assessment was the best data available; and
>
> (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.
>
> (3) At the completion of the review, the Environment Protection Authority must—
>
> (a) report its findings to the Minister;
>
> (b) make a copy of its report available on the Authority's website.

The LTWRA for southern Victoria was submitted to EPA for review on 23 September 2019.

The EPA contracted Nolan Consulting to provide an independent review of the LTWRA for southern Victoria on its behalf of EPA in accordance with section 22N of the *Water Act 1989*.

[1] Victoria has developed four sustainable water strategies for the following regions (year commenced): Central Region (2006); Northern Region (2009); Gippsland Region (2011); and Western Region (2011).

Nolan Consulting formed a specialist Review Panel (the Panel) to undertake the review. The Panel members are:

- John Nolan (Nolan Consulting)
- Professor Barry Hart (Water Science Pty Ltd)
- Professor Michael Stewardson (The University of Melbourne)
- Associate Professor Angus Webb (The University of Melbourne).

Short biographies containing the Panel members' qualifications and experience are attached as Appendix A.

1.2 Review objectives

The *Water Act 1989* (section 22N) requires EPA to review:

- the methodology adopted to carry out the draft LTWRA
- whether or not the data used in the draft LTWRA was the best data available
- whether or not the conclusions reached in the draft LTWRA are supported by the methodology and data.

The Panel was not advised of any other matter required by the Minister to review, consistent with the Minister for Water's letter to EPA formally commencing the review.

1.3 This report

This report provides the Panel's review of the LTWRA for southern Victoria as required under section 22N of the *Water Act 1989.*

1.4 Terminology

The term 'LTWRA' as used in this document refers to the draft LTWRA issued for consultation on 23 September 2019 as well technical reports 01 to 03 (TR01 to TR03) issued in late September 2019 and technical report TR04 issued in October 2019.

The term 'Department' as used in this document refers to the DELWP project team that prepared the LTWRA and its external consultants including the Arthur Rylah Institute for Environmental Research (ARI) that prepared technical report TR04. ARI is a research division of DELWP.

Technical report 04 (or TR04) is also referred to as Sparrow, Moloney, McKendrick, Crowther and Johnson (2019).

1.5 Abbreviations

The abbreviations are as provided in the Overview Report and the key terms are described in the Overview Report's glossary.

The following abbreviations are also used in this document:

- EWR – Environmental Water Reserve
- SWS – Sustainable Water Strategy
- WAfCU – Water available for consumptive use (mean allocation of water for consumptive purposes as per subsection 22L(a) of the *Water Act 1989*)
- WAftE – Water available for the environment (mean EWR as per subsection 22L(a) of the *Water Act 1989* with all above cap water).

2 Review process

2.1 Appointment

The Panel was appointed by EPA in July 2018 through the engagement with Nolan Consulting.

2.2 Panel's engagement with EPA and DELWP

Nolan Consulting's John Nolan is the Panel's Team Leader. He has coordinated Panel member contributions and maintained regular communication with EPA's Project Manager during the review.

Panel requests for further information or clarification or provision of comments on various LTWRA documents have been to the EPA Project Manager who has managed communications with the Department.

The EPA has been invited to all Panel meetings which have generally occurred either prior to or after Department briefing sessions. EPA has not attempted to influence the Panel's opinions at these meetings.

Due to the novelty and complexity of the LTWRA, EPA and DELWP agreed for the Panel to be briefed by DELWP as the work progressed rather than wait for the formal review period to commence. Briefing sessions have been held by the Department to present various aspects of the LTWRA and to seek the Panel's opinion on the information presented. These sessions were:

- 7 August 2019 Draft methods
- 7 November 2018 Data sources, application of the method, and the available preliminary findings
- 7 December 2018 Initial preliminary draft LTWRA
- 25 July 2019 Preliminary draft LTWRA (for southern Victoria)
- 11 October 2019 Draft LTWRA.

Also, Part B Waterway Health specific briefing sessions were held on 2 October and 10 October 2019 to address matters raised by the Panel.

The EPA was present at these briefing sessions.

At these sessions the Panel asked questions and sought clarification. The Panel also provided written comment and questions that the Department responded to through EPA.

2.3 Schedule of panel activities

The schedule of Panel activities is presented in **Table 2–1**.

Table 2–1: Schedule of panel activities

Task	Description	Start	Completion
Provision of background reports	Panel provided with the following documents related to the LTWRA method: DELWP (2018) Long-term water resource assessment method, 4 June 2018. Sparrow, A. and Bond, N. (2018). *Methods for assessing change in river and stream health in Victoria: A framework for the LTWRA*, Report by ARI to DELWP, June 2018 that appeared to be a draft with comments to be addressed. Hale, J. (2018) *LTWRA*: *Data and methods available to determine wetland health*. Report to DELWP, 2018. Jenkins, G., Morris, L. and Morrongiello, J. (2018) *Investigation into data and methods available to determine estuarine health for the LTWRA,* University Of Melbourne, technical report.	03/08/2018	3/08/2018
Update of Sparrow and	The following report was finalised:	-	29/8/2018

Task	Description	Start	Completion
Bond's river and stream health methods report	Sparrow, A. and Bond, N. (2018). *Methods for assessing change in river and stream health in Victoria: A framework for the LTWRA*, Report by ARI to DELWP, August 2018. This report was provided to the Panel on 5/07/2019. The changes from the June 2018 draft appear to relate to the consideration of comments on the draft.		
Initial methods briefing	DELWP presented proposed LTWRA method to Panel. The Panel verbally provided comments. Panel submitted *Issues to consider in LTWRA methodology* to DELWP following briefing. DELWP provided responses to Panel submission on 4 September 2018.	-	7/08/2018
Technical preparations briefing	DELWP presented data sources, application of the method, and the available preliminary findings to Panel. No new documents were provided. The Panel verbally provided comments, and submitted *Issues to consider* to DELWP. DELWP discussed these comments at the 14 December 2018 briefing session.	-	7/11/2018
Part B hydrology	DELWP provided *Description of the hydrology analysis used for Part B* to Panel. The Panel provided feedback to DELWP on this document.	-	8/11/2018
Receipt of preliminary LTWRA	DELWP provided the following preliminary LTWRA documents: Overview Report Basin summaries Technical report TR04 – Sparrow, A., Moloney, P., McKendrick, S., Crowther, D., and Johnson, L. (2018) *Assessment of change in waterway health in Victoria: A quantitative trend analysis for the LTWRA*, November 2018 Technical report TR05 – DELWP (2018) *LTWRA Changes in flow regime*. Several of these LTWRA documents were considered by the Panel to include river basins within southern Victoria and other Victorian river basins.	3/12/2018	5/12/2018
Briefing Session of preliminary LTWRA	DELWP presented the preliminary LTWRA documents provided to the Panel between 3 and 5 December 2018. The Panel verbally provided comments.		7/12/2018
Initial review of preliminary LTWRA	The Panel undertook a review of the Overview Report and technical reports TR04 and TR05 as provided between 3 and 5 December 2018 focusing on the data sources and the application of the method. This review of TR04 and TR05 was at a high level.	3/12/2018	14/12/2018

Task	Description	Start	Completion
	The Panel submitted its written comments to DELWP on 14 December 2019.		
Definition of fallen disproportionately	DELWP provided the Panel (through EPA) with its opinion of '*fallen disproportionately*' as per subsection 22L(a) of the *Water Act 1989* (see section 3.3)	-	8/02/2019
Receipt of preliminary LTWRA	DELWP provided a preliminary LTWRA including: • Overview Report • basin summaries • technical reports TR01 to TR05. Several background technical reports including those related to flow modelling. These documents with the exception of TR04 were for the southern basins. Notes on document dates: TR01 – May 2019 TR02 – 2018 (inside cover) although likely be May 2019 as advised by the Department TR03 – May 2019 TR04 – Sparrow, A., Moloney, P., McKendrick, S., Crowther, D., and Johnson, L. (2018) *Assessment of change in waterway health in Victoria: A quantitative trend analysis for the LTWRA,* January 2019. TR05 – July 2019 DELWP provided a response to the Panel's written comments of 14 December 2018.	-	5/7/2019
Preliminary findings briefing	DELWP presented LTWRA's preliminary findings to the Panel.	-	25/07/2019
Review preliminary draft reports (that is, EPA early review)	The Panel reviewed the preliminary LTWRA and associated technical reports. The Panel provided written comments regarding the veracity of the findings, identified potential gaps in the LTWRA and additional information required for the review.	5/07/2019	5/08/2019
LTWRA – *Part B Assessment Concerns of Review Panel*	The Panel submitted *LTWRA – Part B Assessment Concerns of Review Panel*.	-	11/09/2019
Issue of draft LTWRA	Panel received final LTWRA from DELWP and commenced review. Draft LTWRA included: Overview Report; Basin by basin results report	-	23/09/2019

Task	Description	Start	Completion
	Technical reports 1 to 5. All of these reports were dated September 2019 except for TR04 which was dated January 2019. Also, DELWP provided: response to Panel written comments of 8 August 2019; and supplement – Yarra data for assessing uncertainty. DELWP advised the Panel that the background technical reports provided on the 5 July 2019 including those related to flow modelling had not changed.		
TR04 report review meeting 1	Meeting with DELWP/ARI to review aspects of the TR04 report. This was a face-to-face meeting. ARI provided a PowerPoint presentation to the Panel.	-	2/10/2019
TR04 report review meeting 2	As not all matters to be discussed at the meeting with DELWP/ARI of 2 October 2019 had not been covered a teleconference was held on 10 October 2019.	-	10/10/2019
Draft assessment briefing	DELWP presented LTWRA to Panel and responded to points of clarification raised by the Panel.	-	11/10/2019
Receipt of revised TR04	Panel received the following revised TR04 report: Sparrow, A., Moloney, P., McKendrick, S., Crowther, D. and Johnson, L. (2019). *Assessment of change in waterway health in Victoria: A quantitative trend analysis for the Long-term water resource assessment, report by ARI to DELWP*, October 2019, 356 pp. The Panel also received DELWP's responses to the Panel's queries from the 2, 10 and 11 October meetings.	-	17/10/2019
Review the draft assessment	Panel reviewed the LTWRA according to the requirements of the *Water Act 1989*.	23/09/2019	30/10/2019
Report submission	Panel submitted review report to EPA.	-	30/10/2019

2.4 Technical Advisory Group advice

In undertaking this review the Panel has considered the opinion of other technical specialists.

DELWP established a Technical Advisory Group (TAG) to provide advice and feedback during the development of the LTWRA method. The members of the TAG were Dr Rory Nathan (University of Melbourne), Dr Avril Horne (University of Melbourne), Dr Nick Bond (La Trobe University), Dr Francis Chiew (CSIRO) and Alan Wade (Aquade Groundwater Services). The Panel has high regard for the expertise and experience of the TAG.

The Panel understands the TAG met on 17 October 2017 and 15 November 2017. TAG members also provided written feedback to DELWP.

The DELWP file note titled: 'Feedback provided by the TAG on the final draft of the methods report 4 June 2018' summarises the feedback provided by members of the TAG on the Methods report 4 June 2018. It is assumed that the TAG also had access to studies by Sparrow and Bond (2018), Hale (2018) and Jenkins, Morris and Morrongiello

(2018), which reviewed methods and proposed preferred methods for the s.22L(b) analysis for streams, wetlands and estuaries respectively.

This file note stated that TAG members provided a written review of the *Methods report 4 June 2018,* specifically commenting on whether the method is technically robust and uses the best available information. This feedback was collated by DELWP as follows:

- the high-level feedback received by each TAG member
- more detailed feedback along with comments from DELWP on whether reports will be updated to address comment, whether comments will be considered during implementation, and if DELWP disagrees with the comments
- the Department comments on how this feedback will be addressed.

DELWP provided the Panel with:

- DELWP's response to feedback received at the two TAG meetings and the written feedback provided by TAG members prior to 13 December 2017
- the file note titled: 'Feedback provided by the TAG on the final draft of the Methods report 4 June 2018.'

It is understood that any amendments to the LTWRA method arising from TAG feedback on the methods reports of June 2018 were identified in technical reports TR01 to TR05 and that the methods reports were not subsequently revised apart from Sparrow and Bond's (2018), *Methods for assessing change in river and stream health in Victoria: A framework for the LTWRA,* report being updated in August 2018.

The Department has advised that the TAG involvement in the LTWRA process is as that described above and hence did not extend to a review of the final methods presented in technical reports TR01 to TR05.

The Panel has considered the TAG feedback in this review.

2.5 Victorian stakeholders' forum

The Department provided the Panel with its response to feedback provided at the Southern Victoria Stakeholders Forum on the proposed method dated 31 January 2018.

The Panel has considered this document in this review.

2.6 LTWRA documents

The LTWRA for southern Victoria documents that have been reviewed by the Panel in accordance with section 22N of the *Water Act 1989* are listed below with the terms used for referencing within this report.

Draft LTWRA for southern Victoria documents	**Referred to as**
Overview Report (September 2019)	Overview Report
Basin by basin results report (September 2019)	Basins Report
Technical report 01: Long-term surface water availability (September 2019)	TR01
Technical report 02: Groundwater availability and impacts to waterways (September 2019)	TR02
Technical report 03: Surface water availability for consumptive uses and the environment (September 2019)	TR03
Sparrow, A., Moloney, P., McKendrick, S., Crowther, D. and Johnson, L. (2019). *Assessment of change in waterway health in Victoria: A quantitative trend analysis for the Long-term water resource assessment,* report by ARI to DELWP (October 2019)	TR04
Technical report 05: Changes in the flow regime (September 2019).	TR05

Both the Overview Report and the Basins Report have been made available for community consultation.

The Panel has also considered the following method reports:

- DELWP (2018). Long-term water resource assessment Method, 4 June 2018
- Sparrow, A. and Bond, N. (2018). Methods for assessing change in river and stream health in Victoria: A framework for the LTWRA, Report by ARI to DELWP, August 2018
- Hale, J. (2018). LTWRA: Data and methods available to determine wetland health. Report to DELWP, 2018
- Jenkins, G., Morris, L. and Morrongiello, J. (2018). *Investigation into data and methods available to determine estuarine health for the LTWRA,* University of Melbourne, technical report, March 2018.

Other reports used by the Panel are listed in the References (section 9). These include several basin and regional modelling reports.

2.7 Role of ecohydrological analysis

Two ecohydrological analyses were undertaken with the intention of supplementing the TR04 waterway health analyses. This analysis is described in TR05. The analyses 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 year that defines the pre- and post-SWS period was 2006 for the Central Region and 2011 for the Western and Gippsland Regions. The analyses did not seek to identify causes of changes, such as climate change, consumptive uses or management practices.

The primary ecohydrological analyses method was the percentage of FLOWS recommendations that had implemented in full years for reaches where the streamflow data needed to do these analyses had been captured. Where FLOWS recommendations were not available ISC analysis was undertaken using available streamflow data.

TR05 notes:

> ..flow is also not the only factor which influences and contributes to waterway health. Flow components are rarely impacted in isolation and ecosystem responses do not typically function in a linear manner to changes in the flow regime. These complexities make isolating particular events from the broader flow regime problematic (Rolls and Bond, 2017). This study has only considered the influence of the flow regime and therefore cannot, and does not, conclude that waterway health has changed. Rather, the results provide an indication of where the threat to waterway health due to flow has changed.

The scope of the *Water Act 1989* subsection 22L(b) is to determine if there has been any deterioration in waterway health for reasons related to flow. The method used and analysis undertaken in TR04 is directed towards making this determination. As the ecohydrological assessment reported in TR05 does not make or supplement this determination, it is not considered further in this review.

2.8 Detailed commentary

In undertaking this review, the Panel has identified minor inconsistencies, conflicting information, confusing information and inconsistent terminology, which the Panel considered did not impact on the LTWRA outcomes. For this reason these comments have been provided to the LTWRA team under separate cover.

3 Preliminary considerations

In undertaking the LTWRA it has been necessary to interpret the intent of the *Water Act 1989* on several matters that were not specified.

These matters are:

- linkages with the Sustainable Water Strategies (SWSs)
- scale of assessment
- some definitions.

The Panel's opinion on the adequacy of the LTWRA's interpretation of these matters are provided below.

3.1 SWS linkages for decline/deterioration assessment

The *Water Act 1989* section 22L requires an LTWRA to determine if there has been a decline in the long-term availability of water and whether there has been a deterioration in waterway health. It does not define the period for which these assessments should be made.

3.1.1 LTWRA approach

The LTWRA states: 'The draft LTWRA assesses changes since the SWS'.

Declines in long-term water availability were assessed against the estimates of long-term water availability calculated at the time the relevant SWS was being developed.

3.1.2 Evidence

The Department of Sustainability and Environment (2004) *White Paper: Securing of Water Future together* sets the framework for Victoria's future water security including the requirement for the development of SWSs and the draft LTWRA process in the 2005 amendment to the *Water Act 1989*.

The White Paper stated:

> We can achieve both stability and adaptability in our water allocation system by:
>
> - ensuring storage operating rules, seasonal allocation processes etc. that determine the volume of water made available for consumption each year are public and firm, but can be changed through a transparent, consultative process;
> - assessing the status of the resource base and river health, and whether either is suffering a decline, at regular 15 year intervals;
> - where there has been a decline in river health, or in the resource base with a disproportionate impact on one group, conducting an open review to determine how to restore an acceptable balance, including the last resort option of the Government adjusting entitlements using its reserve powers; and
> - having a minimum interval of 15 years between consecutive adjustments of entitlements using the Government's reserve powers.
>
> The assessments will be undertaken by DSE on behalf of the Minister using expert scientific advice, be independently audited and be available to the public. The initial State Water Inventory and Sustainable Water Strategies will set the benchmark against which future resource assessments will measure long-term changes to the resource base and river health.

Three SWSs were developed within southern Victoria. Their completion dates vary from 2006 to 2011 as follows:

- Central Region – 2006
- Western Region – 2011
- Gippsland Region – 2011.

The SWSs calculated long-term water availability as the average annual volume of water available over the entire period for which historical data for measured or modelled streamflow were available. The estimates were published for each river basin in the relevant SWS.

The Central Region SWS (Table 2.1, page 22) explicitly reports the EWR as a percentage of the total resource. While the Gippsland and Western Region SWS do not explicitly report the relative share, the following tables provided the information from which EWR as a percentage of the total resource could be calculated.

- Gippsland SWS (Table A3.1, page 178)
- Western SWS (Table A2.1, page 265).

These tables report the volume of the environmental entitlement and 'average flows at basin outlet' which is inferred to be equivalent to the sum of passing flows and 'above cap' water.

3.1.3 Panel opinion

The Panel endorses the LTWRA method for assessing a decline in the long-term availability of water against the SWS benchmarks estimates of annual water availability for the river basins within these regions over the available records' period.

The Panel notes that the SWSs, either explicitly or through data interpretation, provide estimates of the proportions of water available under the Environmental Water Reserve (EWR) and consumptive entitlements. The SWSs do not define the waterway's heath.

3.2 Scale of assessment

The *Water Act 1989* section 22L is silent on the scale at which the LTWRA must be undertaken. Options that could be considered are: the site, reach, river, sub-catchment, river basin, region, or whole of southern region level that could be aggregated to a higher scale.

3.2.1 LTWRA approach

The LTWRA used the river basin scale for the assessment (and undertook some waterway health modelling at the region scale as a test of the statistical method).

3.2.2 Evidence

Sites are locations on river and tributary reaches where monitoring occurs. There are typically several river reaches along individual rivers including their tributaries. There are 18 river basins (area of land into which a river and its tributaries drain) within the southern region, and three regions for which SWSs have been prepared. Within these river basins there are about 200 sub-catchments.

The 18 river basins and SWSs within the southern region are listed in **Table 3–1**.

Table 3–1: River basins in each southern Victorian SWS

SWS	River basin
Gippsland	South Gippsland
	Latrobe
	Thomson
	Mitchell
	Tambo
	Snowy
	East Gippsland
Gippsland and Central are assessed as part of Gippsland Region	Latrobe
	Thomson
Central	Werribee
	Maribyrnong
	Barwon
	Moorabool
	Yarra
	Bunyip
Western	Otway Coast
	Glenelg
	Hopkins
	Portland Coast
	Corangamite
The Victorian section of the Millicent Coast basin, which spans the Victorian and South Australian border, was not included in the LTWRA (see Section 4.3.1).	

As shown in **Table 3–1** the Latrobe and Thomson river basins are included in the Central SWS and the Gippsland SWS.

Section 2.1 of the Overview Report states that: 'Estimates of surface water availability were combined and reported at the basin scale.'

The TR04 summary states:

> Any attempted river-, reach- or site-scale statistical analysis would lack statistical power to detect deterioration, even if such a trend occurred. This constraint, in combination with limited resources for undertaking an LTWRA Part B assessment for the first time, and a need to ensure a degree of consistency with the basin-scale analysis undertaken for the LTWRA Part A, meant that it was more practical to do waterway health analyses at basin scale rather than reach or site scale.

TR04 (S2.1, p13) also states:

> For consistency with the LTWRA Part A analyses, the approach focuses on the scale of the river basin but uses a hierarchical statistical method that allows for river, reach and site differences. However, the approach does not try to explain the causes of any differences between river systems, rivers, reaches or sites i.e. while the approach allows for

spatial variation, it does not try to attribute causality of spatial variation in waterway health to characteristics of catchments or localities, because such attribution of causality is not a requirement of the LTWRA Part B.

At the Panel's request the Department provided the advice presented in **Table 3–2** as to why the assessment had not been undertaken at smaller or larger scales.

Table 3–2: LTWRA justification for not using smaller or larger scales

Option	Discussion
Sub-catchment	Could lead to conflicting findings within a river basin (that is, the potential to show a disproportionate impact on consumptive use immediately downstream of a reservoir because passing flows have not changed, but disproportionate impact on the environment further downstream where 'above cap' water provides most of the environmental water) Could lead to a review of only some parts of a river and would reduce options to address an imbalance
SWS region	Risk that rivers where declines have fallen disproportionately are not identified and the imbalance is not addressed The scope of any subsequent review could be larger than required and use public resources unnecessarily
Total southern region	As above

3.2.3 Panel opinion

The Panel endorses the LTWRA interpretation that the assessment be undertaken at the basin scale.

This reflects:

- data availability
- the large scale of the LTWRA
- a logical scale to undertake reviews under section 22P of the *Water Act 1989* if required.

3.3 Definitions

The Panel sought access to legal advice that the Department may have obtained regarding the interpretation of certain LTWRA terms in the *Water Act 1989*. Specifically, advice was sought on the definitions of 'disproportionate' [subsection 22L(a)] and 'EWR' specific to subsection 4A(1) and subsection 22L(a) of the *Water Act 1989*.

3.3.1 LTWRA approach

The Department advised:

- it has not withheld legal advice regarding the interpretation of 'disproportionate'
- external legal opinion is unlikely to be of value on subsection 22L(a) of the *Water Act 1989* because the extent to which the meaning of this section can be analysed and clarified is quite limited
- a more detailed response on the definition of disproportionate was provided on 8 February 2019
- the EWR definition is based on section 22L and subsection 4A(1) of the *Water Act 1989* and is now referenced more clearly in Section 5.1.2 of the Overview Report and in the relevant section of the TR03.

3.3.2 Evidence

Nil.

3.3.3 Panel's finding

In its absence of legal advice the Panel has accepted the Department's interpretations.

3.4 EWR interpretation

Section 22L of the *Water Act 1989* requires an assessment of whether the *'decline has fallen disproportionately on the EWR or on the allocation of water for consumptive purposes'*.

3.4.1 LTWRA approach

The definition of the EWR used in the LTWRA includes the EWR identified under subsection 4A(1) of the *Water Act 1989* and the above cap water set out in the Gippsland and Western SWSs.

3.4.2 Evidence

Section 4A of the Act describes the EWR as follows:

> (1) The EWR comprises water that is set aside for the environment—
>
> (a) as an environmental entitlement; and
>
> (b) through the operation of—
>
> (i) conditions on any bulk entitlement, or any licence, permit or authority issued under this or any other Act, or regulations made under this or any other Act; and
>
> (ii) any management plan under this Act; and
>
> (iii) any other provision of this Act, the *Murray-Darling Basin Act 1993* or the *Groundwater (Border Agreement) Act 1985* or any regulations made under this Act or those Acts.
>
> (2) In this Act a reference to the EWR is a reference to any water to which subsection (1) applies.

Appendix B of TR03 shows the sources of water within the Act under subsection 4A(1). It shows the EWR as including environmental entitlements, bulk entitlements held by the Victorian Environmental Water Holder (VEWH) (or by the Environment Minister), water shares and take and use licences held by the VEWH, passing flows or maximum flow rates for consumptive uses imposed on a bulk entitlement or a licence, passing flows in a streamflow management plan (section 30 *Water Act 1989*), water in a system or area that exceeds a permissible consumptive volume (PCV) (section 22A *Water Act 1989*).

In the Gippsland SWS, the above cap water in the Thomson and the Latrobe basins falls within the EWR because there is a PCV. In the Western SWS, the above cap water in the Otway Coast falls within the EWR because there is a PCV. (See Figure 38 in TR03.)

The LTWRA assessment of EWR includes the EWR currently identified under subsection 4A(1) of the *Water Act 1989*, plus above cap water set out in the Gippsland and Western SWSs. Justification for this is:

> The Government is commited to include all above-cap water across southern Victoria in the EWR by revising the Surface Water Permissible Consumptive Volume (PCV) order. Appendix B of TR03 states '*When the PCV Surface Water Order 2010 is updated to reflect these caps, this water will be incorporated into the EWR. Although this water is not currently within the EWR, its inclusion 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.*

An analysis was undertaken to determine if the findings of the assessment would change when only the EWR is considered (that is, if the water above the cap set out the SWSs was excluded). The volume of water set aside for the environment, EWR and other means, by river basin is shown in Figure 38 of TR03 and the estimated decline in EWR is compared with a decline in water for the environment in river basins where the EWR is less is shown in Table 20 of TR03.

3.4.3 Panel's finding

The LTWRA's interpretation of EWR to include all above cap water across southern Victoria for the purpose of the 'fallen disproportionately' assessment is endorsed.

4 Long-term availability of surface water

4.1 Background

The *Water Act 1989* subsection 22L(a) requires the long-term water resources assessment to identify if there has been any decline in the long-term availability of surface water or groundwater and whether the decline has fallen disproportionately on the EWR or on the allocation of water for consumptive purposes.

This section of the review is limited to the consideration of whether there has been any decline in the long-term availability of surface water as referred to in s22L(a) assessment.

The questions considered in the review of the LTWRA methodology are:

- timeframe
- assessment method
- variability of available water.

The subsection 22L(a) analyses associated with this consideration are reported in TR01 and the Overview Report. TR01 is also an input to the Basins Report (September 2019).

4.2 Method – Timeframe for surface water availability assessment

4.2.1 LTWRA interpretation

The LTWRA (Section 2.2 of the Overview Report) adopted the following time periods for the s.22L(a) assessment of whether there has been a decline in the long-term availability of surface water:

- Pre-SWS: commencement of historical records to date for which the data was available (usually up to a few years before the SWS was published) noting relevant SWS published (2006 for Central SWS, and 2011 for Western and Gippsland SWSs)
- Current: 1975 to present – includes the Millennium drought and the publishing of the southern Victorian SWSs.

4.2.2 Evidence

Section 4 of TR01 discusses the selection of 1975 to present as the current period. The reasons are:

- having a sufficiently long period to ensure that it reflects a range of natural climate variability that could be expected under current climate conditions (that is, including both drought and floods and not being unduly biased towards either)
- not being so long as to include water availability information under quite different climatic conditions than today, and thereby losing the ability to identify changes in water availability attributable to changes in climate.

Three alternative current climate representative periods were considered and rejected. These were full periods of records including the years since SWS, post-1997 and following the relevant SWS.

Post-1997 was rejected as it only provides 20 years of records and is unlikely to capture a reasonably unbiased range of natural variability of rainfall and streamflow expected under current conditions. The Millennium drought is a significant part of this period, and although the severity of the drought has been linked to climate change natural variability still played a significant role.

Post-SWS was rejected as it does not represent a climatically significant ‘breakpoint’, and the limitations of using 2006 onwards (in terms of representing a wide and reasonably unbiased range of natural climate variability) are even more pronounced compared with the post-1997 option. It was also stated that the use of short periods will increasingly reflect wetter or drier periods under natural variability (that is, ‘the weather’), rather than being representative of longer-term climate.

4.2.3 Panel's finding

4.2.3.1 Principal

The selection of the pre-SWS period of historical records to the year for which the data was available (usually up to a few years before the SWS was published) and the post-SWS (current) period of 1975 to present is endorsed (for the purpose of determining whether there has been a decline in the long-term availability of surface water).

4.2.3.2 Secondary

Nil.

4.2.3.3 Considerations for future LTWRAs

Nil.

4.3 Method – Assessment of water availability

4.3.1 LTWRA interpretation

The assessment method is described in Section 2.2 of the Overview Report.

The estimates of the average (mean) annual water availability at the time of the SWSs are referred to as the pre-SWS estimates. These pre-SWS estimates were updated with better data and models than were available when the initial estimates were made. These updates are referred to as the Step A benchmarks.

The LTWRA estimated the current long-term surface water availability using the average annual surface water availability under climate conditions and models used for the Step A estimates. Current climate conditions were characterised by climate in the period 1975 to present. The surface water availability during this period is referred to as Step B in the LTWRA.

To determine long-term changes in water availability, the assessment compared these 1975–present estimates with the Step A estimates.

4.3.2 Evidence

The detailed methodology is described in TR01.

The surface water availability was assessed for nearly 200 sub-catchments in 18 southern Victorian river basins. Some smaller rivers and creeks are excluded from the assessment as they were deemed to be unsuitable for estimating changes in long-term water availability.

The Millicent Coast basin was excluded as there are few waterways, no long-term streamflow gauges, inferred low and intermittent surface water availability, and no material allocation of surface water for consumptive use. Licensed entitlements to water in the Millicent Coast basin total only 4 megalitres. Groundwater and stock and domestic farm dams are the predominant sources of water in this basin rather than licensed surface water use. Also, there were no estimates of water availability for this river basin undertaken in the Western SWS.

Desalinated water is not considered 'available surface water' because it is not sourced from waterways. For this reason it was excluded from the surface water estimates for the Thomson and Yarra basins and all other assessed river basins.

Surface water availability was estimated from gauged streamflow data, adjusted gauged streamflow data, water balance, streamflow transposition and rainfall run-off modelling.

The factors contributing to the changes in long-term surface water availability are presented in Section 4 of the Overview Report (but not TR01) included:

- licensed groundwater extractions
- domestic and stock dams
- rural land cover
- bushfires

- timber harvesting
- urban land cover
- catchment responses to drought.

The impact of licensed groundwater extractions on long-term surface water availability has been quantified in TR02. The Panel's findings on this assessment are presented in Section 5.4.3.

All other contributing factors are assessed qualitatively.

The following uncertainties that potentially affect the assessment outcomes are discussed in Section 4 of TR01:

- the period of analysis
- the method for estimating change
- the metric used to assess change
- data and modelling uncertainty
- the influence of intercepting activities.

The Panel's findings with respect to the period of analysis is presented in Section 4.2.3.

The Department assessed changes in median annual water availability. They found that using median instead of the mean increased the range of the changes but still resulted in a decline in water availability in all river basins except for the Portland Coast and Snowy River basins (Section 4.4 of TR01).

Section 4.4 of TR01 advises that the mean rather than median annual water availability was adopted because it is more conservative when determining water availability decline. The Panel interprets the meaning of 'conservative' to mean reductions in available water are greater when the mean is adopted in preference to median.

4.3.3 Panel's findings

4.3.3.1 Principal

The methodology adopted to consider whether there has been any decline in the long-term availability of surface water is endorsed.

The decline in both the mean and median total water availability should be used in assessing whether there has been a decline in the long-term availability of surface water.

4.3.3.2 Secondary

The exclusion of the Millicent Coast, some smaller rivers and creeks and desalinated water from the assessment is accepted.

The assessment of uncertainty for (i) the method for estimating change, (ii) the metric used to assess change, and (iii) data and modelling uncertainty presented in Section 4 of TR01 is accepted.

The Panel notes that while overall, the 'mean' annual water availability estimated decreases are greater than 'median' estimates, this is not the case for at least three basins where the 'median' annual water availability was estimated to decrease by over 20 per cent .

4.3.3.3 Considerations for future LTWRAs

Nil.

4.4 Method – Treatment of variability in annual water availability

4.4.1 LTWRA interpretation

The volume of water available for allocation to consumptive uses and for the environment is presented in the Overview Report (Section 5.1.1, page 76) and explained in Section 3.4.2 of TR03.

4.4.2 Evidence

This variability, and particularly water availability during extended dry periods, can be important in determining the long-run benefits for consumptive and environmental use. However, the water availability calculation methods do not explicitly consider the variability of water availability between years for either consumptive users or the environment.

Increased variability of water availability is reflected as a reduction in the level-of-service for consumptive users. It is acknowledged by the Department that the methodology for estimating current water availability for urban users in Step B will likely produce reduced level-of-service for urban water users compared to the baseline scenario in basins where total water availability has reduced (TR03, page 35).

The LTWRA does not specifically consider Step B reductions in the level-of-service relating to urban users. The same applies for water available for rural water users. It is noted that for Step C, the method used to calculate urban water demands results in the same level-of-service in the baseline and current scenarios (TR03, page 35). Step C is described in Section 5.3.3 of the Overview Report as reflecting the best available data and models, the period 1975–present period (from Step B) and the current water-sharing arrangements.

Similarly, changes in variability of annual water availability for the environment may affect the ability for environmental water to meet periodic high environmental flow requirements every few years or to meet minimum environmental flow requirements during a sequence of dry years. Important changes in variability of the environmental water availability may not be properly reflected in the change in the annual mean water availability.

4.4.3 Findings

4.4.3.1 Principal

The LTWRA assessment of the impact of reduction in water availability only considers changes in the annual mean water available for urban water users and for the environment, and this may not properly indicate the significance of changes in water availability.

4.4.3.2 Secondary

Changes in the variability of annual water availability for the environment should be examined in considering the need for a review under section 22P of the *Water Act 1989*.

4.4.3.3 Considerations for future LTWRAs

Future LTWRAs should consider updating the LTWRA method to consider variability in annual water availability. The Overview Report (pages 114–115) presents changes in available water in wet years and dry years, but it does not report upon the implications in terms of subsection 22L(a).

4.5 Is the data used the best available?

4.5.1 LTWRA interpretation

Section 4.5 of TR01 states that the best available information and methods to calculate water availability was used in the assessment, while Section 2.4.1 states that the assessment estimated the long-term surface water availability using best available models and the most up-to-date data.

4.5.2 Evidence

The data used is identified in sections 2.2 to 2.4 of TR01.

4.5.3 Panel's findings

4.5.3.1 Principal

The data used is considered the best available for determining the declines in long-term surface water availability.

4.5.3.2 Secondary

Nil.

4.5.3.3 Considerations for future LTWRAs

Nil.

4.6 Conclusions – supported by methodology and data

Section 22N of the *Water Act 1989* requires the review to consider whether or not the conclusions reached in the draft LTWRA are supported by the methodology and data.

4.6.1 LTWRA interpretation

The LTWRA findings on the s.22L(a) assessment are summarised in Section 6.4 of the Overview Report. It states:

> 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 SWSs.

The average (mean) annual long-term water availability declines are presented in Table 4 of TR01 and are repeated in **Table 4–1**

Table 4–1: Estimated LTWRA mean annual long-term water availability declines

River basin	Estimated decline in water availability (%)	River basin	Estimated decline in water availability (%)
Bunyip	7	Portland Coast	12
Yarra	16	Glenelg	6
Maribyrnong	17	East Gippsland	9
Werribee	18	Snowy	9
Moorabool	20	Tambo	14
Barwon	11	Mitchell	12
Corangamite	21	Thomson	5
Otway Coast	4	Latrobe	12
Hopkins	5	South Gippsland	7

4.6.2 Evidence

The basis of the LTWRA long-term surface water availability assessments is presented in TR01.

4.6.3 Panel's findings

4.6.3.1 Principal

The LTWRA s.22L(a) assessment's finding that the long-term surface water availability across southern Victoria has declined is consistent with the methodology and the data.

4.6.3.2 Secondary

Nil.

4.6.3.3 Considerations for future LTWRAs

Nil.

5 Long-term groundwater availability

5.1 Background

Subsection 22L(a) of the *Water Act 1989* requires the long-term water resources assessment to identify if there has been any decline in the long-term availability of surface water or groundwater and whether the decline has fallen disproportionately on the EWR or on the allocation of water for consumptive purposes.

As such subsection 22L(a) is interpreted as requiring an assessment of whether there has been any decline in the long-term availability of groundwater and if that decline has contributed to a disproportionate impact on the EWR or on the allocation of water for consumptive purposes.

This section of the review considers whether there has been any decline in the long-term availability of groundwater and if any decline has contributed to a disproportionate impact on the EWR or on the allocation of water for consumptive purposes.

The Panel's review considered:

- timeframe for groundwater availability
- assessment method
- impact of licensed groundwater extractions on waterways.

The s.22L(a) analyses associated with this consideration are reported in TR02 and the Overview Report.

TR02 presents the assessment of groundwater availability and impacts on waterways. TR02 is also an input to the Basins Report (September 2019).

TR02 notes that the licensed groundwater use in southern Victoria as shown in the state water accounts is on average approximately 36 per cent of the licensed entitlement and about 12 per cent of total water use.

5.2 Method – Timeframe for groundwater availability assessment

5.2.1 LTWRA interpretation

The assessment periods for groundwater availability are described in Section 4.3 of TR02. They are:

- Pre-SWS: 1975–1997 – benchmark (PVCs introduced in 1997 to 2000 in GMAs)
- post-SWS: 1997–2017 – termed assessment period and includes pre- and post-SWS periods, the Millennium drought and groundwater development and management post-PVCS for groundwater management areas (GMAs).

Also, the LTWRA sought to align the assessment of the impact of groundwater licensed extractions on waterways with the current period used in the long-term surface water availability assessment.

The SWSs did not estimate long-term groundwater availability.

5.2.2 Evidence

Sections 3 and 4 of TR02.

5.2.3 Panel's findings

5.2.3.1 Principal

The timeframes (benchmark and assessment period) for the long-term availability of groundwater assessment are inconsistent with the s.22L(a) surface water assessment and the s.22L(b) waterway heath assessment and are not aligned with the pre- and post-SWS periods.

See Section 5.4.3 of this Report for findings on impact of licensed extractions on waterways.

5.2.3.2 Secondary

The availability of data limited the period of groundwater assessment since most monitoring sites were installed in the 1970s onwards.

While there is logic in selecting 1975 and 1997 as milestone dates, their selection ensures that groundwater availability and surface water cannot be added together.

It is not possible to assess the impact of SWSs on groundwater availability based upon these periods.

5.2.3.3 Consideration for future LTWRAs

For future LTWRAs consideration should be given to aligning the post-SWS period with the surface water availability assessment period.

5.3 Method – Assess changes in groundwater availability

5.3.1 LTWRA interpretation

Section 4.2 of TR02 defines groundwater availability as 'the ability of an aquifer to supply water to consumptive users and the environment'.

It states*:*

> An aquifer's ability to supply water to consumptive users is determined by the volume of water in an aquifer which can feasibly be extracted whereas supply of groundwater to waterways is primarily generally determined by the height of the groundwater surface (watertable).

Changes in groundwater availability are estimated as changes in median groundwater levels in the benchmark period compared with the assessment period (the 'current condition' period). The Panel's findings on the assessment period are presented above in Section 5.2.

Changes in the groundwater levels in the lower, middle and watertable aquifers within trend areas are estimated for GMAs and unincorporated areas using state observation bores with varying lengths of level records.

While the Department advised that the LTWRA also reviewed changes in groundwater entitlements and impacts on consumptive users due to management actions, these review aspects do not appear to have been used to assess changes in groundwater availability,

A decline was deemed to have occurred if there is a change in median water levels of greater than 0.1 metre applied to that 'trend area'. The use of 0.1 metres was adopted from the *Ministerial Guidelines for Groundwater Licencing and the Protection of High Value Groundwater Dependent Ecosystems* (DELWP, 2015) where it was identified as the smallest measurable impact to groundwater dependent ecosystems with respect to groundwater supply.

All groundwater management areas recorded a decline of greater than 0.1 metres and most unincorporated areas where data was sufficient also recorded declines of greater than 0.1 metres.

A threshold of 2 metres decrease was adopted to indicate a significant decline in groundwater level. The Department advised that this threshold is based on work undertaken previously in the *Onshore Natural Gas Water Science Studies*, which set varying limits to determine risk to the resource. This study has not been reviewed by the Panel.

5.3.2 Evidence

Sections 3 and 4 of TR02.

5.3.3 Panel's findings

5.3.3.1 Principal

The method used to assess changes in groundwater availability, with water level used as a surrogate for availability, is accepted for this first LTWRA.

5.3.3.2 Secondary

It was necessary to develop benchmark for long-term availability of groundwater at the time of SWSs as these assessments were not provided in the SWSs.

The use of GMAs and unincorporated areas for assessing the long-term availability of groundwater is an appropriate scale for reporting as hydrogeological and extraction data is aggregated at a similar scale.

5.3.3.3 Consideration for future LTWRAs

For future LTWRAs, consideration should be given to using numerical groundwater models (where developed) for GMAs to assessing changes in groundwater availability. This would allow for changes to be identified as proportions of the available water as has been applied to the surface water assessment.

The Department has advised that numerical groundwater models were used where available, but the Panel is of the opinion that these have only been applied to the assessment of licensed extraction impacts.

5.4 Method – Impact of licensed extractions on waterways

To determine disproportionate impacts as required under the s.22L(a) assessment there is a need to consider consumptive groundwater use as a possible contributor to the decline in surface water availability.

5.4.1 LTWRA interpretation

The LTWRA assessed the impact of groundwater extractions on waterways as a contributor to the decline in availability of surface water where disproportionate impacts were identified in TR02 and Section 4.2 of the Overview Report.

These impacts were quantified where licensed groundwater entitlements were determined as likely to be impacting on waterway baseflow.

For the purpose of assessing impacts of groundwater extractions, areas where licensed groundwater entitlements were likely to be impacting baseflow to waterways were identified for further investigation. The areas identified were those with:

- a long-term decline >0.1 metres
- licensed groundwater extraction in the area of decline
- decline that is likely to be connected to waterways.

The results are presented as percentage of change in surface water availability due to licensed extractions for 1997 to 2018 and 1975 to 2018 (see Table 8 of TR02).

Licensed groundwater extractions were found to have contributed to <1 per cent of long-term surface water decline in three river basins (Gellibrand, Latrobe and Mitchell), between 1 per cent and 3 per cent in four river basins (Moorabool, Werribee and Barwon), and had no measurable impact in one basin (Corangamite). In two study areas, a comparison could not be made due to a lack of streamflow data (Jan Juc and Nepean GMAs).

5.4.2 Evidence

The method used to assess the impact of declines of groundwater availability on licensed extractions on waterways is presented in Section 5.2 of TR02. This is limited to an assessment of the impact of licensed groundwater extractions on waterways.

TR02 advises that any impacts from all extraction and climate changes are observed in changes (levels) in the aquifer and waterways and included in the surface water assessment.

Several assumptions were used to identify the study areas based on the potential for groundwater consumptive use to impact on the environment. These were:

- groundwater entitlement density should be greater than 0.05 ML/y/ha (the smallest entitlement density inferred to have a measurable impact on waterways)
- stock and domestic use where not accounted for (only the Nepean and Deutgam GMAs exceed 0.05 ML/y/ha for stock and domestic use and both were included in the assessment based on licensed entitlement density)
- aquifer connection to waterways was defined by the pathway with confined aquifers having no potential to impact (except where exposed to the surface at the margins of the aquifer, such as within the Jan Juc, Gerangamete and Gellibrand GMAs, where considered unconfined and possibly connected to waterways) and unconfined aquifers with waterways located in the area of groundwater extractions having some potential
- the Warrion, Bungaree, Jan Juc and Bungaree GMAs were identified as study areas by reviewing wetlands and waterways with seasonal watering plans.

TR02 identified 10 GMAs that were considered to have groundwater extraction and declining water levels that intersect with waterways and wetlands across Victoria. All the study areas identified are located within a GMA, and in most cases the GMA was adopted as the study area boundary.

5.4.3 Panel's findings

5.4.3.1 Principal

The s.22L(a) assessment is interpreted as requiring an assessment of whether there has been any decline in the long-term availability of groundwater and if that decline has contributed to a disproportionate impact on the EWR or on the allocation of water for consumptive purposes.

The assessment considers the impact of licensed groundwater extractions on the change in surface water availability. The inclusion of other factors, such as climate changes, that also contribute to changes in groundwater inflows to surface waters would result in a greater percentage change in surface water availability due to groundwater than that caused by licensed extractions only.

The groundwater assessment considered the impact of total, rather than the 'change' in total, licensed groundwater extractions on the available surface water decline. The use of 'change in total' would reduce the effect of licensed groundwater extractions on the available surface water decline from that shown in TR02.

5.4.3.2 Secondary

Although outside of the scope of s.22L(a) assessment, the environmental impact of changes in baseflow of waterways during low flows may be significant.

The assessment excludes calculations of percentage change in surface water availability associated with Jan Juc GMA (Salt Creek, Painkalac Creek – Otway Coast river basin) and Nepean GMA (Drum Drum Creek, Allocation Creek – Bunyip River basin) due to a lack of stream gauges.

5.4.3.3 Consideration for future LTWRAs

For future LTWRAs consideration should be given to:

- assessing the impact of groundwater on changes in baseflow to waterways during low flows
- including calculations of percentage change in surface water availability associated with Jan Juc and Nepean GMAs.

5.5 Is the data used the best available?

5.5.1 LTWRA interpretation

The data used for the groundwater availability assessment is described in TR02.

The monitored water levels of 2,500 observation bores in the State Observation Bore Network (SOBN) and 1,000 observation bores in southern Victoria were used as indicators of a change in the volume of water stored in an aquifer as well as a possible decline in baseflow to waterways.

The data used to assess the impact of licenced groundwater extractions on waterways are presented in Section 5.1 of TR02. These include groundwater entitlements and metered use data from the Victorian Water Register, Spatial datasets from the Victorian Spatial Data Library, aquifer properties in study areas from literature or published report, gauged waterway data from WMIS and selected published literature and reports on groundwater systems

5.5.2 Evidence

The data used is summarised in Section 5.1 of TR02.

5.5.3 Panel's findings

5.5.3.1 Principal

The data used is considered the best available for determining in the long-term groundwater availability declines, except for the absence of groundwater modelling results.

5.5.3.2 Secondary

Nil.

5.5.3.3 Consideration for future LTWRAs

For future LTWRAs consideration should be given to:

- provision and monitoring of stream gauges within Salt Creek, Painkalac Creek (Otway Coast river basin) and Drum Drum Creek, Allocation Creek (Bunyip River basin)
- using numerical groundwater models (where developed) for GMAs to assess changes in groundwater availability.

5.6 Conclusions – supported by methodology and data

Section 22N of the *Water Act 1989* requires the review to consider whether or not the conclusions reached in the draft LTWRA are supported by the methodology and data.

5.6.1 LTWRA interpretation

The LTWRA s.22L(a) assessment conclusions regarding:

- any decline in the long-term availability of groundwater are summarised in Section 3.3 of the Overview Report and Section 4.4 of TR02
- disproportionate impact of any decline in the long-term availability of groundwater are presented in Section 4.4 of the Overview Report and sections 5.3 and 5.4 of TR02.

5.6.2 Evidence

See TR02.

5.6.3 Panel's findings

5.6.3.1 Principal

The LTWRA's finding that the groundwater levels have declined in some areas is endorsed.

The finding that the groundwater levels in watertable aquifers throughout southern Victoria is endorsed as being consistent with the methodology and the data.

As groundwater level declines have been used as a surrogate for long-term groundwater availability declines, the conclusion in TR03 that long-term groundwater 'availability' has declined across southern Victoria is not strictly true.

The LTWRA groundwater assessment is biased towards long-term groundwater availability declines due to below average climate including the Millennium drought.

5.6.3.2 Secondary

While it is likely that a decline in groundwater levels occurred in most of southern Victoria's GMAs, the analysis of long-term median levels suggests that a few basins may not have suffered declines.

5.6.3.3 Consideration for future LTWRAs

For future LTWRAs consideration should be given to all sources of groundwater when assessing the impact of baseflow declines on waterways.

6 Sharing of changes in water availability

Subsection 22L(a) of the *Water Act 1989* requires the long-term water resources assessment to identify if there has been any decline in the long-term availability of surface water or groundwater and whether the decline has fallen disproportionately on the EWR (WAftE) or on the WAfCU.

The LTWRA determined that there have been declines in the long-term availability of surface water (Section 4) and groundwater (Section 5). This section of the review considers whether the decline has fallen disproportionately on the WAftE or on the WAfCU.

The questions considered in the methodology review are:

- interpretation of WAfCU
- interpretation of WAftE
- should current water-sharing rules be included
- criteria for determining a disproportionate impact.

The s.22L(a) analyses associated with this consideration are reported in TR03 and the Overview Report.

As part of this review several background basin and regional modelling reports have been interrogated with a more detailed assessment of the following background reports undertaken:

- Melbourne Water (2018). *Long-term water resources assessment analysis*
- HARC (2019). *Update of Barwon – Moorabool REALM model. Technical report – Model inputs*
- GHD (2018b). *Latrobe water resource model daily input – Stage 2, input derivation and validation.*

The Barwon–Moorabool REALM modelling report was not included in the package of background documents provided to the Panel.

TR03 is also an input to the Basins Report (September 2019).

6.1 Method – Water available for consumptive uses (WAfCU)

6.1.1 LTWRA interpretation

Section 5.1.1 of the Overview Report concludes:

> WAfCU 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.
>
> WAfCU 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.

6.1.2 Evidence

WAfCU is estimated as the average annual volume available to be taken by consumptive users under the terms and conditions of bulk entitlements and private diversion licences. Where there is not full uptake of water entitlements, historic water use should be less than WAfCU.

There are several water uses that are excluded from the WAfCU. Importantly, these include water taken for uses that do not require the Minister's approval, such as private rights to water for stock and domestic purpose and water harvested in stock and domestic farm dams. Instead, the effects of these excluded uses are considered in the assessment of water availability in total for consumptive and environmental uses. Hence, while an increase in farm dams for stock and domestic uses, in principle, would result in a reduction in surface water availability, it does not represent an increase in WAfCU. The justification for this exclusion is that it is a 'statutory right' as set out in section 8 of the *Water Act 1989*, a right is issued by the Minister.

The LTRWRA team advised that as the LTWRA requires an assessment of the allocation of water for consumptive use, section 8 water rights were not included (Overview Report, page 76). The draft LTWRA does not provide any justification for this significant finding. There appears to be no legal justification for treating stock and domestic farm dams differently from entitlement holders.

Often water released to meet a consumptive demand is greater than the amount actually withdrawn by the water user with the residual amount referred to as 'loss'. The LTWRA method explicitly considers how different types of losses should be treated (TR01, page 19). Transmission losses within the river network – for example, through bank seepage or evaporation – were not included in the WAfCU, while transmission losses in irrigation channels, pipes and other delivery infrastructure were included in the WAfCU. Operational losses are where additional water is released from a storage to ensure adequate water is available for water users and the surplus water continues to travel down the river. Where operational losses are associated with releases for consumptive use, these are also included in the WAfCU.

The *Water and Catchment Legislation Amendment Act 2019* amended section 22P of the *Water Act 1989* to require in any LTWRA for the Minister to have regard to any relevant:

- economic and environmental matters
- Aboriginal cultural values and uses of waterways
- social and recreational matters.

Section 1.3.2 of the Overview Report states:

> The review will consider relevant social, economic and environmental issues, including relevant Traditional Owner values and uses of water.

The Department advised this approach to explaining how the LTWRA considers Aboriginal cultural values was agreed upon by the Department's Aboriginal Water Unit and after consultation with Traditional Owners.

6.1.3 Panel's findings

6.1.3.1 Principal

The interpretation of WAfCU appears to be consistent with the intent of subsection 22L(a) of the *Water Act 1989*.

6.1.3.2 Secondary

The treatment of losses is logical and consistent with the intent of the LTWRA.

The manner in which Aboriginal cultural values and uses of waterways, and social and recreational uses and waterways values should be considered is not stated.

6.1.3.3 Consideration for future LTWRAs

For future LTWRAs consideration should be given to whether stock and domestic uses should be excluded.

For future LTWRAs consideration should be given to explicitly stating how Aboriginal cultural values and uses of waterways, and social and recreational uses and waterways values should be considered.

6.2 Method – Water available for the EWR (WAftE)

6.2.1 LTWRA interpretation

Section 5.1.2 of the Overview Report states:

> The Act requires the LTWRA to determine if there has been a decline in the volume of water available for the 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. The environment also benefits from other water that is not included in the EWR.
>
> 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.

6.2.2 Evidence

The *Water Act 1989* directs the LTWRA to consider the EWR in defining the WAftE. The EWR is defined in the *Water Act 1989* as water set aside for the environment by provisions made under the Act, including environmental water entitlements, passing flows, or a cap on water diversions. However, additional volumes of water are also available for the environment in Victoria including water shares and take-and-use licences held for the purposes of providing water for the environment and water exceeding winterfill sustainable diversion limits specified in SWSs. The LTWRA assessment includes these additional provisions in the definition of WAftE as consistent with the intent of the *Water Act 1989*.

In order to comply with the explicit meaning of the *Water Act 1989* a separate assessment of changes in the EWR is also provided.

6.2.3 Panel's findings

6.2.3.1 Principal

The broader interpretation of WAftE appears to be consistent with the intent of s.22L(a) assessment and is supported.

6.2.3.2 Secondary

Nil.

6.2.3.3 Considerations for future LTWRAs

Nil.

6.3 Method – Should current water-sharing rules be included?

6.3.1 LTWRA interpretation

The LTWRA is required to assess impacts of long-term water availability declines on WAftE and WAfCU and specifically whether there has been a disproportionate impact. The assessment focuses on determining if there is a change in the proportion of water available for each of these uses over the long term relative to a baseline. The LTWRA method defines the baseline as the water management arrangements in place at the time the previous SWS was produced. Water availability for this baseline state were modelled using the climate series used in the SWS to characterise climate conditions at that time.

The method requires an assessment of change in water availability for consumptive use and the environment. The LTWRA method distinguishes the effect of declines in total water availability from the effects of changes in water-sharing arrangements on water available for the environment and consumptive uses.

This is achieved using a three-step process:

- Step A determines WAftE and WAfCU at the time of the SWS
- Step B determines WAftE and WAfCU over the period 1975 to 2017 with water-sharing arrangement in place at the time of the SWS
- Step C determines WAftE and WAfCU over the period 1975 to 2017 with current water-sharing arrangements.

6.3.2 Findings

6.3.2.1 Principal

Step C should not be used to determine disproportionate impacts of reduced water availability on WAftE and WAfCU, because Step C confounds the effect of declining water availability due to climate with changes in water-sharing arrangements introduced since the SWS.

A comparison of WAfCU and WAftE in Step B compared with Step A is an adequate basis for determining disproportionate impacts as required by the *Water Act 1989*. The Act refers explicitly to the LTWRA needing to assess the effect of a decline in water resource availability on WAfCU and WAftE. Step B best reflects this intent.

6.3.2.2 Secondary

The Step C comparison may be useful to stakeholders focused on a review of water-sharing arrangements. However, the Panel highlights an important distinction between post-SWS changes in water management arrangements intended to maintain proportion of water for consumptive users and for the environment in the face of declining water availability, from those intended to alter water shares. Importantly, across Victoria water management arrangements have changed in recent years with the specific intent of increasing the environmental share to achieve improved environmental objectives. These interventions were generally a response to substantial shortfalls in environmental water provisions at the time of the relevant SWS and not declining water availability. In these cases, the effect of reduced water availability should be assessed relative to the intended increases in environmental water shares and improved environmental objectives rather than water shares and environmental conditions at the time of the SWS.

Although not claimed in the LTRWA, the results from Step C in the current method may give a false assurance concerning the effect of climate change on water shares. For example, where declines in environmental water shares have been offset by increased environmental water provisions, this should not be considered a successful outcome of planning for climate change.

The correct interpretation is that climate change has reduced environmental water shares in some catchments and this has undermined the substantial efforts in environmental water recovery, planned and implemented in Victoria over several decades. This is apparent in the findings for the Thomson River basin (Overview Report, page 21) which states:

> The increased volume of environmental entitlements in the Thomson basin since the SWS 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.

Although adequate for this LTWRA, the Step B approach has a shortcoming in that it neglects consideration of any water management interventions since the last SWS, which were specifically intended to offset effects of reduced water availability on water availability of either consumptive use or the environment. Such interventions may become more common in the future with improved understanding of climate change effects on water resource systems.

If there have been changes in water-sharing arrangements specifically intended to offset the effects of declining water availability, then this offset should be accounted for in assessing the disproportionate impact and hence the possible need for review. However, this same logic does not apply to water management interventions specifically intended to alter the proportions of water available for the environment and consumptive users. This cannot also be considered as an offset for impact of declining water availability in determining the need for review of water-sharing arrangements.

6.3.2.3 Considerations for future LTWRAs

For future LTWRAs consideration should be given to accounting for water management interventions introduced since the last SWS specifically intended to offset the effects of declining water availability in assessing disproportionate impact and hence determining the need for a review under section 22P of the *Water Act 1989*. Such interventions may become more common in the future with improved understanding of climate change effects on water resource systems.

6.4 Method – Criteria for determining a disproportionate impact

6.4.1 LTWRA approach

The LTWRA established a 1 per cent change in the proportion of water for the environment and for consumption as the threshold for a ‘disproportionate’ change.

6.4.2 Evidence

The Department’s interpretation of ‘fallen disproportionately’ as provided on 8 February 2019 is summarised below. It confirms that the *Water Act 1989* does not provide a definition of this term.

The Department suggests that a common-sense approach should be used; that is, how can the provision be interpreted and applied in a way that gives the provision purpose and meaning? It recommends that the threshold should be where meaningful observations can be made (not minute, tiny or trivial).

The LTWRA established a 1 per cent change in the proportion of WAftE and WAfCU as the threshold for a ‘disproportionate’ change. The Panel suggested to the Department that this appeared to be a small change that needed to be better justified.

In response, the Department undertook sensitivity analyses for Merri River and Little River in August 2019 (see Appendix F (LTWRA Analysis Case Studies) of TR03). This showed that the uncertainties in each of the individual input components could be high; however, when comparing across scenarios to estimate the disproportionate change, the uncertainties in the change were generally very low. In both case studies, large sensitivities in inputs (up to 50 per cent) typically resulted in a shift in the change in the environment's portion of water availability across scenarios of less than 0.1 per cent . This indicates that the changes in relative water availability across scenarios are generally robust to input uncertainties in the two case studies considered. Thus, the likelihood that basins above (or below) the 1 per cent threshold would be incorrectly targeted for review because of assessment uncertainty is low.

The Department notes that a degree of value judgement is required in interpreting and applying this threshold as the provision is incapable of being given a scientifically precise meaning, and it is ultimately a call for the Minister in making the assessment under section 22K as to whether she is satisfied that she is meeting the requirements of section 22L.

6.4.3 Panel’s findings

6.4.3.1 Principal

The LTWRA interpretation of ‘fallen disproportionately’ is endorsed.

A threshold of 1 per cent for determining a disproportionate in the proportion of WAftE and WAfCU is a reasonable balance in the face of uncertainty and the risk of failing to detect disproportionate impact.

6.4.3.2 Secondary

Nil.

6.4.3.3 Considerations for future LTWRAs

Nil.

6.5 Is the data used the best available?

6.5.1 LTWRA interpretation

The *Water Act 1989* requires that the LTWRA uses best available models and data. For this reason, the LTWRA applied any available improvements in models or data for the baseline scenario, meaning that WAfCU and WAftE in the LTWRA baseline may differ from availability determined at the time the SWS was developed.

6.5.2 Evidence

As part of this review of whether any declines have fallen disproportionately, several basin and regional modelling reports have been interrogated. The following have been subject to a more detailed assessment to inform the overall review:

- Melbourne Water (2018). *Long-term water resources assessment analysis* – for Yarra River basin
- HARC (2019). *Update of Barwon – Moorabool REALM model. Technical report – Model inputs*
- GHD (2018b). *Latrobe water resource model daily input – Stage 2, input derivation and validation reports.*

The key comments are provided below and the detailed comments are presented in Appendix B of this report.

6.5.2.1 Yarra basin modelling

Unlike the rest of Victoria, the urban entitlement for the Melbourne System is based on a climatically variable diversion limit that was directly linked (as part of the setting of this diversion limit) to Melbourne Water's target level of service for reliability of supply. The Melbourne system also has potential to access a climate-independent source of water from the Victorian Desalination Project.

The Department has advised that the diversion limit cannot be exceeded and represents an upper bound on urban diversions and that the levels of service can be achieved by accessing other water supplies.

The methods for modelling changes availability for consumptive and environmental uses are broadly consistent with the approach specified for the LTWRA. The modelling approaches are reasonable given available models and data, with assumptions generally well documented.

The LTWRA method states that urban water availability should be updated for Step C by scaling water demand to maintain levels-of-service as the baseline model (TR03, page 35). Also, TR03 (page 79) states: ‘For urban water supply, demands at full uptake are demands at which level-of-service objectives are just met.’ The use of the diversion limit demand in Step C is considered as meeting this requirement.

6.5.2.2 Barwon basin modelling

The Barwon basin model includes the Barwon River basin, the Moorabool River (but not all not all of the rivers in the Moorabool basin such as Little River).

The extent of the Barwon–Moorabool model is set out in the relevant REALM modelling report (see Figure 3–1 Barwon–Moorabool model schematic).

The original SWS model has undergone extensive improvements and these are comprehensively documented. It is not possible to review the details of these amendments from the information provided, but it is noted that the intent of these amendments is consistent with the LTWRA method specified by the Department. The analysis and validation of the updated model is well documented.

It was not possible to reconcile the water availability for consumptive users and the environment presented in tables 8 and 11 of TR03 and Appendix B of HARC (2019). Subsequent to the Panel's review of HARC (2019), the Department advised that it had identified errors in the HARC (2019) report that were subsequently corrected in further modelling runs, and the updated results for the Moorabool and Barwon river basins were reported in TR03. The outputs of the modelling runs were not sought by the Panel.

6.5.2.3 Latrobe basin modelling

The GHD (2018), *Latrobe water resource model daily input – Stage 2 input derivation and validation* report is concerned with derivation of inflows and current level of demands, and incorporating improvements to farm dam modelling.

The large volume of return flows from power station cooling towers and mine dewatering, along with recycled water from the Gippsland Water Factory, are not included in WAfCU or WAftE calculations consistent with definitions applied by the LTWRA method.

From the information provided, the scenario definitions and broader methodology are consistent with the LTWRA method.

While model improvements are generally only briefly described in GHD (2018b), a more detailed description is provided in DELWP (2018c), *Latrobe system scenario modelling long-term water resource assessment*. This latter report provides documentation of the improvements to the Latrobe model for the purposes of the LTWRA, including the derivation of new yield demands for power generators, the environmental entitlement, and improvements to the representation of the Blue Rock drought reserve for yield modelling. This latter report was not subject to a detailed assessment by the Panel.

6.5.3 Panel's findings

6.5.3.1 Principal

The approach of using updated models and data to represent the baseline water shares is endorsed.

6.5.3.2 Secondary

An interrogation of several modelling reports indicates the scenario definitions and broader methodology is generally consistent with the LTWRA method.

6.5.3.3 Consideration for future LTWRAs

Nil.

6.6 Conclusions – supported by methodology and data

Section 22N of the *Water Act 1989* requires the review to consider whether or not the conclusions reached in the draft LTWRA are supported by the methodology and data.

6.6.1 LTWRA interpretation

The Overview Report (Sections 5.6, 5.6.1, figures 49 and 51) provide a comparison of Step B compared with Step A.

Section 5.6 of the Overview Report stated that the assessment:

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.

6.6.2 Evidence

See Section 3 of TR03.

The Step B to Step A comparison (TR03, Table 17) indicates that the change for the following river basins are 1 per cent or greater:

- Yarra 7 per cent
- Werribee 5 per cent
- Moorabool 4 per cent
- Thomson 3 per cent
- Barwon 2 per cent
- Latrobe 1 per cent
- Maribyrnong 1 per cent.

6.6.3 Panel's findings

6.6.3.1 Principal

The conclusions reached in the draft LTWRA on whether the decline has fallen disproportionately on the WAftE or on the WAfCU are supported by the methodology and data.

Although there are uncertainties with the data and the method, it is recommended that the 1 per cent impact of decline in the WAftE in the Latrobe and Maribyrnong river basins be considered disproportionate.

6.6.3.2 Secondary

Nil.

6.6.3.3 Consideration for future LTWRAs

Nil.

7 Waterway health

Subsection 22L(b) of the *Water Act 1989* requires an LTWRA to identify whether there has been any deterioration in waterway health for reasons related to flow.

The questions considered in the methodology review are:

- definition of waterways
- definition of waterway health
- use of indicators to determine waterway health
- hydrological indicators
- timeframe for waterway health assessment
- statistical trend methods
- presentation of results.

7.1 Background

Subsection 22L(b) requires an assessment of whether there has been any deterioration in waterway health for reasons related to flow. The LTWRA split this requirement into two objectives:

- Has there been any deterioration in waterway health with time?
- Can any deterioration be attributed to reasons relate to flow?

In addressing these two objectives, the following assessments were undertaken:

- *River health* – three sets of analyses were undertaken, these being (TR04, Section 2.1, page 9):
    - Trends with time – using a segmented statistical regression ('broken stick') analysis for separately testing trends and changes in trends across three time periods (see below) in selected waterway health indicators (water quality, macroinvertebrate and fish) at the basin scale.
    - Causality analysis – using structured equation modelling (SEM) to assess how much of the trends and changes in trends in waterway health indicators could be attributed to flow.
    - Spatial analysis – using hierarchical models to see if the trends and flow causality differed at different spatial scales (for example, basin scale and SWS region scale).
- *Wetland and estuary health* – explored (using selected datasets) the possible assessment of the health of one estuary (Gippsland Lakes).

The subsection 22L(b) analyses are reported in TR04 and the Overview Report.

The ecohydrological assessment reported in TR05 is not considered further in this review as the results were not used in the LTWRA.

7.2 Clarity of second objective of subsection 22L(b) requirement

Subsection 22L(b) requires a determination of whether any deterioration in waterway health can be attributed to reasons related to flow.

7.2.1 LTWRA interpretation

The Overview Report (Section 6.1) interprets this objective as the extent to which changes in indicators could be explained by flow (shown as the percentage of the change related to flow).

7.2.2 Evidence

Section 4 of TR04 addresses the subsection 22L(b) task as a two-stage question:

- to identify if there had been a reduction in ecological condition

- to assess whether any of that reduction could be attributed to flow.

The attribution of causality to flow for each river basin for all indicators is presented in tables 3 to 19 of TR04 for time periods 1990–2005, 2006–2010 and 2011–2018. The Panel notes that flow causality in these tables does not indicate which type of flow was responsible for the changes in the indicator trends.

7.2.2.1 Principal

The Panel accepts the LTWRA interpretation of reasons related to flow for this assessment, with the caveat that the type of flow related to a trend was not identified.

7.2.2.2 Secondary

The ‘reasons related to flow’ requirement is ecologically and analytically vague. There are many flow-related changes that could influence waterway health, including climatic variability or changes due to human interventions, such as interception of flow by reservoirs, extraction of water for consumptive use, or addition of environmental flows to a river as a result of the implementation of an SWS.

The s.22L(b) assessment does not include the Bunyip River basin. The reason for this is stated as insufficient long-term data available to assess the water quality, macroinvertebrate or fish waterway health indicators in this basin.

7.2.2.3 Considerations for future LTWRAs

For future LTWRAs, consideration should be given to better defining the term ‘reasons related to flow’ to make a clearer distinction between the influence of flow changes due to climate variability and those due to the implementation of SWS-recommended actions.

7.3 Method – Definition of waterway

7.3.1 LTWRA interpretation

The LTWRA (Section 6.6.1) defines waterways as including regulated and unregulated rivers, their associated estuaries and floodplains (including floodplain forests and wetlands) and non-riverine wetlands.

7.3.2 Evidence

The definition of waterway under the *Water Act 1989* includes:

a. a river, creek, stream or watercourse

b. a natural channel in which water regularly flows, whether or not the flow is continuous

c. a channel formed wholly or partly by the alteration or relocation of a waterway as described in paragraph (a) or (b)

d. a lake, lagoon, swamp or marsh.

7.3.3 Panel’s findings

7.3.3.1 Principal

The LTWRA’s interpretation of waterways for this assessment as regulated and unregulated rivers (and their associated estuaries and floodplains (including floodplain forests and wetlands) and non-riverine wetlands) is consistent with the *Water Act 1989*, and is endorsed.

7.3.3.2 Secondary

Nil.

7.3.3.3 Considerations for future LTWRAs

Nil.

7.4 Method – Definition of waterway health

7.4.1 LTWRA interpretation

Waterway health is comprised of particular ecological characteristics (such as the presence, abundance and diversity of species, habitat condition and extent, feeding and breeding opportunities, and water quality) (see Glossary of Overview Report).

The Overview Report (Section 6.6.1) considers waterway health to include 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.

7.4.2 Evidence

The *Water Act 1989* does not provide an explicit definition of waterway health. However, section 4B of the *Water Act 1989* includes an implicit definition that incorporates the concepts commonly discussed in the scientific literature, namely:

> The EWR objective is … to preserve the environmental values and health of water ecosystems, including their biodiversity, ecological functioning and quality of water and the other uses that depend on environmental condition.

7.4.3 Panel's findings

7.4.3.1 Principal

The LTWRA interpretation of waterway health, which is consistent with section 4B of the *Water Act 1989*, is endorsed.

7.4.3.2 Secondary

Nil.

7.4.3.3 Considerations for future LTWRAs

Nil.

7.5 Method – Use of indicators to determine waterway health

7.5.1 LTWRA interpretation

The waterway health indicators used in the s.22L(b) assessment include: six water quality indicators, two biodiversity indicators related to macroinvertebrates, and three indicators related to fish.

The Overview Report (Section 6.2.1, page 126) states 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 for before 2005.

The Overview Report (Section 6.2.1, page 126) also states:

> Macroinvertebrates and fish indicators were the only biodiversity indicators available as there was insufficient data for other biodiversity values such as for in-stream and riverside vegetation, waterbirds, amphibians and platypus. This Report also states that inadequate data was available for indicators of ecosystem function (such as processing of nutrients or production of overall biomass).

7.5.2 Evidence

When the *Water Act 1989* was amended in 2005 to include the requirement for LTWRAs to be undertaken every 15 years, no monitoring system or data collection strategy was initiated to specifically meet the LTWRA's needs. Consequently, it was necessary that data collected for other purposes be screened for the s.22L(b) assessment and the best available dataset be selected (this is discussed in Sparrow & Bond, 2018).

7.5.2.1 Indicators

The Overview Report (Section 6.2.1) identified water quality and macroinvertebrates as the only indicators that met the necessary long-term requirements. The assessment complemented these indicators with some native fish datasets for which limited data was available before 2005. The indicators used are listed in Table 7–1.

Table 7–1: LTWRA water health indicators

Type	Indicator
Native fish	Nativeness by biomass
	Observed to Expected ratio
	Observed to Predicted ratio
Macroinvertebrates	SIGNAL2 (Stream Invertebrate Grade Number – Average Level)
	Odonata Coleoptera Hemiptera (OCH)
Water quality	Dissolved oxygen (DO)
	Salinity as electrical conductivity (EC)
	Turbidity
	Total suspended solids (TSS)
	Total phosphorus (Total-P)
	Nitrate and nitrite as Nitrogen (NO_2 + NO_3^-N or NO_x^-N)

Sparrow and Bond (2018) stressed that as there is no single metric or indicator of waterway health, multivariate data and analysis must be used for the s.22L(b) assessment. Also, the data must, where possible, be statewide, involve repeated measures at the same locations, and be measured using consistent methods.

Sparrow and Bond (2018) assessed available data pertaining to river and stream health against these criteria, including consideration of the definition of waterway health and the wide range of indicators of waterway health used in previous research and monitoring. That report identified a set of five large-scale water quality, macroinvertebrate and fish monitoring datasets that offered the most potential for LTWRA purposes and noted that each might be supplemented to some degree with additional research-related datasets.

TR04 (Section 2.2, page 13) chose the six water quality indicators listed in **Table 7–1**. These indicators were considered to represent a range of potential waterway stress indicators, influenced by a range of potential drivers and pressures, within a multivariate concept of water quality. In general, all six indicators have been measured monthly at the 80 sites across southern Victoria. These water quality data have been collected (largely monthly) since the mid-1970s although only data from 1990 was used in the LTWRA. Filtering of water quality data was reported as being undertaken to remove observations where the quality code cast doubt on the validity or accuracy of measurement or data recording.

Two macroinvertebrate metrics, based on family-level data, were calculated for each sample in the dataset (See **Table 7–1**). The final dataset for 53 sites across 13 river basins produced 1,213 data points (see **Table 7–1**), following filtering to exclude sites where the number of observations between 1990 and 2018 was less than 10.

TR04 (Section 2.4, page 17) refers to statewide fish community indicators. Four of the five fish metrics developed for the *Sustainable Rivers Audit* (Davies et al. 2010) were calculated for each site-date observation in the dataset. Those calculated are the three presented in **Table 7–1** and 'Proportion of native species'. Filtering was conducted to exclude sites where the number of observations between 1990 and 2018 was less than 8.

7.5.2.2 River basin water health monitoring data

The sites for water quality, macroinvertebrate and fish samples within each southern Victorian river basin are given in TR04 Appendix E, and the data are plotted in Appendix B (water quality), Appendix C (macroinvertebrates) and Appendix D (fish). A consolidated list of the data used for the 17 southern Victorian river basins, excluding the Bunyip, is provided in **Table 7–2** below.

Table 7–2: Water quality macroinvertebrate and fish data available for s.22L(b) – summary

Basin	Water quality		Macroinvertebrates		Fish	
	Sites	Data	Sites	Data	Sites	Data
Barwon	2	682	3	50		
East Gippsland	4	1,235	1	20		
Glenelg	9	2,533	9	181	1	31
Hopkins	2	668				
Lake Corangamite	2	348	2	22		
Latrobe	6	1,761	5	222		
Maribyrnong	7	1,011	*	*	*	*
Mitchell	2	677	2	50		
Moorabool	3	993	1	47	1	8
Otway Coast	7	2,031	8	119		
Portland Coast	2	677	1	23		
Snowy	3	603	6	180		
South Gippsland	1	306	5	77		
Tambo	5	1,162	4	85		
Thomson	10	3,247	7	137		
Werribee	5	917	*	*	*	*
Yarra	10	3,663	*	*	*	*
Totals	**80**	**22,514**	**54**	**1,213**	**2**	**39**

*Data held by Melbourne Water but not available for this analysis

There was a significant lack of biological monitoring data for rivers in southern Victoria (**Table 7–2**). For example, adequate fish data (that with eight or more observations at a site) was only available for the Moorabool and Glenelg rivers. Additionally, the frequency of macroinvertebrate observations has been very limited over the period 1990 to 2018.

The raw data for hydrology, water quality and macroinvertebrates are all public and held by DELWP and Melbourne Water. The fish data were compiled across many projects, with LTWRA-specific permissions for use obtained from owner/funders and researchers.

The dataset is currently held at ARI, and when finalised, will be deposited in the LTWRA repository with the rest of the assessment data.

7.5.2.3 Aggregation of indicators

TR04 states:

> There is no evidence to suggest that water quality, macroinvertebrate and fish community are effective surrogate indicators for all dimensions of aquatic ecosystems. As a consequence, any detections of deterioration and improvement in waterway health in these analyses are constrained within a subset of the fully holistic concept of waterway health.

However, the Panel believes this argument to be counterproductive regarding the purpose of the LTWRA. It has already been established that there cannot be one overall indicator of waterway health and that choices must be made. The choices made are reasonable based on data availability and on working definitions of waterway health adopted around the world. The Panel sees no justification to then cast doubt on whether these indicators are actually indicative of stream health. A brief comment in the LTWRA report discussion noted that these indicators do not cover aspects such as ecosystem function would be sufficient.

The Panel notes that despite TR04 suggesting a multivariate approach is needed, there was no attempt to link these indicators together to determine if waterway health has deteriorated. Each indicator was considered separately and even then only a trend was reported (as positive or negative) with no attempt to provide any information on how important the trend was regarding water quality or biological 'health'. The approach taken in TR04 is best conceived of as a multivariable (as opposed to multivariate) approach to assessing waterway health.

TR04 (page 3) also advised:

> Importance implies an underlying or assumed set of values, in the social sense of the word 'values'. While at least water quality values in Victoria are coded through the SEPP (Waters) objectives, the complex analysis required to assess for trend against site-specific, percentile-based SEPP Objectives was beyond the scope of the current work.

7.5.2.4 Quality control

TR04 noted some quality control issues associated within the selected water quality indicators. These included changes in the analytical methods used, equipment or data handling over the period 1990–2018; and difficulties in the resolution of low concentrations (for example, there was a change in analytical methodology for Total-P concentrations around 2009, resulting in quite different patterns in the temporal variability of Total-P observations before and after 2009) (see TR04, Appendix B.5).

7.5.3 Panel's findings

7.5.3.1 Principal

For southern Victorian river basins, there is a reasonably adequate set of water quality data (although only post-1990 data has been considered), an incomplete set of macroinvertebrate data, and almost no fish data.

These indicators do not reflect the overall waterway heath as ecological functioning data was not available, and the biodiversity data was limited to macroinvertebrates and fish data (post-2005) for the Glenelg and Moorabool river basins.

This lack of ecological functioning and limited biodiversity data does not mean the LTWRA has 'failed' with regard to choosing indicators of ecosystem health since truly ecological functional indicators (for example, rates of stream metabolism) are rare in long-term datasets and so it would have been impossible to compile any meaningful datasets. Within the intended purpose of the s.22L(b) assessment, the indicators chosen are acceptable indicators of waterway health.

Importantly, the water quality, biological or ecological importance of any improving or deteriorating trend was not considered, nor has there been any consideration of the aggregation of multiple indicators as a measure of waterway health as this considered to be beyond the scope of the current work.

7.5.3.2 Secondary

Water quality indicators

- The water quality indicators selected are broadly supported except for the inclusion of DO, the exclusion of pH, and nitrogen being reported in the dissolved form (as NO_3+NO_2-N) whereas phosphorus was reported in the particulate and dissolved forms (as Total-P).
- The selection of dissolved oxygen as an indicator is questionable as it is a notoriously variable indicator, with its value depending on temperature, biological activity and the time of the day when measurements are taken. The only 'waterway health' signal from DO monitoring is when it crashes to low levels and causes fish kills. These are always temporary. The Panel is unaware of any long-term changes in DO in waterways (lakes perhaps, but not streams) associated with ecological health. More data will not help this. Thus, it is unlikely that any long-term changes in dissolved oxygen concentrations in rivers will be detected, and even more difficult to relate any such changes to changes in flow.

- The nutrient indicators are somewhat confused in that Total-P measure phosphorus in both particulate and dissolved forms, while NO_2+NO_3-N measures only the dissolved forms of nitrogen (as nitrite and nitrate). It is unclear why Total-N concentration was not adopted as this would equate more closely with Total-P. While the form of P and N reported would have been more equivalent if either the particulate and dissolved form or dissolved (bioavailable) form was chosen for both parameters, this has not impacted on the s22L(b) assessment since few significant trends in nutrients were found.
- pH is considered a suitable water quality indicators and is an environmental quality indicator in SEPP (Waters). No reason was given for its exclusion.
- Trend analysis for water quality indicators using data back to the mid-1970s, when water quality monitoring of most southern Victorian river basins commenced, has been undertaken for many years by DELWP using generalised additive modelling. The Panel is surprised that this analysis was not undertaken in the LTWRA, although it is not possible to know whether such an analysis would have changed the conclusions regarding trends in the water quality indicators.

Macroinvertebrate and fish indicators

- Thomson et al. (2012) compiled over 7,000 macroinvertebrate samples from over 2,000 sites across Victoria. Thomson et al. (2012) used modelled streamflow, and therefore included sites for which there was no nearby streamflow gauge. In the LTWRA, macroinvertebrate sampling sites were excluded from assessment of flow-related change if there was no gauging station close to the sampling site (TR04, Section 2.7, page 18). Even if southern Victoria had less than half this number of samples, there could be about 3,000 data points that could have been used rather than the 1,200 that were used.
- The decision that a site needs to have more than 10 data points (for macroinvertebrates) and 8 points (for fish) before it could be used has meant that many available data did not get used.
- Thomson et al. (2012) found strong evidence for temporal changes (reduction) in macroinvertebrate communities across Victoria including at the scale of individual basins and with a shorter-term dataset than was available for this analysis. However, flow was not identified as a major driver of this pattern in these declines in macroinvertebrate condition. Thomson et al. (2012) states:

> There was considerable spatial variability in trends… [in macroinvertebrate indices], but this spatial variation was not explained statistically by spatial variation in climate (basin scale) or flow (reaches scale) trends. The lack of strong associations between abiotic (climate and flow) trends and macroinvertebrate trends is somewhat surprising…and may reflect difficulties in estimating trends precisely at small spatial scales.

- TR04 (Section 3.2, page 66) reported that the exploratory regional-scale Bayesian models found declines in macroinvertebrate indices (SIGNAL2) over the period 1990–2006 in all regions except the Central Region. Strong attribution due to flow was found in the Gippsland Region, but not in the Western Region.
- Adequate fish data was only available for the Moorabool and Glenelg rivers, and then only since 2005.
- There are additional macroinvertebrate and fish data for the Maribyrnong, Yarra and Werribee rivers collected by Melbourne Water, but this was apparently not made available. The use of this data may have assisted in determining whether the waterway health in these basins had deteriorated for reasons related to flow.
- The general lack of biological data for southern Victorian rivers is regrettable.

Overall

- The waterway health indicators used included six water quality indicators and biodiversity indicators related to macroinvertebrates and fish.
- In the case of the water quality and macroinvertebrate indicators, the 2018 Victorian SEPP (Waters) and the 2018 *Australian water quality guidelines for fresh and marine waters* were not used to assess whether any trends were ecologically or biologically important regarding waterway health.

7.5.3.3 Considerations for future LTWRAs

For future LTWRAs, consideration should be given to:

- conducting further work to establish what combinations of the various indicators might be used to identify whether deterioration has occurred in waterway health within river basins

- assessing the importance of trends in waterway health indicators (particularly water quality and macroinvertebrates) against the 2018 SEPP (Waters) environmental quality indicators and objectives and the 2018 *Australian water quality guidelines for fresh and marine waters*
- reviewing the adequacy of current state waterway health monitoring programs for the purpose of the LTWRA. The Panel understands that this review is underway. It should consider the findings from this review, the TR04's opinion that there is no evidence to suggest that water quality, and the macroinvertebrate and fish communities are effective surrogate indicators for all dimensions of aquatic ecosystems, and the TR04 (Section 4) recommendations for future LTWRA s.22L(b) assessments.

7.6 Method – Hydrological indicators

7.6.1 LTWRA interpretation

The s.22L(b) assessment used five flow indicators – mean discharge, max discharge, days of no flow, days since end of last no flow, baseflow index, and calculated flow trends for these indicators for each of six antecedent periods (30, 60, 90, 120, 240 and 365 days). These antecedent periods recognised that water quality, and particularly biological response, measured at a particular time is not necessarily driven by the same characteristics of water regime as water availability.

7.6.2 Evidence

The 30-day antecedent period provided the best fit for water quality with the flow indicators for the basin-level regression models (TR04, Table 49). No trends were identified for the biological indicators (where there was available data) across the 17 basin-level segmented regression models.

7.6.3 Panel's findings

7.6.3.1 Principal

The use of antecedent periods for hydrological indicator variables for the s.22L(b) assessment is broadly supported.

7.6.3.2 Secondary

The Millennium drought was expected to have a greater impact on the s.22L(b) assessment due to the shorter duration of hydrological data (compared to the s.22L(a) time period); the drought made up around 35 per cent of the total span of the average flow data.

The relevance of the other antecedent periods for macroinvertebrate and fish indicators was essentially untested because of the limited (or no) biological data.

7.6.3.3 Considerations for future LTWRAs

Nil.

7.7 Method – Timeframe for waterway health assessment

The first part of the s.22L(b) assessment objective was to determine if there had been any 'deterioration' in waterway health over the selected time period (1990–2018). The methodology adopted briefly involved:

- determining the (linear) trends of each selected water quality and biological indicator over the period 1990–2018
- deciding whether these trends are statistically significant
- deciding whether the trend indicated an improvement or deterioration of the indicator. This is further discussed in this review.

7.7.1 LTWRA interpretation

The LTWRA (Section 6.2.5 of the Overview Report) adopted the period 1990 to 2018 and the following three time periods for the s.22L(b) assessment:

- 1990–2005 – pre publishing of SWSs and first part of the Millennium drought
- 2006–2010 – most impacted part of the Millennium drought and after SWS for central region published and prior to western and Gippsland SWSs being published
- 2011–2018 – post-Millennium drought and SWS for all southern Victorian SWSs.

7.7.2 Evidence

TR04 advises that Sparrow and Bond (2018) provided a rationale for selection these three time periods as:

> The hydrology of Victoria's waterways varies continuously under the influence of many catchment processes operating at a range of temporal scales. Single rainfall events lead to hydrological changes in hours to weeks, rainfall and evapo-transpirational seasonality lead to annual cycles, and El Niño cycles and major drought lead to quasi-cyclic changes over many years. Most indicators of waterway health vary, in turn, continuously at all temporal scales in response to the complex hydrological dynamics.
>
> Any assessment of trend in waterway health must take into consideration the dynamic, multi-scale variability of these ecosystems. In the context of the last 40 years, the period for which Victoria-wide data are available for a range of waterway health indicators, the Millennium Drought (2001–2010) represents a very significant departure from the historic range of variability that might be represented in a 40-year sample of data and has the potential to strongly influence apparent trends. Without explicitly recognising and incorporating the Millennium Drought into the structure of analyses, assessment focus only any deterioration of waterway health from pre-drought to drought and/or improvement in waterway health from drought to post-drought conditions has the potential to obscure deviations from these obvious cyclic patterns that would have the greatest implications for environmental management. Thus, Sparrow and Bond recommended these three time periods which combine critical aspects of the timeframes for the initial LTWRA assessment as specified in the Water Act (the twelve-year period 2006–2018) with the span and, in particular, the breaking of the Millennium Drought (2001–2010).

The 'current' time period (2011–2018) used in the s.22L(b) assessment to assess overall flow changes is different from the s.22L(a) assessment (1975–2018). The former current time period does not include the Millennium drought while the s.22L(a) current time period includes the Millennium drought.

The s.22L(a) assessment, used hydrological data over the period 1975 to the current (2017) for all river basins (except for East Gippsland and South Gippsland which are shown in Figure 6 of the Overview Report as 2015) as the current time period to enable long-term comparison of historical (pre-1975) and current climates to be made for each river basin. The change in mean water availability over multiple years was undertaken, with calculations undertaken on the basis of calendar years. The influence of the Millennium drought (2000–2010) was expected to be modest relative to the 43 years (1975–2018) of data used as representative of the current climate.

7.7.3 Panel's findings

7.7.3.1 Principal

The Panel is not convinced that the splitting of the time period for this analysis (1990–2018) into three sub-time periods was either necessary or helpful for the s.22L(a) assessment.

Assessment over a single time period (1990–2018) would have made interpretation of possible deterioration in waterway health indicators much more straightforward.

7.7.3.2 Secondary

The DSE (2004) White Paper states:

> the Government may choose to adjust entitlements to share more equitably the impact of a long-term reduction in the resource base caused by climate change, or to change the balance between consumptive entitlements and the EWR in response to a discernible downward trend in river health.

The requirement for an LTWRA every 15 years was driven by the need to take account of the possible effects of a long-term reduction in the resource base or a discernible downward trend in river health, and to determine whether the SWSs need to be reviewed to account for these changes; for example, to determine if there is a need for more water for the environment.

Thus, the s.22L(a) and s.22L(b) assessments needed to consider what period of data was representative of the 'current', as opposed to 'historical', flow record. For the s.22L(a) assessment this was selected as the period 1975 to 2017 for most river basins and for the s.22L(b) assessment from 1990 to 2018. The selection of 1990 as the start of the period for the s.22L(b) assessment was for pragmatic reasons given that there was little relevant biological waterway health data collected before that date.

Both the s.22L(a) and s.22L(b) assessments were concerned with the influence of flow changes over the relevant time period due to both to climate change and to the additional changes to environmental flow due to the introduction of the

SWSs (2006 for the Central Region and 2011 for the Western and Gippsland Regions). The flow record during both time periods was significantly influenced by the Millennium drought.

Because the Millennium drought made up a large proportion of the 1990–2018 time period, the s.22L(b) assessment attempted to specifically account for the drought and to understand the effects of water-sharing actions on waterway health by splitting the time period into three, rather than the two periods used in the s.22L(a) assessment (before and after the SWS implementation).

These three periods have been applied to all basins independent of the years in which the SWSs were published (2006 for Central Region and 2011 for Gippsland and Western Regions).

The reason for the difference in the s.22L(a) and s.22L(b) assessments' current time periods has not been adequately justified, noting the Millennium drought is only included in its entirety in the s.22L(a) post-SWS (current) period of 1975 –2018,

Both the Millennium drought and the introduction of the SWSs could have influenced the effect of flow on the trends – they are statistically confounded. But even if it is assumed that the drought had the greatest effect on trends, the three selected time period do not separate the influence of the Millennium drought cleanly, since both the first (1990–2005) and second (2006–2011) time periods contain part of the drought.

While the spit into the three time periods probably did not reduce the statistical power of the analysis, it may have overly complicated the interpretation of any trends.

Given that the primary influence of the Millennium drought was to reduce flow through southern Victorian rivers, any difference in ecological response would have been captured by including flow terms in the regression analysis. This was the approach adopted by Thomson et al. (2012). A segmented approach would be justified if there was evidence that the effects of flow varied among the different time periods (that is, there is was a difference in the relationship – the regression coefficient – between flow and response). However, the model structure used includes only single terms for each of several flow variables, which assumes that the effect of that flow variable is consistent over the entire 28-year data period.

7.7.3.3 Considerations for future LTWRAs

Nil.

The next LTWRA is for northern Victoria in 2025 when the Millennium drought will have less influence on trends.

7.8 Method – Statistical analysis

7.8.1 LTWRA interpretation

Linear segmented (or 'broken stick') regression models were used to test the significance of trends in the indicator variables at the river basin scale, with time and with changes in flow.

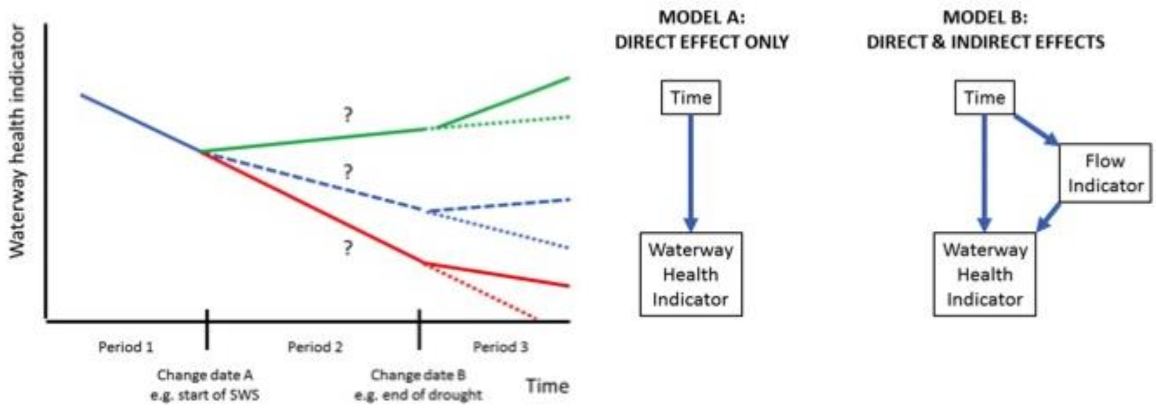
7.8.2 Evidence

A review of possible statistical methods (models) that could be used to determine trends in the waterway health indicators was undertaken by Sparrow and Bond (2018, pages 19–30) prior to the s.22L(b) assessment. These were all BACI (Before-After-Control-Impact) regression models. The BA part of the model was focused on separating the influence of 'Before' and 'After' the introduction of the relevant SWS. The CI part of the model was focused on separating the 'Impact' of the SWS changes from the situation in a 'Control' section of the river where flow changes had not occurred.

Because of the lack of field controls available (for example, direct unregulated river analogues of regulated river reaches) this approach was not feasible. Sparrow and Bond (2018) recommended instead the use of a quasi-controlled BACI model, where the ecological condition under the counterfactual situation (without flow changes under the SWS) is modelled. Unfortunately, the application of this method was not used as the necessary additional modelling requirements to establish the counterfactual conditions could not be completed because of time and budget limitations.

Instead, a linear segmented (or 'broken stick') regression model was used to test the significance of trends in the indicator variables, with time and with changes in flow. This is method is shown diagrammatically in Figure 1.

Figure 1: Conceptual segmented regression trend analysis method



The Department considered that this approach balanced:

- the short duration of available water quality and biological data sequences
- the need to test for deterioration of waterway health indicators
- the need to test whether any deterioration relates to flow
- the absence of 'real' or 'modelled' controls to causally ascribed the effects of flow to climatic variability or the introduction of the SWSs
- the effects of the Millennium drought and its potential to dominate the trends, depending on the start and end dates for any data sequence.

Trend analyses were undertaken at two spatial scales: the river basin scale and the regional (SWS) scale (Overview Report, Section 6.2.6). These are discussed below.

7.8.2.1 River basin-scale trends

A trend analysis was undertaken to determine if each indicator changed over time, and then variance partitioning was used to determine how much of the trend (or change in trend – see below) in each indicator was attributable to flow. The results for the time and flow causality trends are summarised in tables 3 to 19 of TR04 for southern Victorian river basins, with detailed trends for each river basin reported in appendices B (water quality), C (macroinvertebrates) and D (fish).

- <u>Time trend</u> – undertaken over the period 1990–2018 to determine if each indicator had a significant temporal trend over the first period (1990–2005), and then whether the trend changed between the three time periods (1990–2005; 2006–2010; 2011–2018). The model equation is of the form:

  $$y_i = Time + Time2 + Time3 + fRiver$$

  Where y_i is a data point of one of the waterway health indicators.

  Time is the temporal trend from 1990–2005, *Time2* is the change in that trend in the next period (2006–2010) and *Time3* is the further change in trend from 2011–2018; *fRiver* is a 'random factor' that acknowledges that starting points for waterway health indicators may vary among rivers within the same basin, and a different value will be fitted for each river. This term fills an equivalent role to an intercept term in a standard regression analysis, with the refinement that it varies among rivers. There is no attempt to account for the repeated measures taken at each site within a river basin, although it was often the case that there was only a single site for a river and so the *fRiver* term would have filled this role for such sites.

- <u>Flow effect</u> – variance partitioning was used to see how much of the trend in each indicator can be explained by flow. A second trend analysis was run that included all terms from the first model plus additional terms for each of the potential flow components. Attribution of flow effects was determined by looking to see how the Sum of Squares for the temporal trend in period 1 (*Time*) and the change in temporal trend in from periods 1 to 2 (*Time1*) and from periods 2 to 3 (*Time3*) changed once flow terms were included. The analysis logic was that if there was a reduction in trend (or change in trend) Sum of Squares of at least 20 per cent , then a substantial portion of the trend (or change in trend) could be attributed to the flow terms used.

The statistical models were fitted using the base R Package (version 3.5.1) driven through R Studio (version 1.1.456; TR04, page 22).

7.8.2.2 Regional-scale trends

Spatial analysis using a Bayesian hierarchical model (R library brms (version 2.6.0; TR04, page 24)) was undertaken to test whether the trends and flow causality analyses differed at different spatial scales, namely river basins, SWS regions and southern Victoria.

TR04 reports trends (and flow causality) at the three SWS regions (Central, Gippsland and Western) for the three time periods (TR04, page 66–74).

The models employ the same basic structure as the river basin-scale analyses, with the addition of a term testing for effects of the SWS regions, analogous to the *fRiver* random effect, but at a larger scale.

Attribution of flow causality for the regional-scale models was done on the basis of whether a significant flow effect (*Time*, *Time2*, or *Time3*) changed to non-significant flow effect once flow terms were included in the model. For the Bayesian analysis, significance was assigned if the 95 per cent credible interval (the Bayesian equivalent of a confidence interval) did not include 0 for the parameter (for example, *Time*) estimate.

The trends, changes in trends, and flow causality are summarised in tables 39 to 46 of TR04. The results (trends and flow causality) are quite variable for the different indicators and the different regions, making it difficult to conclude that waterway health in the three southern Victorian SWS regions has deteriorated (or not) over the period 1990 to 2018, and whether flow has been a major driver of any deterioration.

7.8.3 Panel's findings

7.8.3.1 Principal

The statistical method used in the LTWRA did not provide any clear indication of deterioration in waterway health in southern Victorian rivers or indeed any clear causal link to flow.

The Panel has concerns with the statistical analysis methods used to test for river basin-scale trends (changes) in waterway health with time and whether any deterioration is flow-related.

7.8.3.2 Secondary

River basin-scale trends

The Panel has concerns with the statistical analysis methods used to test for river basin-scale trends (changes) in waterway health with time and whether any deterioration is flow-related.

The Panel notes that the Technical Advisory Group extensively discussed the question of the most appropriate statistical methods (see Section 2.4). However, there is no record of the Group's final recommendation on the preferred method for the s.22L(b) assessment.

The Panel also found it difficult to determine from the methods described in TR04 the details of the how the segmented regression analysis method was implemented. At the request of the Panel, the Department made a presentation of worked examples for the Yarra and Glenelg rivers, which provided some of the necessary details, but only though extensive meetings and conversations with the department. It is *recommended that these worked examples (with appropriate written commentary) at a minimum be added to the final version of TR04. Improved methods sections for both basin-scale and regional-scale analyses are also required.*

The first part of the s.22L(b) assessment was required to determine if there has been a deterioration in waterway health. However, the method adopted actually tested whether there was a trend in each indicator over the first time period (1990–2005), and then if the trends differ when moving from the first time period to the second (2006–2010) and from there to the third (2011–2018).

Statistically significant results could therefore be changes in the direction of the trend or changes in the magnitude of the trend within the same direction. This makes it difficult to determine whether there has been *deterioration* in the indicator as required of the s.22L(b) assessment. For example, if an indicator showed a downward trend (assume a deterioration) in the first period (1990–2005), then showed a reduced downward trend in the second period (2006–2010), it is arguably still getting worse. So the answer in this example would be that 'yes, there is deterioration'. But it might also be decided that there is actually an improvement because the slope is improved relative to the first period.

The Panel believes there are 27 combinations of outcomes possible from the three-segment broken stick regression (positive trend, no trend, negative trend for time period 1 multiplied by the same possible three trends in time period 2 and time period 3). Within this, changes in trend (either positive or negative) may result in a change in trend from positive to negative or may change the trend within positive or negative. This convolution makes the interpretation of the statistical analysis in terms of the s.22L(b) assessment question extremely difficult.

Additionally, the *importa*nce (water quality, biological or ecological) of these changes cannot be inferred from these trends. For example, what decreasing trend in a macroinvertebrate SIGNAL score is considered as an environmentally significant deterioration in waterway health? Equally, what increasing trend in electrical conductivity is considered an environmentally significant deterioration in water quality or waterway health? However the determination of what constitutes an environmentally significant effect size (trend) is a difficult process that would require consultation with different specialists, and consideration of guidelines, such as the 2018 Victorian SEPP (Waters) and the 2018 *Australian water quality guidelines for fresh and marine waters*.

The Panel has several technical comments on the choice of the statistical analysis method. These are as follows.

- The Panel was assured that the segmented regression approach employed uses the entire data when assessing the significance of the first trend period or the change in trend from period 1 to 2 or from 2 to 3 [Sparrow (personal communication.) (This does not appear to be detailed in TR04]. Presumably, this means that standard errors around fitted lines for the three periods are pooled and used to assess the significance of the trend with the full degrees of freedom used in assessing the resulting *t* statistic. *It is recommended that this be made clear in the final TR04 because otherwise a reader is left with the conclusion that splitting the data among time periods is likely to have reduced the ability to detect basin trends because of reduced sample size (and therefore statistical power) for each period.*
- Conducting separate analyses for each basin may have reduced statistical power to detect effects. Thomson et al. (2012) found strong evidence for temporal changes (reduction) in macroinvertebrate communities across Victoria including at the scale of individual basins and with a shorter-term dataset than was available for this analysis. However, flow was not identified as a major driver of this pattern in these declines in macroinvertebrate condition. TRO4 (Section 3.2, page 66) reported that the exploratory regional-scale Bayesian models found declines in macroinvertebrate indices (SIGNAL2) over the period 1990–2006 in all regions except the Central Region. Strong attribution due to flow was found the Gippsland Region, but not in the Western Region.
- The decision to exclude any site for which less than the threshold data points was available would have substantially reduced the amount of data. Again, Thomson et al. (2012) used 7,372 macroinvertebrate samples from 2,135 sites over the period 1990–2009 in a statewide analysis. Accepting that the current analysis covers only half the state, there is some overlap and some sites with waterway heath data do not have strongly matched stream gauging stations, it is still likely that about 3,000 data points plus all data collected since 2009 should have been available.
- It is not clear to the Panel from reading TR04 whether all the data from the same river has been pooled regardless of site origin, or has been pooled by river reach/site as a random variable.
- The decision to exclude sites for which <10 data points were available is predicated on the need to identify temporal trends, but if all data from the same river had been pooled regardless of site origin this would be logically inconsistent. The way the model is structured, trends are assumed to be identical across an entire basin, with 'starting condition' (the model intercept) varying among rivers within that basin. An identical structure could have been used with a random factor of sites rather than rivers, and then all data points could have been used (acknowledging that sites with few data points would play a smaller role in estimating trends).
- If data was pooled at the river level, the model would suffer from *pseudoreplication* (*sensu* Hurlburt, 1984) in that an inappropriate number of degrees of freedom are assigned to the analysis. More specifically, the model assumes all samples to be independent, but in reality the unit of replication in the analysis is the site within a river basin. Pseudoreplication does not affect the estimate of the trend or change in trend, but it will inflate p-values to make statistical tests more powerful than they should be. Here, a trend or change in trend is more likely to be significant

than should be the case. As noted above, for the current dataset, it was often the case that a single site was present within a river. If that is the case, then the analysis is completely valid. However, it is not clear how many of the analyses will have been affected. Given that statistical significance has been used to assess trends and changes in trends in the current analysis, this is of concern.

- The decision to break the time series of data at 2005 and 2010 carries with it the assumption that drivers not included in the model (and their effect on environmental or ecological conditions) are different among the three time periods. Another approach may have been to not break the time series into different periods, but instead attempt to find temporal trends in environmental condition, with covariates being used to account for other sources of variation (including those potentially associated with the drought). This approach would have simultaneously assessed changes over time and whether flow is a driver of change. For the water quality data (and possibly for the macroinvertebrate data) generalised additive models (GAMs) could have been used to account for non-linear trends over time (incorporating any effects of the SWS or drought end) plus additional covariates. This approach has been used in a great number of water quality trend analyses across Victoria for more than 15 years. The interpretation of results of structurally simpler analyses would have been much more straightforward than that for the broken stick regression.

Despite the above concerns, the Panel notes and acknowledges the very large amount of development work and effort that has gone into the segmented linear regression statistical modelling approach to determine trends in the waterway health.

Regional scale trends

The regional-scale Bayesian hierarchical models potentially answer one of the panels concerns above – relating to the separating of data into separate river basins. Keeping an analysis structure that is logically consistent with basin-scale analyses is appropriate.

However, it has been difficult to determine the details of the how the Bayesian hierarchical model was implemented from the TR04. At the request of the Panel, the Department made a presentation with a worked example for the trend in Total-P concentration at the regional scale (Central and Gippsland SWSs and southern part of the Western SWS regions), but this still did not provide the necessary details to fully understand how the method had been applied.

The hierarchical structure of the regional-scale models remains unclear. Which basin-scale variables are linked through hyper-parameters (a higher-level term from which the basin-scale parameters are drawn)? Which terms are pooled across basins? Which terms are separate among basins? *The Panel recommends that this worked example (with appropriate written commentary) be included in the final version of TR04, along with a much more detailed methods section. Currently, the draft does not contain sufficient detail of application of the Bayesian hierarchical modelling method.*

The failure to detect significant overall trends in waterway health indicators at a regional scale in southern Victoria, apart from those presented in Section 3.2 of TR04, is considered to be due both to the deficiency of available data (particularly for fish), and the split into the three time periods.

7.8.3.3 Considerations for future LTWRAs

For future LTWRAs, consideration should be given to conducting a wider-ranging assessment of possible statistical models, including time periods that could be used to assess whether there has been any deterioration in waterway health for reasons related to flow.

Additionally, consideration should be given to consulting in advance of future LTWRAs to determine what constitutes an environmentally (or ecologically) significant effect size (trend). This is a difficult process that requires consultation with different stakeholders over probably an extended time period.

7.9 Method – Presentation of results

7.9.1 LTWRA interpretation

The Overview Report (Figure 57) summarised changes in waterway health indicators across basins over the period 2011–2018. The changes in waterway health indicators for 1990– 2005 and 2006–2010 were also summarised in TR04 (Appendix C, figures 63 and 64).

The Basins Report only presents graphical summaries of post-2011 trends in waterway health indicators for each river basin.

7.9.2 Evidence

The Panel sought further information from the Department regarding the translation of results from the segmented regression analysis into the Basins Report's graphical summaries of post-2011 trends in waterway health indicators specifically with regard to:

- the choice of the third period (2011–2018) only to summarise the outcomes
- how the results from the segmented regression were translated into the graphical summaries.

7.9.2.1 Choice of 2011–2018

The Department summarised their logic regarding the choice of time period as (an unpublished briefing note):

> One focus of the LTWRA analyses was to determine if there had been any ongoing deterioration in waterway health since the implementation of the SWSs. SWSs were released at different times for different regions of the State (2006 for Central; 2009 for Northern and 2011 for Western and Gippsland). While the Central SWS was released in 2006, this was also the period that experienced the strongest effects of the millennium drought, leading to delays in implementation of SWS interventions to meet the recommended environmental entitlements in many waterways.
>
> The 2011-2018 period was considered the best fit with respect to representing changes in waterway health post SWS across the State in the draft public documents as this time period would capture changes under the Central, Western and Gippsland SWSs without being unduly influenced by the Millennium drought.

However, the Panel notes that 2011–2018 is also a period marked by recovery from the Millennium drought as higher flows came through rivers. It is reasonable to expect that improvements in waterway health during this period would have little to do with the implementation of the SWSs. As noted above, the choice of 2011–2018 is likely to paint an overly rosy picture of the trajectory of waterway health in Victoria. Although the LTWRA notes that written commentary on the summary results is provided in Section 6.4 for the Overview Report, it is the graphical summaries that will be picked up and widely circulated.

The Panel notes the difficulty in determining how to simply present results from the analyses is a result of the complex approach taken to statistical analysis through the segmented regression.

7.9.2.2 Translation of result to graphical summaries

The worked example of the Moorabool basin provided by the Department leaves the Panel with major concerns regarding the current translation of results into graphical summaries. This also demonstrates that the summaries do not only rely on the 2011–2018 period, but on a complex logic associated with the set of statistical results for the trend over time period 1, the change in trend to time period 2, and the change in trend to time period 3 (as outlined above).

The summary presents 'green lights' for five out of six water quality indicators, indicating 'improving' conditions – a statistically significant change. The statistical results are summarised below.

7.9.2.2.1 Dissolved oxygen

- 1990–2005: statistically significant negative trend – that is, reduction in water quality (95.6 per cent attributable to flow)
- 2006–2010: statistically significant change in trend after 2005 towards positive, but although the reported sign of the trend is positive, the slope is very close to zero and probably would not be significant by itself during that period (97.7 per cent attributable to flow)
- 2011–2018: no statistically significant change in trend after 2010 (no attribution to flow).

On this basis, the summary result is presented as green (improving) with 98 per cent attributable to flow. However:

- mean DO in 2018 is lower than in 1990, indicating an overall reduction in water quality over the analysis period
- the statistical results indicate a significant reduction in the rate of degradation after 2005 (with 98 per cent attributable to flow), but no indication of an actual increase in DO (the line over 2006–2010 looks flat)
- the visually perceptible increase in DO after 2011 is not statistically significant as a change from the flat trend of 2006–2010 and therefore has no attribution to flow calculated.

On this basis, it is difficult to see how water quality can be classified as improving, and the attribution to flow does not come from 2011–2018 data.

7.9.2.2.2 Nitrate+Nitrite-N

The visual interpretation of the result for nitrate/nitrite is also challenging:

- 1990–2005: clear (and significant) negative trend (improving)
- 2006–2010: trend replaced by a slight positive trend (degrading), which is statistically significantly different to the previous trend (although it's not clear if the trend by itself is significantly positive)
- 2011–2018: the trend shifts slightly negative (improving), but not significantly different from the previous period.

However, because a statistically significant negative trend (improving) undergoes a statistically significant change towards positive in 2006 and then there is no further statistically significant change in 2011 (even though the trend turns negative again), the result is deemed as a deterioration in water quality with 95 per cent (the amount attributable to the change in slope in 2006) attributable to flow (but the actual flow components is not reported).

For this example, the Panel notes that Nitrate+Nitrite-N concentrations are hugely lower in 2018 than they were in 1990, but the summary deems the result to be a degradation in water quality.

7.9.2.2.3 Other indicators

The interpretations for salinity (improving, 96 per cent attributable to flow) and Total-P (improving, 73 per cent attributable to flow) are more straightforward, with clear downward trends in concentration (improving water quality) over the period 2011–2018 visible from the plots of data and fitted lines. However, the attribution score for salinity (EC) comes from the percent variation explained by flow for the change in trend from moving from 1990–2005 to 2006–2010, and that for Total-P comes from the change in trend moving from 2006–2010 to 2011–2018.

7.9.3 Panel finding

7.9.3.1 Principal

The graphical summaries presented in the Overview Report and the Basin Report should be preceded with text outlining the concerns identified in this review regarding the current translation of results into graphical summaries. It would be referable for the summaries to be redone to compare the 1990 figure to the 2018 figure, perhaps with some comment on the trends between these dates.

7.9.3.2 Secondary

The graphical summary results presented in the Overview Report for the period 2011–2018 do not relate only to this period. Because of the way that the statistical results are presented (as changes in slopes after the first period, rather than as slopes themselves) most summaries rely on a change from one period to the next and this may be the change from 1990–2005 to 2006–2010.

The convoluted logic necessary to summarise results is a clear and almost unavoidable consequence of the choice made to use the segmented regression approach and the designation of terms as trend period 1 (*Time*), change in trend (*Time2*), and further change in trend (*Time3*).

This logic has unintended consequences such as the two outcomes listed above where a clear deterioration in water quality over the 1990–2018 period (dissolved oxygen) is labelled as an improvement, and conversely a large improvement in Nitrate+Nitrate-N over the 28 years is labelled as a degradation.

The percentage attribution to flow used in the graphical summaries are drawn from different time periods (and from different flow components), with the latest significant result being used (if one exists), which will often be substantially removed from the 2011–2018 that is claimed to be reported.

7.9.3.3 Considerations for future LTWRAs

Nil.

7.10 Estuary and wetland health

7.10.1 LTWRA interpretation

The LTWRA included estuaries and wetlands in the waterway definition. An estuarine case study was undertaken. No wetland case study was conducted.

7.10.2 Evidence

The s.22L(b) assessment focused on rivers, as this is where the most suitable long-term data was available. Separate preliminary studies on wetlands and estuaries were undertaken to identify 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.

Section 2.8.3 of TR04 describes the Gippsland Lakes estuarine case study model.

The Gippsland Lakes was selected as the estuarine case study, with Black Bream as the waterway health indicator. The intent of the case study was to confirm if the method and data were suitable and to demonstrate how wetland and estuary assessments might be carried out on these other types of waterways, were further suitable data to be identified.

Black bream monitoring commenced in 2008, and for this analysis two fish indicators were calculated – catch per unit effort (CPUE) on the basis of numbers and biomass. A segmented regression model was used with three predictor variable (site, days since 1 January 2006, and days since 1 January 2011). To test for flow dependence, the same hydrological variable and antecedent periods as for the river trend analysis were used (TR04, page 23) and calculated for three regions of the Gippsland Lakes – western, central and eastern.

The results of the Gippsland Lakes estuarine case study model are presented in Section 3.3 of TR04.

The analysis found that black bream populations (CPUE by numbers and CPUE by biomass) in the Gippsland Lakes declined significantly during 2008–2010 and increased significantly during 2011–2018 in each of the three regions. There was essentially no relationship with flow for either the decrease or the increase when aggregated at the scale of zones within the lakes complex.

7.10.3 Panel's findings

7.10.3.1 Principal

The Panel accepts that the analysis reported in TR04 found that changes in the black bream populations within the Gippsland Lakes were unrelated to flow.

However, the Overview Report notes that other studies have shown that river flow can influence the reproduction and age of black bream. This is because of the effect of river flow on the interface between fresh and estuarine water (the halocline), which is where spawning occurs (Green, 2014).

7.10.3.2 Secondary

The concerns regarding the segmented regression approach employed for river systems described in Section 7.8 above apply equally to the proposed approach for estuarine systems. Indeed the length of the first period (<3 years) for the Black Bream model means that there is very little ability to estimate a trend for that period separately.

7.10.3.3 Considerations for future LTWRAs

Nil.

7.11 Is the data used the best available?

7.11.1 LTWRA interpretation

LTWRA used the best available river health indicator data (for water quality, macroinvertebrates and native fish) and supplemented this with analyses of flow data over several time periods.

7.11.2 Evidence

The data used is identified in sections 2.2 to 2.7 of TR04. Notes on data sourcing and handling are presented in Appendix A of TR04.

7.11.3 Panel's findings

7.11.3.1 Principal

The data used was the generally the best data available except for the absence of pH, the fact that water quality data pre-1990 was not used, the absence of Melbourne Water biological data and the screening out of substantial amounts of data where there were below a minimum threshold of points at a site. As noted above, this criterion is not consistent with the way the models were eventually structured.

7.11.3.2 Secondary

The data could be improved by:

- including pH as a water quality indicator
- including water quality data pre-1990
- including the macroinvertebrate and fish data for the Maribyrnong, Yarra and Werribee rivers that are held by Melbourne Water
- testing the influence of including shorter sequences from individual sites Webb and King (2009) set 4 as the minimum number at a site; Thomson et al. (2012) used all data, including those where only a single sample existed at a site).

Additionally, N data in the particulate and dissolved form (that is, Total-N) or alternatively P data in the dissolved (bioavailable) form should be used.

7.11.3.3 Considerations for future LTWRAs

For future LTWRAs, consideration should be given to improve the data as per the above supporting findings.

7.12 Conclusions – supported by methodology and data

The *Water Act 1989* (section 22N) requires this review to consider whether or not the conclusions reached in the draft LTWRA are supported by the methodology and data. In forming its opinion on this requirement, the Panel has interpreted this as meaning the actual methodology and data used, rather than that which the Panel considers might have improved the ability to respond to the requirement of the s.22L(b) assessment.

This review also includes the Panel's findings on whether a deterioration in waterway health for reasons related to flow would have been identified if the methodology had been amended and data had been updated (or upgraded) in accordance with the above Panel's findings on these aspects of the LTWRA.

7.12.1 LTWRA interpretation

The LTWRA findings on the s.22L(b) assessment are summarised in Section 6.4 of the Overview Report. It states:

> 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, most indicators deteriorated during the Millennium drought and improved 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 change in an indicator is increasing or decreasing over time, the key requirement of the LTWRA. This method does not directly show the size of any change or whether the value of any indicator is in a healthy or unhealthy condition. I.e. any deterioration (or improvement) detected may be very small.

The Overview Report s.22L(b) assessment key findings concluded:

> 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.

7.12.2 Evidence

The results of the s.22L(b) assessment for all river basins, excluding the Bunyip River basin, are presented in tables 3 to 19 of TR04. The results of the regional hierarchical models are discussed in Section 3.2 of TR04. The results are also summarised in section 6.4 of the Overview Report.

These results provide a variable and rather complicated picture of possible trends in waterway health indicators (water quality, macroinvertebrates and fish) in the various southern Victorian river basins.

This makes it difficult to form a firm opinion on the LTWRA conclusions regarding the s.22L(b) assessment.

7.12.3 Panel's findings

7.12.3.1 Principal

The data for the post-2011 period has been used in the Overview Report (DELWP, 2019a, Figure 57) to provide a summary position for waterway health. The Panel is uncomfortable with summarising the s.22L(b) assessment results in this way as it may provide an overly rosy picture of the trends in waterway health in southern Victorian rivers.

Based upon the methodology and data used in the s.22L(b) assessment, the Panel accepts the inconclusive findings presented in the Overview Report regarding deterioration of waterway health in southern Victoria due to reasons related to flow.

The Bunyip River basin was not included in the s.22L(b) assessment and no finding regarding deterioration in waterway health could be reported.

The Panel has concerns with the statistical analysis methods used and with the segmenting of the time period into three, and is convinced that other less complicated statistical models may have produced more meaningful results. However, it is not possible for the Panel to conclude that the application of such other models would have shown deterioration in waterway health over the period 1990–2018.

7.12.3.2 Secondary

Based on the actual methodology and data used

The current assessment period for the s.22L(b) assessment is considered by the Panel to be 1990 to 2018 rather than 2011 to 2018.

The methodology adopted for the s22L(b) assessment of whether waterway health has 'deteriorated' was:

- to determine the (linear) trend of each indicator over the 1990–2005 period, and then whether that trend changed over the 2006–2010 and 2011–2018 time periods
- to decide whether these trends were statistically significant
- to decide whether these trends indicated an improvement or deterioration of the indicator
- for those deteriorating trends, to decide whether these were flow-related.

For all river basins within southern Victoria, excluding the Bunyip River basin, the LTWRA has attempted to provide information on linear trends and possible flow causality for the adopted waterway health indicators.

TR04 suggest that the lack of clear trends is largely the result of significant limitations in the waterway health data (water quality, macroinvertebrates, and fish) available for analysis. This is almost certainly the case for the fish indicators, where there was no or very little data for most river basins and no data prior to 2005. But, there are large amounts of data for water quality and the macroinvertebrate dataset should be large enough to reach some conclusions at least.

It is agreed that it has not been possible, using the adopted methodology and data, to conclude from the river basin-scale or regional-scale analyses that waterway health, as determined from the trends in the water quality, macroinvertebrates and fish indicators in the three southern Victorian SWS regions, has deteriorated for reasons related to flow over the assessment period.

Reporting only the post-2011 data makes it difficult to determine whether waterway health in a particular river has improved, deteriorated or remained essentially the same over the 1990 to 2018 period. This practice also calls into question the use of the segmented regression approach.

Based upon amendment of methodology and updating of data in accordance with the Panel's findings

If other statistical methods (See Section 7.8.3 of this report) and improved data (See Section 7.11.3 of this report) had been used, it is likely that a greater number of significant trends in these indicators would have been found, together with an improved indication of those trends that were flow-related. However, it is not possible to say whether these improved results would have been sufficient to conclude that deterioration on waterway health due to flow has occurred in some or all of the southern Victorian river basins over the period 1990–2018.

The lack of data for indicators of waterway health may have contributed to the inability to determine consistent and significant trends. These data limitations, the split into the three time periods, and the variability in overall fit of the statistical trend models all influenced the statistical significance of the trends and the determination of possible flow causality.

The trends on their own do not provide a measure of the ecological importance, and hence an assessment of whether there has been a deterioration in waterway health.

7.12.3.3 Considerations for future LTWRAs

Nil.

8 Conclusions

8.1 Response to section 22N requirements

Subsection 22N(2) of the *Water Act 1989* requires EPA to review the following aspects of the LTWRA:

- the methodology adopted to carry out the draft assessment
- whether or not the data used in the draft assessment was the best data available
- whether or not the conclusions reached in the draft assessment are supported by the methodology and data.

The Panel's findings for these aspects are presented in **Table 8–1**.

Table 8–1: Panels finding associated with s.22L(a) and s.22L(b) LTWRA assessments

s.22L LTWRA requirement	The methodology adopted	Whether or not the data used was the best data available	Whether or not the conclusions reached are supported by the methodology and data
s.22L(a) assessment			
A decline in the long-term availability of surface water	Supported. Median declines water availability and variability in annual water availability should be considered when determining the need for a review.	Supported.	Supported.
A decline in the long-term availability of surface water or groundwater	Partially supported. Method could have been improved with use of	Supported. For method applied.	Supported.

s.22L LTWRA requirement	The methodology adopted	Whether or not the data used was the best data available	Whether or not the conclusions reached are supported by the methodology and data
	numerical models where available.		
Has any decline resulted in a disproportionate effect on the EWR or on the allocation of water for consumptive purposes?	Supported. On the basis that Step B is adopted for comparison purposes with Step A.	Supported.	Supported. Subject to the Latrobe and Maribyrnong river basins being considered as having declines that are considered disproportionate.
s.22L(b) assessment			
A deterioration in waterway health for reasons related to flow	Not supported. The statistical methods used to test for basin-scale trends with time and whether any deterioration is flow-related. The Panel queries whether other simpler analyses may have generated results that were easier to interpret. The Panel notes that the statistical method used did not provide any clear indication of deterioration in waterway health in southern Victorian rivers or indeed any clear causal link to flow.	Partially supported. The dataset was limited for the following reasons: • water quality data between 1975 and 1990 was available but not used • the macroinvertebrate dataset was limited because sites with <10 data points were excluded and macroinvertebrate data for the Yarra, Maribyrnong and Werribee rivers held by Melbourne Water was not made available • the fish data was very limited with only data for two rivers (Moorabool and Glenelg) suitable and that only from 2005.	Conclusions were inconclusive. The Panel is of the opinion that the inconclusive results are due to the statistical methods adopted and the relatively limited database available. If other statistical methods and improved data had been used, it is likely that a greater number of significant trends in these indicators would have been found, together with an improved indication of those trends that were flow-related. However, it is not possible to say whether these improved results would have been sufficient to conclude that deterioration on waterway health due to flow has occurred.

8.2 Considerations for future LTWRAs

This review has recommended several matters to be considered to enhance future LTWRAs. These are listed below.

1. Updating the LTWRA method to consider variability in annual water availability. (While the Overview Report (page 114 and page115) presents changes in available water in wet years and dry years it does not report upon the implications in terms of s.22L(a)).
2. Aligning the post-SWS groundwater availability period with the surface water availability assessment period.

3. Using numerical groundwater models (where developed) for GMAs to assess changes in groundwater availability. This would allow for changes to be identified as proportions of the available water as has been applied to the surface water assessment and the assessment of the environmental impact of changes in baseflow to waterways during low flows.
4. Provision and monitoring of stream gauges within Salt Creek, Painkalac Creek (Otway Coast river basin) and Drum Drum Creek, Allocation Creek (Bunyip River basin) and inclusion of calculations of change in surface water availability associated with Jan Juc and Nepean GMAs to assist in assessing the contributions of reduced groundwater availability.
5. Considering all sources of groundwater when assessing the impact of baseflow declines on waterways.
6. Reviewing where to include stock and domestic uses in the long-term availability assessment.
7. Explicitly stating how Aboriginal cultural values and uses of waterways, and social and recreational uses and waterways values should be considered.
8. Conducting further work to establish what combinations of the various indicators might be used to identify whether deterioration has occurred in waterway health.
9. Assessing the importance of trends in waterway health indicators (particularly water quality and macroinvertebrates) against the 2018 SEPP (Waters) environmental quality indicators and objectives and the 2018 *Australian water quality guidelines for fresh and marine waters.*
10. Reviewing the adequacy of waterway health monitoring programs for the purpose of the LTWRA. Consideration could be given to the TR04 (Section 4) recommendations, the data-related findings from this review and the TR04 opinion that there is no evidence to suggest that water quality, macroinvertebrate and fish communities are effective surrogate indicators for all dimensions of aquatic ecosystems.
11. Conduct a wide-ranging assessment of possible statistical models, including time periods that could be used to assess whether there has been any deterioration in waterway health for reasons related to flow.
12. Consulting in advance of future LTWRAs to determine what constitutes an environmentally significant effect size (trend). This is a difficult process that requires consultation with different stakeholders over probably an extended time period.
13. Improving the waterway data as per the secondary findings. There is an urgent need to improve the LTWRA-relevant biological/ecological monitoring program for Victoria.

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Appendix A

Review Panel members

John Nolan

John has a B. Eng. (Civil), M. Eng. Sc. and a Dip Ed (Secondary). He is an EPA-accredited auditor for natural resources and industrial facilities.

John has over 35 years' experience in the provision of specialist hydrogeological, environmental and advisory consultancy services. His clients include state and federal government agencies, water authorities, catchment management authorities, and waste management authorities, as well as corporates and SMEs.

John has directed a diverse range of projects covering hydrogeological and environmental assessment and approvals (water, extractive industries, pulp and paper, and waste industries), water recycling, life cycle assessment, strategic waste management, organics processing, and landfill design, construction and operations. He has been a key driver for the use of tools to guide policy development and decision making, particularly in packaging, recycling and technology comparisons.

John is a Victorian Environment Protection Authority–accredited environmental auditor for industrial facilities and natural resources management. He has conducted both statutory and non-statutory audits across the water, waste management and natural resource management sectors.

His expertise extends to expert witness roles that, to date, includes 40 cases encompassing civil litigation, Victorian Civil and Administrative Tribunal hearings, government-appointed panels, and commissions of inquiry.

In the past decade John has supported public and private sector organisations to improve their governance arrangements and strategic planning processes.

John's consultancy work is highly regarded by governments of all levels and major companies.

He has held previous positions as a Board Member of ECO-Buy, Chair of the Oaktree Foundation, Chair of Sustainable Resource Use, Deputy Chair of Waste Aid, Managing Director of Nolan-ITU, National Water and Environment Sector Leader for Hyder Consulting, a member of Sustainability Victoria's Expert Reference Group – Waste Management, and the Victorian State President of the Waste Management Association of Australia.

Professor Barry Hart

Barry is Director of environmental consulting company – Water Science Pty Ltd, established after he retired from Monash University. He was appointed an Emeritus Professor by Monash University. Previously he was Director of the Water Studies Centre at Monash University and Deputy Director Research of the CRC for Freshwater Ecology.

He has received several prestigious awards. He was made a Member of the Order of Australia (AM) in the 2012 Queen's Birthday Awards.

He is well known for his sustained efforts in developing knowledge-based decision making processes in natural resource management in Australia and South-east Asia. He has established an international reputation in the fields of natural resources decision making (water quality and catchment management, environmental flows), ecological risk assessment and environmental chemistry.

He recently (June 2017) edited a book with Dr Jane Dolan entitled *Decision-Making in water resources policy and management: the Australian experience* (Elsevier Publishing, 367 pages).

Relevant projects

Murray–Darling Basin Authority

Professor Hart has just completed (May 2018) nine years as a member of the Board of the Murray–Darling Basin Authority. His term commenced from the initial establishment of the Authority in 2009. During this time he has been involved in the development and implementation of the Murray–Darling Basin Plan, and has gained considerable knowledge and experience in national and state water resource policy, planning and management. In particular, he contributed to developing new environmental watering plans.

Commonwealth Long-Term Intervention Monitoring Program

Professor Hart and Dr Rhonda Butcher recently (March 2018) completed a mid-term review of the Commonwealth's Long-Term Intervention Monitoring (LTIM) Program. This is the main program for addressing the Commonwealth Environmental Water Office's (CEWO) requirements under the *Water Act 2007* (Cwth) and the Murray–Darling Basin Plan. The LTIM Project commenced on-ground monitoring in June 2014, after an initial two-year scoping and development phase. The monitoring will occur over a five-year period, ending in June 2019.

The Program involves two components: (a) a basin-scale assessment being run by the Murray–Darling Freshwater Research Centre (MDFRC) who are using information generated by (b) seven local-area projects, which are (major water-related assets in brackets): Edward–Wakool river system (in-stream and fringing wetlands); Goulburn River (in-stream and fringing wetlands); Gwydir River system (in-stream, wetlands and floodplains); Lower Lachlan River system (in-stream and fringing wetlands); Murrumbidgee River system (in-stream, fringing wetlands and floodplains); Lower Murray River (in-stream, connected wetlands, floodplain and temporary non-connected wetlands); and Warrego–Darling River system.

Scientific Inquiry into Hydraulic Fracturing of Onshore Unconventional Reservoirs in the Northern Territory

This controversial inquiry, established by the NT government, was required to establish whether onshore shale gas hydraulic fracturing could be carried out with acceptable low risks environmentally, socially, culturally and economically. The inquiry was chaired by Justice Rachel Pepper with Professor Hart as deputy chair, and reported to the NT Government in March 2018. Professor Hart had responsibility for the chapter related to risks to NT water resources.

Review of the Management of Water Assets in the Geographe Catchment, WA

Professor Hart completed an Independent Review of the Current and Future Management of Water Assets in the Geographe Catchment for the WA Minister for Water in March 2014. The review focused on (a) the management of the Vasse–Wonnerup Ramsar Wetlands, (b) overall catchment water quality management leading into Geographe Bay, and (c) water quality management of local waterways, including the Lower Vasse River, Vasse diversion drain, and Toby Inlet.

Discussion Paper of Load Targets for the Port Phillip Bay Environmental Management Plan

This Discussion Paper for Melbourne Water, completed in 2017 by Professor Hart and Alluvium Consulting Australia, provides information and recommendations on catchment load target ranges for total nitrogen (TN) and total suspended solids (TSSs) relevant to the new Port Phillip Bay Environmental Management Plan (PPB EMP). These load targets were required to address a key objective of the draft EMP that 'nutrients and sediment loads do not exceed current levels and pollutant loads are reduced where practicable'. The Discussion Paper reviews the current understanding of the system (Port Phillip Bay and its catchment) with a focus on nitrogen and sediment, then discusses the key features of the current and new EMPs, and finally addresses the central objective – the load target ranges most appropriate for tracking the effectiveness of the management of the catchment and the protection of the Bay's health.

Review of Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP)

Professor Hart completed an independent review of VEFMAP in November 2014. This review was used with other information by DELWP to determine Stage 5 of this program, which commenced in 2015.

Professor Michael Stewardson

Professor Michael Stewardson is Discipline leader, Environmental Hydrology and Water Resources in Infrastructure Engineering at Melbourne University. His research includes fundamental work examining the ecohydraulics of rivers and the application of this knowledge to inform water management and policy. Over 25 years, Michael has led many projects in interdisciplinary river science and water resource systems analysis. Michael teaches postgraduate courses in sustainable water resource systems and international river basin management.

Since the early 1990s, Michael has participated as an expert advisor across a range of water reforms at all levels of government in Australia including innovations in: basin-wide assessment of river health; environmental flow assessments methods which consider seasonal and interannual flow variability; active management of environmental water; monitoring and evaluating outcomes of river restoration; and adaptive environmental management of rivers. In 2014 he led a large interdisciplinary team to identify opportunities to boost water productivity in Australia and he is currently and editor and author of five chapters for a book on international environmental water management practice published by Elsevier in 2017.

Relevant projects

Vulnerabilities for Environmental Water Outcomes in a Changing Climate (ARC Linkage Project)

Professor Stewardson is Project Leader. This project assesses the vulnerability of freshwater ecosystems to extended droughts in a variable and changing climate. This includes modelling of changes in environmental consumptive water use during extended dry periods, and coupling this to models of ecological dynamics and failure thresholds. The extent to which such climate threats can be mitigated through policy changes will be assessed for a large and complex case study system in northern Victoria. Project industry partners are VEWH, DELWP and BoM.

Commonwealth Environmental Water Office (CEWO) Long-Term Intervention Monitoring Program.

Professor Stewardson leads the Hydrology Team. Commencing in 2014, this project is monitoring the hydrological and ecological outcomes of the CEWO's environmental water delivery. The hydrology theme evaluates changes in river flow regimes and hydrological connectivity as a result of the CEWO program. The program considers outcomes throughout the Murray–Darling basin. This includes working with water resource modellers to evaluate the impacts of CEWO and synthesising results in a digestible form by a wide range of stakeholders.

Optimising Seasonal Watering Decisions (ARC Linkage Project)

Professor Stewardson is Project Leader. CIs Professor Michael Stewardson (Melb Uni), Associate Professor Rory Nathan (Melb Uni), Dr Avril Horne (Melb Uni), and Dr Angus Webb (Melb Uni). POs Commonwealth Environmental Water Office, Murray–Darling Basin Authority, Jacobs, Melbourne Water, Victorian Environmental Water Holder, NSW Office of Environment and Heritage, Department of Environment Land Water and Planning, Bureau of Meteorology: This project is developing a decision support tool – Seasonal Environmental Water Decision Support (SEWDS) to inform decision making for environmental water delivery within and among seasons to improve ecological outcomes achievable with a given volume of environmental water. It uses optimisation approaches to identify optimal decision sets within constraints imposed externally by the water resource system and employing existing knowledge of ecological responses to different watering actions.

A decision support model for active management of environmental water releases has been developed for the Yarra River, in testing stage for the mid-Murrumbidgee River and in development for the Goulburn River. A method to define ecological outcomes within an optimisation tool has been developed and implemented across the case study regions, and methods have been developed to evaluate downscaling of climate model outputs for assessment of water resource impacts.

Independent Scientific Review of Ecological Elements of The SDL Adjustment Method (MDBA).

It was a requirement of the Basin Plan that the ecological elements of the scoring method for SDL adjustments must be science-based, independently reviewed and fit for purpose. Consequently, the MDBA commissioned this independent review of the Ecological Elements Development Project. The Independent Review Panel interacted with the MDBA technical team and the basin jurisdictions over a period of 12 months to inform its report on the ecological elements method.

Independent Sustainable Rivers Audit Group (MDBA)

Professor Stewardson was the Hydrology Expert on this Group. The Independent Sustainable Rivers Audit Group reported on the condition of the Murray–Darling basin's rivers. In his role as hydrology lead in the group, Professor Stewardson designed the assessment methods including underpinning hydrological analysis, selection of evaluation metrics, and completion of the final report.

Associate Professor Angus Webb

Associate Professor Angus Webb has a growing reputation as one of Australia's leading experts in the monitoring and evaluation of environmental flows programs. Dr Webb was instrumental in the development of the Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP) in 2005, and has maintained constant involvement with this program since. VEFMAP re-shaped the way we monitor environmental flows, emphasising a long-term and large-scale view of monitoring centred on partnerships between researchers and managers. Lessons from VEFMAP were incorporated into the Commonwealth Environmental Water Office's Long-Term Intervention Monitoring Project – Australia's largest ever monitoring and evaluation project for environmental water – and where Dr Webb leads the Lower Goulburn River selected area project

Relevant projects

Sydney Water: Wet Weather Overflow Monitoring and Research Program Expert Panel 2016–2021

Associate Professor Webb sits on the expert panel advising Sydney Water on monitoring and research needs for their wet weather overflow monitoring and research program. In Sydney, large numbers of sewage overflow points are activated during major rain events, discharging sewage to urban streams. Ecological and social impacts ensue. Sydney Water is developing a major monitoring program to test for water quality, ecological, social and human health impacts of these events. Associate Professor Webb has particularly been central in providing advice around experimental design of monitoring programs, along with approaches to modelling predicted responses to different rain events through a proposed predictive ecological response model.

Commonwealth Environmental Water Office: Long-Term Intervention Monitoring Project – Goulburn River 2013–2019

Associate Professor Webb leads the team undertaking monitoring in the lower Goulburn River, a consortium with six partners spanning universities, government research agencies, local river managers and private consultants.

Associate Professor Webb coordinates inputs from all partners, leads the centralised statistical modelling of their results, and coordinates and writes much of the annual report delivered to the Commonwealth Environmental Water Office. As value-added activities to this project, Associate Professor Webb has also been active in promoting the LTIM project in international conferences, peer-reviewed publications and mainstream media.

Murray-Darling Basin Authority: Development of a Method to Assess the Ecological Effects of 'Complementary Measures' to Environmental Flows 2017

Associate Professor Webb was part of a CSIRO-run project to develop a robust approach to predicting the likely ecological benefits of complementary measures (for example, fishways, habitat restoration) for augmenting the ecological benefits of environmental flows being delivered under The Basin Plan. Associate Professor Webb provided leadership on the key elements of the final proposed method: using formal expert elicitation to develop quantitative predictive models of ecological response, and using rapid evidence synthesis of the literature to provide an additional line of evidence in support of model predictions. With the likely approval of the SDL adjustment mechanism, the method developed will be important for MDBA operations in coming years.

Murray–Darling Basin Authority: Analysis of Lake Victoria Shoreline Monitoring Data 2012

Associate Professor Webb led a project to undertake the first major analysis of 10 years' worth of monitoring data collected on the shoreline of Lake Victoria, NSW, a major water storage in the Murray–Darling basin, but also one with significant cultural heritage importance for local Aboriginal and Torres Strait Islander communities. Although data had been collected for many years to assess compliance with the lake's operating permit, the MDBA did not have the skill to analyse the complex datasets.

Associate Professor Webb's team was able to establish rates of erosion and deposition in shoreline environments, and also assess changes in vegetation designed to manage erosion. Crucially, his research showed that the two monitoring programs were not sufficiently aligned to assess whether vegetation plantings were actually affecting erosion rates. The project led to a change of monitoring practice and has recently resulted in funding for a PhD project to conduct research in the area.

Murray–Darling Basin Authority: Expert Advisory Group for Monitoring Effects of the First Step Decision for the Living Murray Initiative 2005–2009

The Living Murray initiative was the first major environmental flows program within the Murray–Darling basin, and was instrumental in informing developing the Basin Plan's environmental watering program. Associate Professor Webb sat on an expert panel advising the Murray–Darling Basin Authority on approaches to monitoring the ecological responses at the 'icon sites' that were the target of Living Murray water deliveries. The work primarily involved liaising with contracted consultants on their plans for monitoring and providing advice to the Authority about statistical power and potential issues with proposed approaches.

Appendix B

Yarra, Barwon and Latrobe rivers basin modelling reviews

As part of this review of whether any declines have fallen disproportionately on the EWR or on the allocation of water for consumptive purposes, several basin and regional modelling reports have been interrogated. The following have been subject to a more detailed assessment to inform the overall review:

- Melbourne Water (2018). *Long-term water resource assessment analysis*;
- HARC (2019). *Update of Barwon – Moorabool REALM model. Technical report – Model inputs*; and
- GHD (2018b). *Latrobe water resource model daily input – Stage 2, input derivation and validation*.

The detailed findings are provided below.

B.1 Yarra basin modelling

Steps A, B and C (Scenarios B, C and D in Melbourne Water (2018)) all use the same annual consumptive water demands. This applies for use of water in the urban areas, by private diverters and from farm dams. Specifically, the urban water demands in all three scenarios are the same (although water use varies because of different levels of water supply reliability). The consumptive demands are set to reflect urban water demands represented in the models used for the baseline condition in Central Region SWS. These urban water demands were not intended to represent actual water use, but to represent the maximum urban water use set by the sustainable diversion limits at the time. Total demand from private diversions were also unchanged for all three scenarios and modelled based on full uptake of current licences for all these three scenarios (Table 3, page 31 in modelling report). Similarly, the volume of farm dams is unchanged for the three LTWRA scenarios (page 21). The Tarago/Bunyip model uses 2006 levels of farm dam development, and the Yarra basin model uses 2009 levels of development (page 21). Although volume of farms dams is unchanged, the impact is adjusted to reflect changes in inflows with the current inflow conditions.

Environmental water demands for steps A and B are set at their historic levels prior to the SWS. These were substantially increased as an outcome of the SWS. Step C uses an environmental demand reflecting current environmental entitlements which are substantially higher than for steps A and B. This is consistent with the intent of Step C to represent changes in entitlements since the SWS.

Consumptive water demands are supplied as an input for water resource models used in these basins. Average water use over the modelling period is less than this demand because the model also represents water restrictions reflecting actual water restriction policy. For the case of urban water demands, water restrictions only apply to a relatively small portion of the demand with the bulk remaining unrestricted regardless of the hydrological conditions. The proportion of water demand that is affected by restrictions is specified as an input. For steps A and B, 21 per cent of demand is considered to be affected by restrictions (TR05 Table 5) and it is 13 per cent of total demand for Step C. This seems to be an effort to represent changing demographics and housing density.

In order to maintain the same mean annual urban water use for Scenario’s Step A as for the existing model run for the SWS, the urban water demand (which is an input to the model) was adjusted to account for substantial changes in the updated Step A model. This is not an effort to replicate changes in actual demand but a modelling approach to maintain the same water use despite changing inflows, infrastructure and entitlements. TR03 Table 2 reports the adjusted urban water demand for each scenario. The adjustment is relatively small and the Panel considers this approach is acceptable.

These same consumptive water demands are applied for steps A, B and C but the actual water use declines in steps B and C relative to Step A. This is the result of increased water restrictions with use of the drier post 1975 inflow conditions (Step B) and the increased environmental water provisions (Scenario C). This decline in modelled water use is used for the LTWRA to indicate the change in water availability for consumptive users.

Importantly, water availability for consumptive users modelled in steps A and B are not intended to replicate actual water use in these two scenarios. Water availability in this case represents the full use of water up to the sustainable diversion limit. This is consistent with the approach specified for the LTWRA. For the case of Step C, this is inconsistent with the methodology proposed for the LTWRA, which states that urban demand should be scaled to maintain levels-of-service (page 35 of TR03).

TR03 Table 2 specifies the period of record used for all scenarios. Step A (the baseline) uses inflows for the period July 1913 – Jun 2004 (91 years) for the Yarra basin and July 1913 to June 1998 (85 years) for the Thomson basin. It is noted that these baseline period includes a substantial period used to represent current climate (that is, subject to climate change) which is defined in the LTWRA as July 1975 onwards. This is consistent with the methods proposed for the LTWRA.

The method for deriving inflow series for current climate (post-1975) used in steps B and C is not documented in the modelling report. For these scenarios, July 1913 to Jun 2017 inflows are used but these are adjusted to reflect the post-1975 climate. Given the purpose of the LTWRA is to examine effect of changing climate, the lack of a description of the adjustment methods seems to be a significant oversight. The TR03 specifies use of decile-based scaling to match the characteristics of post-1975 flows, according to the method in DELWP (2016) *Guidelines for assessing the impact of climate change on water availability in Victoria*.

B.2 Barwon basin modelling

The Barwon basin model includes the Moorabool River basin and the Barwon River basin.

In tables 2–1 and 6–1 (and elsewhere in HARC (2019)), steps A, B and C appear to have mislabelled as steps B, C and D. This seems to have no obvious impact on study results. In this Appendix the correct names for these steps as defined in TR03 have been applied.

Table 7–1 provides a good summary of the model scenarios for steps A, B and C. This is mostly consistent with the LTWRA method, noting the comment on farm dams below.

Farm dam impacts and private diversions are unaltered between Step B and Step C (Table 7–1). This is a shortcoming of the approach since these should be set at the SWS levels for Step B and current levels for Step C. However, given this, it is surprising that farm dam impacts on the water balance for the Moorabool River are different between Step B of 9,678 ML/year (Table 7–5, and mistakenly reported as Step C) and Step C of 4,070 ML/year (Table 7–10, and mistakenly reported as Step D).

It is odd that groundwater private diversions are reported for Step B (in Table 7–5) but not Step C (Table 7–10) since Table 7–1 indicates they are identical for all scenarios.

HARC (2019) provides an initial set of results reported in Chapter 7. These results were subsequently updated by DELWP and documented as a file note in Appendix B of HARC (2019). The changes to the model for these amended results are poorly documented but are consistent with the LTWRA method.

B.3 Latrobe basin modelling

The GHD (2018b), *Latrobe water resource model daily input – Stage 2 input derivation and validation* is concerned with derivation of inflows and current level of demands, and incorporating improvements to farm dam modelling.

The DELWP (2018c), *Latrobe system scenario modelling long-term water resource assessment* provides documentation of the improvements to the Latrobe model for LTWRA purposes, including the derivation of new yield demands for power generators, the environmental entitlement, and improvements to the representation of the Blue Rock drought reserve for yield modelling. Because yield modelling in the Latrobe system is conceptually complex, the full rationale for demands and operation of the drought reserve is detailed in this report (and was expert-reviewed). This report was not subject to a detailed review by the Panel.

The Department advised it last undertook updates to the Latrobe model system file in 2017, immediately prior to the LTWRA commencing, such that the model system file did not require extensive updates for representing current infrastructure and entitlements. However, extensive modifications to the system file were required to ‘re-create’ the SWS level of development starting from the best available [that is, current] system file. These changes are documented, step by step, in DELWP (2018c), *Appendix A: Creating a SWS level of development model*.

The large volume of return flows from power station cooling towers and mine dewatering along with recycled water from the Gippsland Water Factory are not included in water available for consumptive users or the environment consistent with definitions applied by the LTWRA method.

From the information provided, the scenario definitions and broader methodology is consistent with the LTWRA method.

Model improvements are generally only briefly described in GHD (2018b), *Latrobe water resource model daily input – Stage 2, input derivation and validation reports* and a more detailed description is provided in DELWP (2019), *Latrobe system scenario modelling long-term water resource assessment*. This latter report was not subject to a more detailed assessment.

In this report steps B, C and D seem to refer to steps A, B and C in TR03.