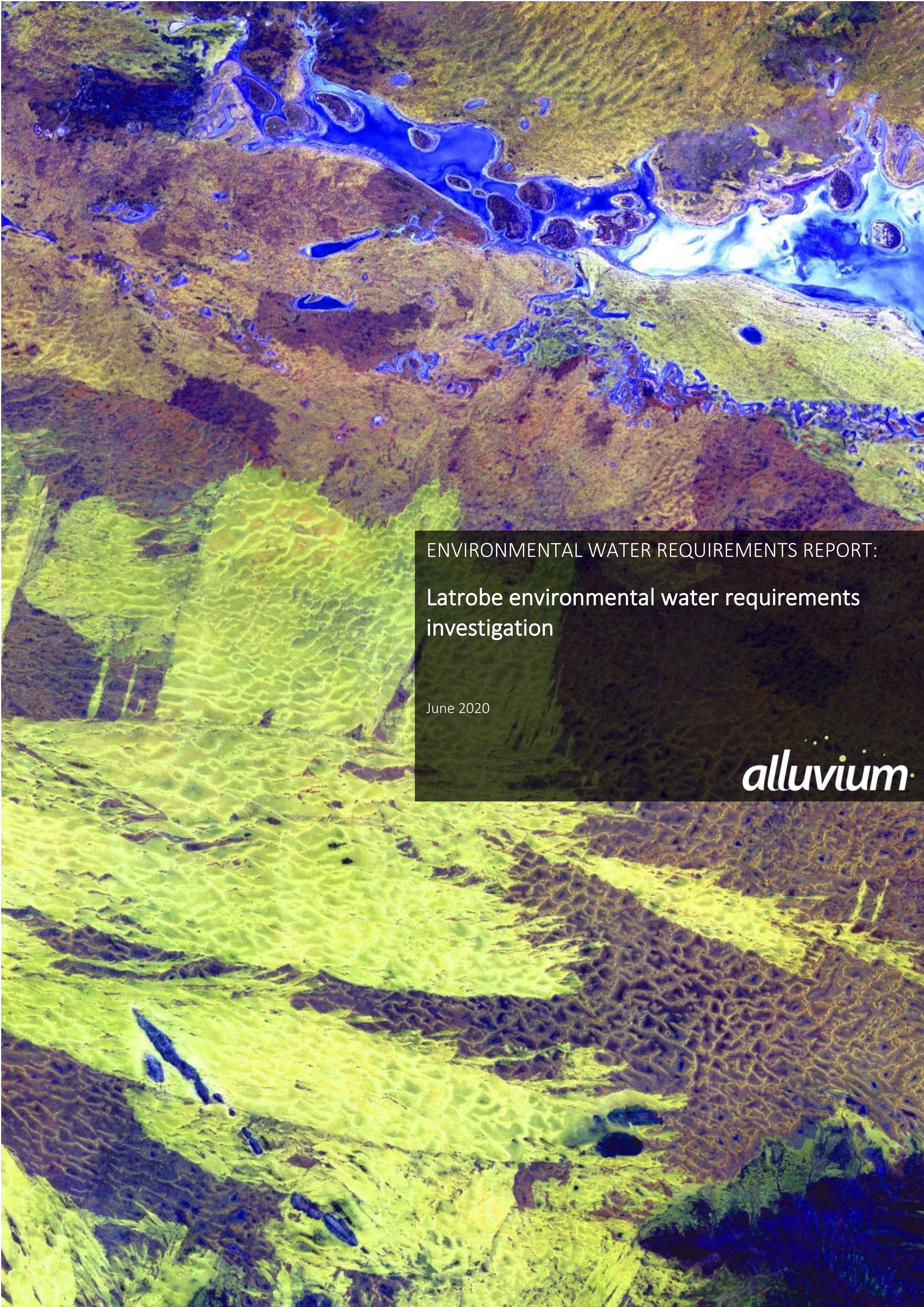

ENVIRONMENTAL WATER REQUIREMENTS REPORT:

Latrobe environmental water requirements investigation

June 2020

alluvium

This Environmental Water Requirements Report has been prepared by Alluvium Consulting Australia Pty Ltd for the West Gippsland CMA under the contract titled 'Latrobe environmental water requirements investigation'.

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Acknowledgement

Alluvium and the West Gippsland Catchment Management Authority would like to acknowledge and pay our respects to the Gunaikurnai as the Traditional Owners of the lands on which the project is based. We look forward to continuing to work collaboratively with the Gunaikurnai Land and Waters Aboriginal Corporation on achieving water for Traditional Owner cultural values and uses.

Photo: Heart Morass from above after October – November 2019 flood (supplied by WGCMA)

Summary

Water dependent values of the Latrobe river system

The Latrobe system, comprising the Latrobe River, its tributaries and the Lower Latrobe Wetlands, supports plant and animal species of high conservation significance. The Latrobe River also provides an essential source of freshwater to the Ramsar-listed Gippsland Lakes site, of which the Lower Latrobe Wetlands are an important component.

International significance	National significance	State significance
Lower Latrobe Wetlands Ramsar listing	*Dwarf Galaxias* *Australian Grayling* *Growling grass frog* *Green and golden bell frog* *River swamp wallaby grass* *Caspian tern* *Nankeen night heron*	*Striped Gudgeons* *South Gippsland spiny crayfish* *Strezelecki burrowing crayfish* *Azure kingfisher* *Wavy swamp wallaby grass* *Eastern water ribbons* *Veiled Fringe-sedge* *Lacey River Buttercup* *Swamp Scrub EVC*

In additional to the environmental values, the Latrobe system supports cultural, social, recreational and economic values. Gunaikurnai people are the traditional owners of Gippsland, and the Latrobe system. Waterways and wetlands in the region contain important ceremonial places and for thousands of years the Latrobe River provided resources such as food and medicines to the Gunaikurnai people.

As with many of Victoria's river systems, the Latrobe River system has been modified. These changes have interrupted many of the natural river and wetland processes needed by native plants and animals to survive, feed and breed. Water for the environment is released into rivers, estuaries and wetlands to improve their health and protect environmental values.

This report sets out the method and outcomes from a study to determine the water regime required to support environmental values identified for the rivers, estuary and wetlands of the Latrobe system.

Project approach

This investigation into the environmental water requirements for the Latrobe system was undertaken in accordance with the FLOWS and EEFAM methods. These methods are the adopted approach for the determination of environmental water requirements for waterways and estuaries across Victoria. While there is significant complexity and some uncertainty in determining environmental water requirements, the methods adopted for this investigation sit within the 'holistic' methods, which are becoming the standard approach, adopted globally, for the assessment of environmental flow requirements (refer Poff et al. 2017).

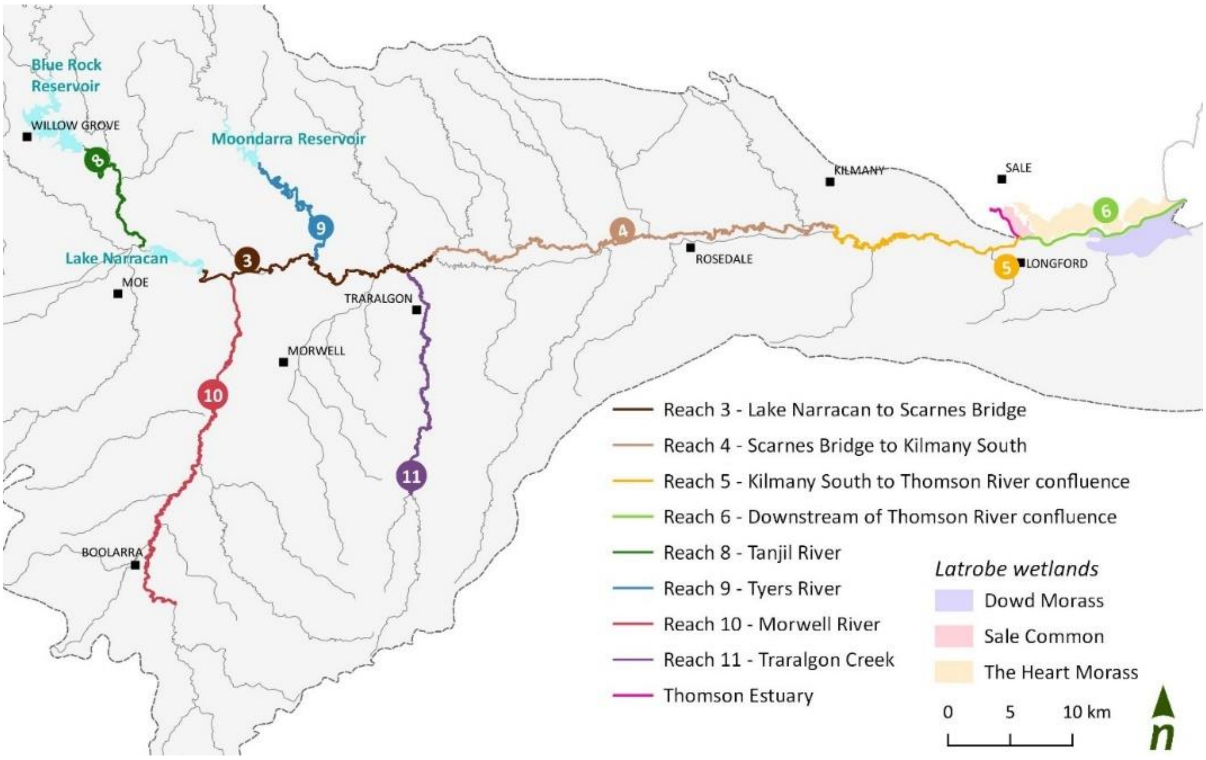
The key steps of this approach include establishing environmental objectives with stakeholders, and then using hydraulic and hydrologic models, ecological knowledge and system understanding, to determine environmental flow recommendations.

There were three key groups involved in developing the environmental flow recommendations for the Latrobe system:

- Environmental Flows Technical Panel. The Environmental Flows Technical Panel provide an independent science base to inform the investigation, they provide expertise in areas of ecology, hydraulics, hydrology, geomorphology, and water quality, and jointly make decisions and recommendations.
- Steering Committee. The Steering Committee oversee project implementation, provide direction on the scope of work, and review and provide feedback for key milestones throughout the project.
- Project Advisory Group (PAG). The PAG ensure that the broader stakeholder groups of the Latrobe system are adequately represented, providing a source of local knowledge and community expectations.

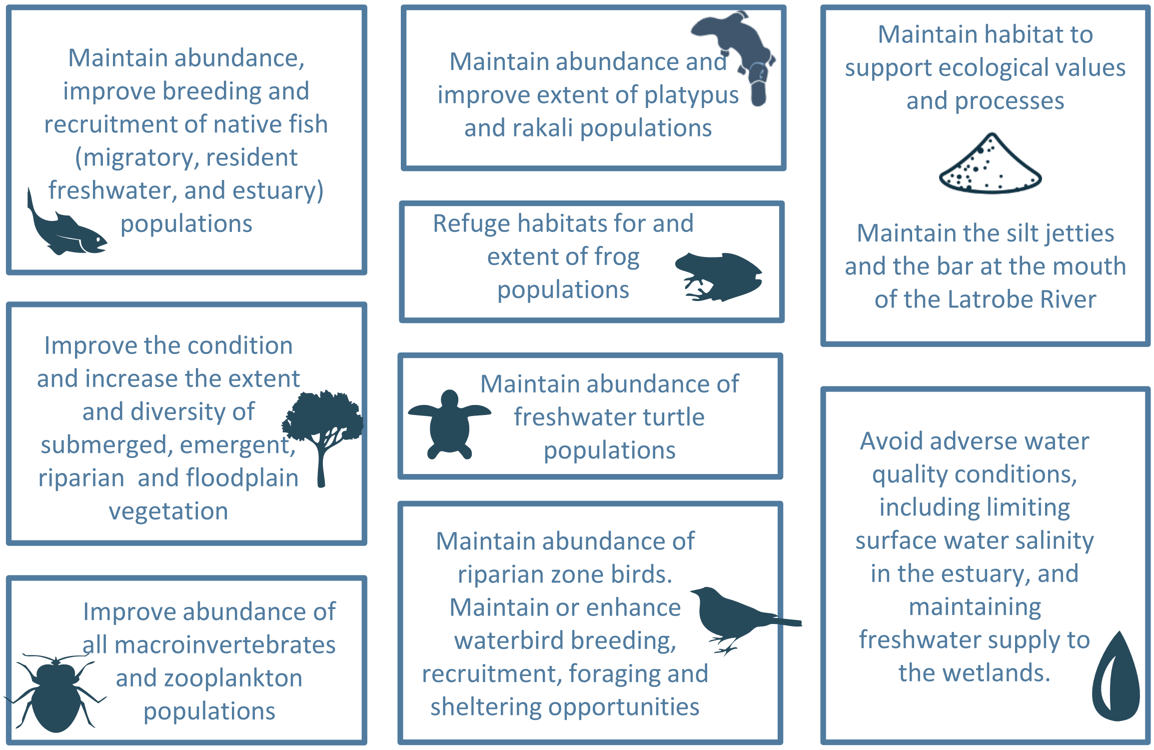
This project was undertaken to provide an update to the environmental water requirements previously established for the Latrobe system for the river reaches (Earth Tech, 2007) and the estuary (Brizga et al. 2013), incorporating new knowledge and system understanding, stakeholder expectations, and incorporating rivers, wetlands and the estuary into one study.

The spatial scope of the investigation has been the regulated sections of the Latrobe, including the estuary and Lower Latrobe Wetlands (Dowd Morass, Heart Morass and Sale Common), and the following tributaries of the Latrobe River: Tanjil River, Tyers River, the Morwell River, Traralgon Creek, and the Thomson River estuary.



Summary of environmental objectives

Environmental objectives guide the water requirement for the system and represent the values that society seeks to improve or maintain with water for the environment. The following environmental objectives were developed with stakeholders and the Environmental Flows Technical Panel. These values have been informed by existing waterway and estuary management strategies and related documents. The full environmental objectives and the relevant supporting information can be found in Section 4 of this report.



Water for the environment, provided to improve the health of rivers, wetlands and estuaries, can also help to sustain cultural values for Indigenous people. The cultural values of Indigenous people can be integrated into investigations to determine environmental water requirements. An Aboriginal Waterways Assessment (AWA) was undertaken by the Gunaikurnai Land and Waters Aboriginal Corporation (GLaWAC) and will be used as an input to the Latrobe Valley Regional Rehabilitation Strategy. The Traditional Owner cultural water values, including healthy country, meeting place (quarenook), key species pelican (Boran) and musk duck (Tuk), platypus (Balagen) and fairy wren (Yeerung and Djeetgun) have been incorporated into this environmental water requirements investigation.

Flow recommendations

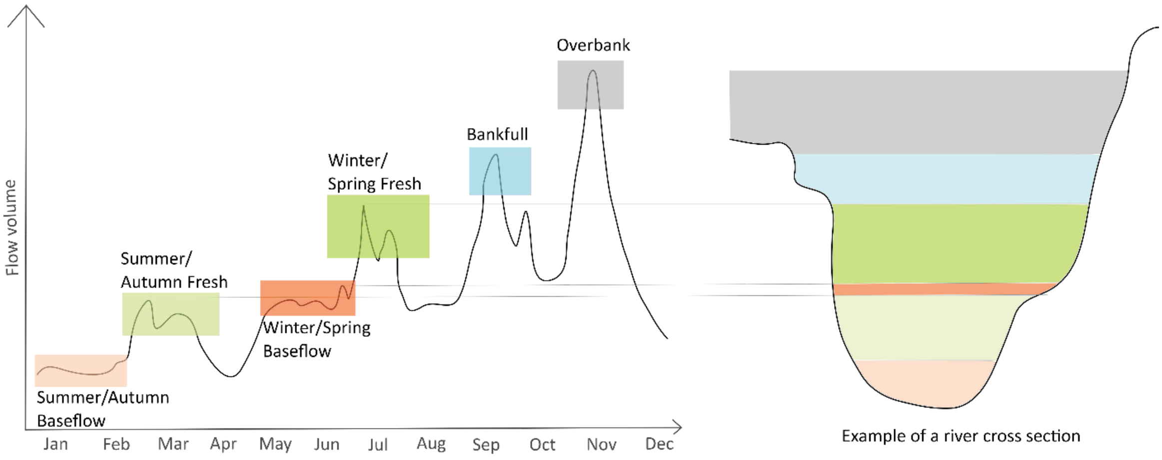
Using the best available scientific information, the Environmental Flows Technical Panel developed criteria outlining how the flow regime can support the achievement of the environmental objectives. Combining this information with hydrologic and hydraulic, and hydrodynamic models of the rivers, estuary and wetlands, the Environmental Flows Technical Panel developed environmental flow recommendations for each reach and wetland. These flow recommendations are expressed as the volume, timing, duration, frequency and quality of each flow component. The different flow components for the river and estuary reaches are shown below.

The environmental flow recommendations can be found in

- Section 6.2 of this report for river reaches
- Section 7.2 for the estuary
- Section 8.2 for the Lower Latrobe Wetlands.

The updated flow recommendations arising from this investigation differ from those developed from previous studies. Some of the reasons for differences include:

- refined and updated environmental objectives
- updated ecological and system knowledge
- improved hydrologic and hydraulic modelling.



The provision of environmental water alone will not result in the attainment of the adopted environmental objectives; therefore, this report also includes recommendations for complementary measures. These complementary measures include riparian vegetation management, structural arrangements to improve fish movement, bed and bank stability management, water quality management, the reinstatement of meanders previously cut off from the Latrobe River, and water infrastructure upgrades. Monitoring also plays an important role in understanding the role of environmental water and improving knowledge of the system over time. Recommendations for complementary measures have been developed and are provided in section 8.1 of this report.

A separate investigation and a supplementary report are under development to complement this environmental flow recommendations report. This supplementary report explores the difference between the current flow regime (and possible future flow regimes based on climate and development scenarios) and a flow regime that includes the environmental flow recommendations. The supplementary investigation and report will:

- identify volumetric shortfalls
- assess the performance (compliance) against the flow regime of the current and future flow regimes
- identify priorities for the provision of environmental water.

Using the environmental flow recommendations

The flow recommendations provided in this report are the minimum environmental flow regime needed, alongside complementary measures, to meet the agreed environmental objectives. These flow recommendations can be used to inform environmental water delivery and decisions about water sharing across users contemplated by the Sustainable Water Strategy (SWS) and the Latrobe Valley Regional Rehabilitation Strategy (LVRRS).

Contents

Figures

Tables

1 Introduction

The Latrobe system, comprising the Latrobe River, its tributaries, and the lower Latrobe wetlands, supports plant and animal species of high conservation significance. The Latrobe River also provides an essential source of freshwater to the Ramsar-listed Gippsland Lakes, of which the lower Latrobe wetlands are an important component.

In order to optimise the value from water for the environment, and in preparation for a new iteration of the Sustainable Water Strategy (to be developed in 2019-2020 for the Southern Region), the West Gippsland CMA (WGCMA) required a focussed study to improve the understanding of environmental water requirements and shortfalls in the Latrobe system. Recommended through an initial scoping study (Alluvium 2018), this investigation and report have sought to update the understanding of the environmental water requirements and shortfalls in priority reaches of the Latrobe system. A sound understanding of how much water is required, and under what conditions the water is needed, is essential to ensuring that environmental values are maintained and or improved in the system.

In addition to the above, the state government of Victoria has committed to the development of a Latrobe Valley Regional Rehabilitation Strategy (LVRRS). The LVRRS seeks to establish a long-term plan for closure of the existing Latrobe Valley coal fired power stations and accompanying open cut coal mines. As part of this closure planning, the water demand at the mine sites may change. Changes could include the filling of old mine pits to establish pit lakes.

An updated and improved understanding of environmental water requirements, and the risks associated with not meeting these requirements, can be used to inform rehabilitation recommendations and support the achievement of environmental outcomes through the period of change that is underway in the Latrobe system.

1.1 Project objectives and approach

The **scope of this project** includes:

- Review and update (where required) the environmental objectives and conceptual models to establish an understanding of the current system condition and trajectory, water related threats to the values, and conceptual flow-ecology relationships and develop robust, agreed and measurable ecological objectives for the environmental flows in the system

- Update the hydraulic and hydrodynamic modelling (for selected reaches) and update the environmental flow recommendations to reflect contemporary understanding of the system and the revised objectives in line with the current FLOWS and EEFAM methods

- Calculate shortfalls under different climate scenarios, prioritise the environmental flow recommendations to achieve objectives and understand the risks of not delivering the environmental water recommendations and the benefits of delivering the recommendations (inclusive of environmental, social, cultural and economic values) and clearly link risk/benefit with specific components of the shortfall

This study includes freshwater reaches, estuary reaches and wetlands. Therefore, an approach that incorporates FLOWS2 and EEFAM methods has been adopted. These methods are the adopted approach for waterways across Victoria; while there is significant complexity and uncertainty in understanding environmental water requirements, the method adopted for this study is considered a holistic method, which are effectively becoming the standard approach adopted globally for assessing the environmental flow requirements of rivers (refer to Poff et al. 2017). The project outputs have been designed to provide environmental water managers with the essential information needed for the planning and delivery of environmental water. The **overall approach** to the project, consisting of five stages, is provided in Figure 1.

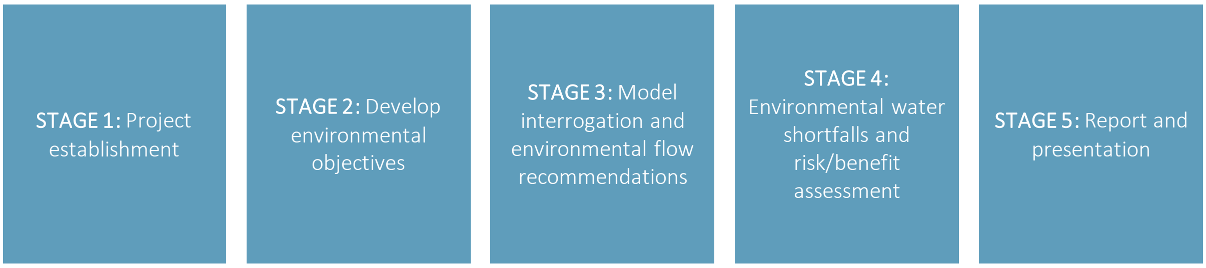


Figure 1. *Project approach*

The **spatial scope** of this project is the regulated sections of the Latrobe, including the estuary and lower Latrobe wetlands, excluding upstream of Lake Narracan (reaches 1 and 2) and excluding Lake Wellington. The scope also includes the following tributaries of the Latrobe River: Tanjil River downstream of Blue Rock Reservoir, Tyers River downstream of Moondarra reservoir, the Morwell River downstream of Boolarra, Traralgon Creek, downstream of the Taylors Road bridge, and the Thomson River estuary. Reach delineation and site selection is discussed in section 1.3 and Appendix B.

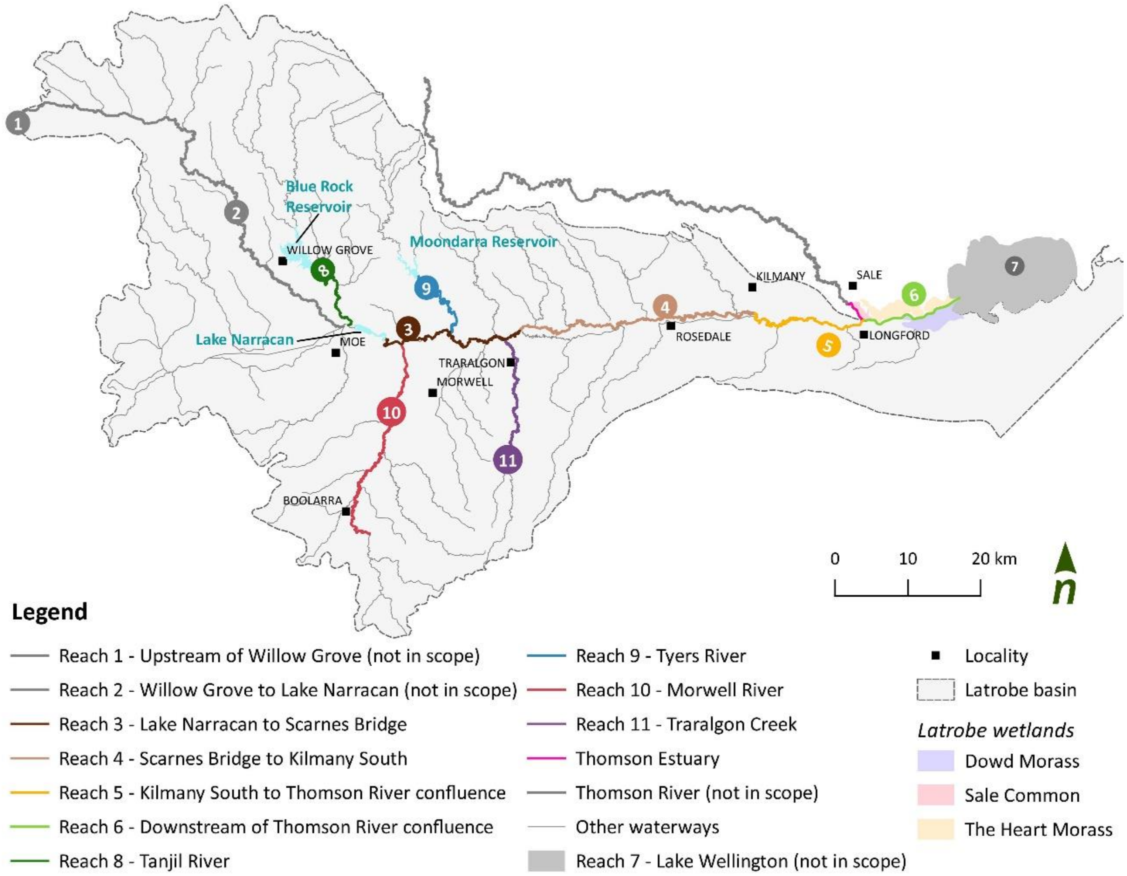


Figure 2. *Study area*

The **Environmental Flows Technical Panel** members and project team contributing to this project are shown below.

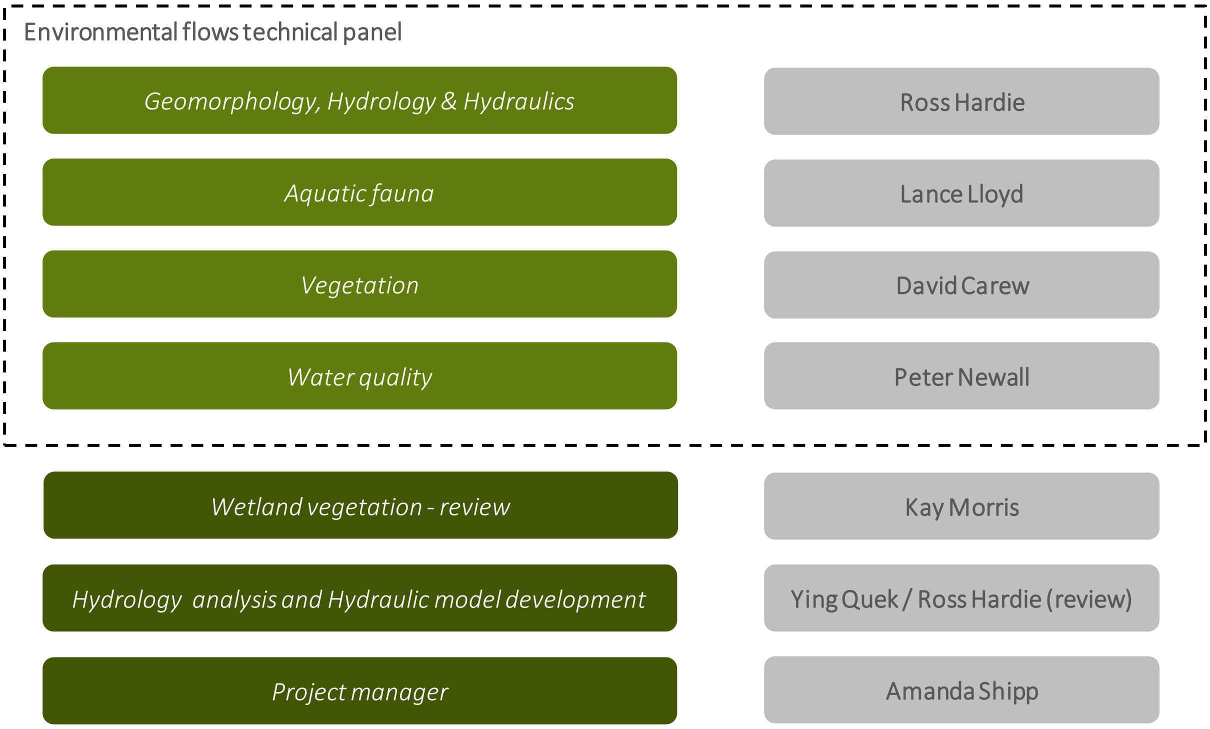


Figure 3. *Environmental (and estuary) Flows Technical Panel and project team*

Stakeholder engagement
The following groups were engaged with this project:

- Steering Committee. The purpose of the Steering Committee was to oversee project implementation, provide direction on the scope of work, and review and provide feedback for key milestones throughout the project. The Steering Committee is comprised of representatives from the following organisations:
    - Department of Environment, Land, Water & Planning (DELWP)
    - West Gippsland Catchment Management Authority (WGCMA)
    - East Gippsland Catchment Management Authority (EGCMA)
    - Victorian Environmental Water Holder (VEWH)
    - Gunaikurnai Land and Waters Aboriginal Corporation (GLaWAC)

- Project Advisory Group. The purpose of the Project Advisory Group (PAG) was to ensure that the broader stakeholder groups of the Latrobe system are adequately represented. This group will provide a source of local knowledge and community expectations. This group includes landholders and business operators, Parks Victoria, Native Fish Australia, Gunaikurnai Land and Waters Aboriginal Corporation (GLaWAC), Latrobe Field Naturalists, WGCMA, Gippsland Water, Field and Game Australia, Southern Rural Water, VEWH, EGCMA, DELWP, and VR Fish.

The first Project Advisory Group (PAG) meeting was held on the 4th December 2018 and included input on values, objectives, issues and opportunities, which has guided the material set out in Sections 2 - 4 of this report. A second PAG meeting was held on the 12th March 2019 to review the draft environmental water recommendations (Sections 6 - 8). A summary of the input provided in these workshops is in Appendix A.

The PAG identified a set of principles for the Environmental Flows Technical Panel to consider when developing the flow recommendations:

How – We need to understand how the system works

Why – Identify why the system and its values are the way they are

What – Look at different options and scenarios and consider what is practical and feasible

When – Consider timescale when developing objectives and future changes in the system (climate change, mine rehabilitation, salinity regime)

Traditional Owner cultural values

Water for the environment, provided to improve the health of rivers, wetlands and estuaries, can also help to sustain cultural values for Indigenous people. The cultural values of Indigenous people can be integrated into investigations to determine environmental water requirements. An Aboriginal Waterways Assessment (AWA) was undertaken by the Gunaikurnai Land and Waters Aboriginal Corporation (GLaWAC) and will be used as an input to the Latrobe Valley Regional Rehabilitation Strategy. The Traditional Owner cultural water values have been incorporated into this environmental water requirements investigation.

1.2 Purpose and structure of this Report

This is the environmental water requirements report for the *Latrobe environmental water requirements investigation*. The report is set out as follows:

- **Part A: Context and objectives (Sections 2 to 4)**
  This part includes an overview of water resource development in the Latrobe system, and system changes, issues and values to guide the assessment. Each environmental value is described in terms of the current condition, and conceptual model of the water requirements and objectives for environmental water determination.

- **Part B: Environmental water requirements (Sections 6 to 8)**
  Environmental water requirements for the Latrobe system: freshwater river reaches, estuary and the lower Latrobe Wetlands, including environmental flow objectives and criteria, and hydrologic and hydraulic modelling and assessment that guided the requirements.

- **Part C: Environmental water delivery and management (Section 9)**
  This part includes information to help guide environmental water management in the Latrobe system (including the implementation of the environmental water requirements). This includes complementary measures, and monitoring recommendations for the system.

A separate supplementary report under development provides further information on the volumetric shortfalls and performance under the current flow regime and possible future development and climate changes.

1.3 Reach and site selection

A site inspection was undertaken on 16 and 17 November 2018. Attendees included Environmental Flows Technical Panel members (Ross Hardie, Lance Lloyd, and David Carew), Alluvium project manager (Amanda Shipp), WGCMA project manager (Adrian Clements) and DELWP Steering Committee members (Natasha Sertori, Brett Davis).

Based on a review of the available information, one change to reach extents was recommended and adopted. The downstream part of reach 5 (downstream of Kilmany South) has a vegetated floodplain that is more frequently engaged, partly due to recent meander reinstatement works, and it is also influenced by Lake Wellington and the Latrobe Estuary backwater. The Latrobe River between Rosedale and Kilmany South (previously part of reach 5) was assessed more similar to Reach 4 in terms of land use, channel morphology and connectedness to the floodplain. Therefore, Reach 4 now includes the Latrobe River from Scarnes Bridge to Kilmany South (immediately downstream of Crooks Lane Bridge), and reach 5 extends from Kilmany South to the Thomson River confluence.

Representative sites have been selected for each reach; these are described in Appendix B.

Part A: Context and objectives

Photo: Sale Common, October 2017 (Supplied by WGCMA)

2 Water resource development in the Latrobe system

2.1 Surface water – river reaches

The Latrobe River has been recognised as a 'working' river as it has been highly modified from its natural state for consumptive demands, productive land uses, power generation and urban development (Alluvium 2009). Although the headwaters of the Latrobe River are unregulated and are generally forested, much of this land have been cleared for grazing and cropping (Earth Tech 2007).

The mid and lower Latrobe River, also known as the Latrobe Valley, is a highly regulated system with a significant portion of land used for intense agricultural and mining activities. Within the Latrobe River catchment, there are eight bulk and environmental entitlement holders that share the water resources available in the system and comprise power generators, Southern Rural Water, Gippsland Water, and the Victorian Environmental Water Holder.

There are three major storages present in the catchment (Gippsland Water 2012, Southern Rural Water 2018a, Southern Rural Water 2018b):

- Lake Narracan located on the Latrobe River upstream of the Yallourn power station (8,600 ML)
- Blue Rock Reservoir on the Tanjil River (198,280 ML)
- Moondarra Reservoir on the Tyers River (30,300 ML)

These storages are operated by Southern Rural Water and Gippsland Water. A number of pipelines across the supply system provide water for power generation, urban and industrial use. The entitlement holders are entitled to a sharing of the capacity and inflows into Blue Rock Reservoir and Lake Narracan (Alluvium 2017a).

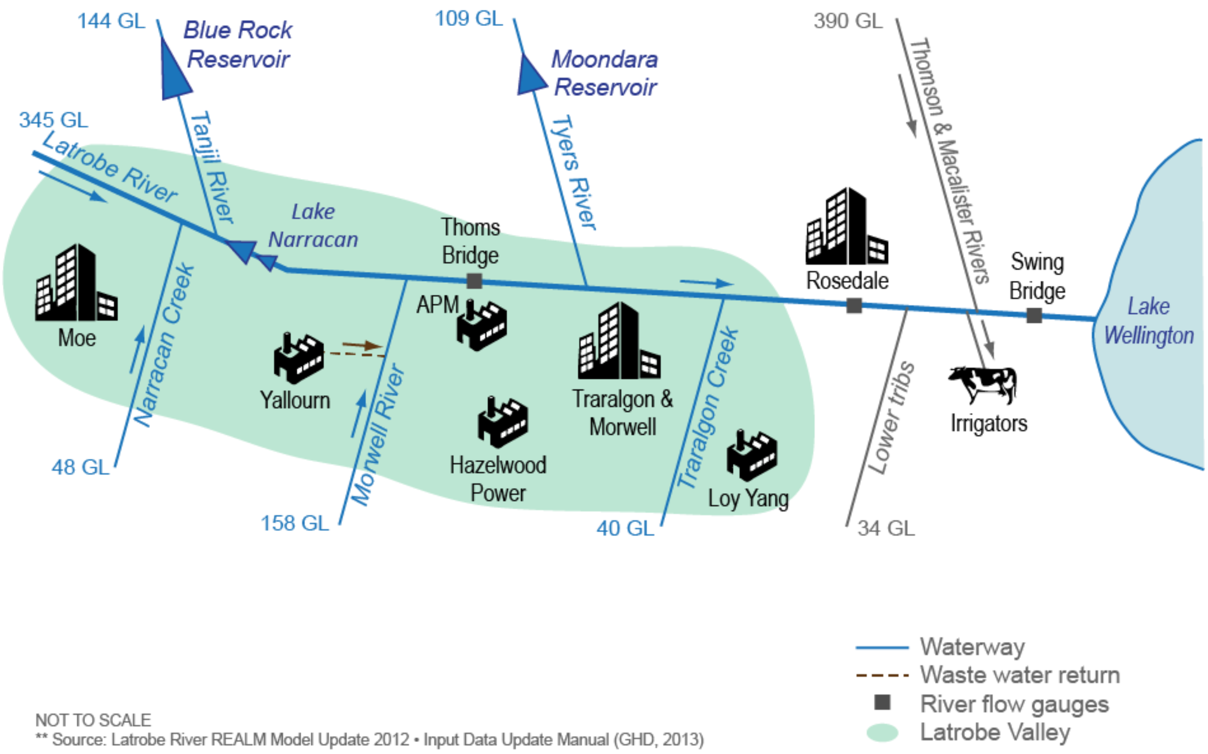


Figure 4. *Schematic of the Latrobe River system and mine sites, showing 1957 to 2012 average annual inflows and selected flow gauges (DELWP 2017)*

Lake Narracan is managed by Southern Rural Water and primarily provides water for cooling the power station generators in the Latrobe Valley. Lake Narracan is also supplemented with flows from Blue Rock Reservoir (SRW 2018). Moondarra Reservoir is managed by Gippsland Water to provide water to industry and towns in the

Latrobe Valley. Blue Rock Reservoir is operated by Southern Rural Water and supplies water through a number of pathways (Gippsland Water 2017). Blue Rock Reservoir:

- supplies water to be used for generating electricity in the Latrobe Valley coal fire power plants
- supplies water to Gippsland Water for water supply in towns in and around Latrobe Valley
- pumps water to supplement natural inflow to Moondarra Reservoir in drier years (managed by Gippsland Water)
- extracts water from Tanjil River and Blue Rock Reservoir to supply water treatment plants in Moe and Willow Grove (managed by Gippsland Water)
- releases water into Latrobe River as part of the environmental water entitlement (VEWH 2017).

There are some constraints in the system; for example, the Moondarra outlet, the Blue Rock outlet and the channel capacity of the Tanjil River and lower Latrobe River act as constraints to the delivery of environmental water in the Latrobe River. Lake Narracan can assist in mitigating these constraints, but without a share of the storage capacity, this option is not always possible.

Table 1. Delivery constraints, adapted from in the Latrobe River Seasonal Watering proposal 2018-19

Potential constraints	Impact on priority watering action
Available outlet capacity share	Limits release volume/timing
Total available outlet capacity	Limits release volume
Flooding risks for private land in Tanjil River reach	Limits ability to release larger volumes from Blue Rock Reservoir
Maintenance of water levels in Lake Narracan during water ski season (January – March) (impact on other entitlement holders)	Reduces capability to charge Lake Narracan with releases from Blue Rock to allow for larger releases into Latrobe River (related to previous constraint)
Flooding risks for private land in Latrobe River Reach 5	Limits release volume Not this depends on the influence of Lake Wellington due to wind conditions.

The long-term annual average yield for the Latrobe River downstream of the Latrobe Valley has been reported to be around 844 GL (DELWP 2017). The upper Latrobe catchment and the inflow into Blue Rock Reservoir contributes around 489 GL per year. The major tributaries (Morwell River, Tyers River, Narracan Creek and Traralgon Creek) contribute around 355 GL into the Latrobe River per year. Further downstream, the Thomson and Macalister Rivers contribute an additional estimated 390 GL per year. Additional (smaller) tributaries also contribute around 34 GL into the Latrobe River, giving a total annual average yield for the Latrobe River at Lake Wellington to be 1,268 GL (Alluvium 2017a).

Bulk and environmental entitlements

The Latrobe system is a fully allocated system and has several bulk entitlements and two environmental entitlements. A total of 208 GL in bulk entitlements are currently held by Southern Rural Water, Gippsland Water, and other users (Alluvium 2017a; Table 2). Average annual water use from 2010-2015 was 115 GL, around half the overall entitlement volume.

Water can be set aside for the environment through water entitlements, passing flows and other regulatory limits on the water allocated to consumptive users. Passing flows set aside water for the environment through conditions on bulk entitlements. These conditions specify minimum passing flow requirements at offtakes and immediately downstream of reservoirs to be provided for environmental purposes. A limit, called a permissible consumptive volume, has been placed on allocation of water to consumptive users in the Latrobe basin.

There are two main environmental entitlements relevant to the study area:

- Blue Rock Environmental Entitlement 2013
- Lower Latrobe Wetlands Environmental Entitlement 2010

Neither of these entitlements are specific volumetric entitlements. The *Blue Rock Environmental Entitlement* 2013, which now includes 9.45% of inflows into Blue Rock and a share of storage capacity, and the Lower Latrobe Wetlands Environmental Entitlement 2010 allows watering of the Lower Latrobe wetlands[1].

During the 2015-2016 water year, amendments were made to the Blue Rock Environmental Entitlement 2013 to increase the environment's proportional share of inflows (from 9.00% to 9.45%), to reflect the change in the recorded volume of Blue Rock Reservoir (VEWH 2016).

Two other environmental entitlements can also contribute water to the Latrobe estuary and lower Latrobe wetlands through the Thomson River:

- Macalister Environmental Entitlement 2010
- Bulk Entitlement (Thomson River – Environment) 2005

Surface water hydrology

Surface water extraction and storage in Latrobe River basin have impacted the hydrology of the system and the condition of Lake Wellington. This flow regulation has decreased the volume and variability of downstream flow, affecting sediment transport and disconnecting floodplains throughout the entire river (EarthTech 2005; Tilleard et al. 2009; Water Technology, 2013). Alluvium (2009) reported that the Latrobe River system is a flow stressed system and is currently over-extracted. In particular, the development on the adjoining floodplains for Hazelwood power station, Loy Yang power stations, and Yallourn power station have compromised the stream condition through ongoing water extractions and diversions from the Latrobe River and its tributaries.

The reduction in riverine flows in the Latrobe River as a result of high industrial/agricultural and urban demands reduces the volume of riverine discharge into Lake Wellington. Lake Wellington is one of the largest lakes within the Ramsar listed-Gippsland Lakes and wetlands system and is an important habitat for a large range of resident and migratory waterbirds, fish and vegetation communities. Tilleard et al. (2009) estimated that the average freshwater discharge to Lake Wellington had reduced by 33% from the natural condition and could further impact on the ecological system in Lake Wellington. The frequency and duration of flows that flush salinity from the estuary and wetlands are limited by reduced flows in the Thomson, Macalister and Latrobe Rivers, further threatening the existing character of the wetlands. The CRCFE (1999 and 2001) estimated that total flow volume in the Lower Thomson has reduced by around 50%, and median annual flows in the Macalister River have reduced by 47%, while the Latrobe River still maintains around 70% of surface water flow.

Available data: stream gauges

Water Technology (2017) undertook a project to develop and analyse a field monitoring program to inform the assessment of environmental flow responses in the lower Thomson and Latrobe River systems from 2013 to 2016. The stream gauges relevant to each reach in the Latrobe River system were obtained from Victoria's Water Measurement Information System (VWMIS): http://data.water.vic.gov.au/monitoring.htm. Table 3 lists the available gauge information that could be used for this FLOWS study.

[1] https://www.water.vic.gov.au/water-reporting/monthly-water-report/reports/2018/march-2018/monthly-water-report-march-2018/environmental-water-march-2018

Table 2. Bulk and environmental entitlements of the Latrobe Valley - based on 2015 data (Alluvium 2017a)

Authority	Entitlement Name	Entitlement volume (ML) in 2015	Share of Capacity (%)			Average annual use (ML) (2010 to 2015)	Average annual forfeiture (ML) (2010 to 2015)	Water users
			Blue Rock Lake	Lake Narracan	Moondarra Reservoir			
Gippsland Water	Boolarra (unregulated)	145	-	-	-	31	112	Residential and commercial including power generation
	Erica (unregulated)	340	-	-	-	90	250	
	Mirboo North (unregulated)	270	-	-	-	186	84	
	Moe – Narracan Creek (unregulated)	3,884	-	-	-	2,112	1,772	
	Moondarra Reservoir(regulated)	62,000	-	-	100	39,057	22,943	
	Noojee(unregulated)	73	-	-	-	-	73	
	Thorpdale(unregulated)	80	-	-	-	14	64	
	Gippsland Water – Blue Rock(regulated)	20,000	17.08	-	-	3,458	11,692	
Southern Rural Water (SRW)	Latrobe – Loy Yang B (regulated)	20,000	8.61	16.40		14,559	5,441	power generation
	Latrobe – Southern Rural(regulated)		2.10	-	-	4,836	7,773	Irrigation
	Latrobe Reserve (regulated)	-	18.87	-	-	-	-	Reserve for all bulk entitlement holder in Latrobe regulated supply system
Loy Yang Power	Latrobe – Loy Yang A(regulated)	40,000	17.22	32.80		21,118	18,882	Power generation
Minister for Environment	Latrobe – Loy Yang 3/4 Bench(regulated)	25,000	10.95	20.86	-	-	25,000	Currently unused
Energy Australia Yallourn Pty Ltd	Latrobe – Yallourn (regulated)	36,500	15.72	29.94	-	25,330	11,170	Power generation
Victorian Environmental Water Holder (VEWH)	Blue Rock Environmental Entitlement (regulated)	-	9.45	-	-	3,866	9,183	Environment
	Lower Latrobe Wetlands Environmental Entitlement (unregulated)	-	-	-	-	-	-	Environment
Total		**208,292***	**100**	**100**	**100**	**114,658**	**114,438**	

*Note> Blue Rock Reservoir volume is now 198280 ML (post-survey information)

Table 3. Gauges selected for each reach within this study.

Reach number	Reach name	Gauge number	Gauge name	Gauge start date	Gauge end date
3	Latrobe River (Lake Narracan to Scarnes)	226005*	Latrobe River @ Thoms Bridge	16/01/1962	04/09/2018
4	Latrobe River (Scarnes Bridge to Kilmany South)	226228	Latrobe River @ Rosedale (mainstem)	1/12/1936	05/09/2018
5	Latrobe River (Kilmany South to Thomson confluence)	226227	Latrobe River @ Kilmany South	17/12/1976	06/09/2018
Estuary	Latrobe River (Downstream of Thomson River Confluence)	226027*	Latrobe River @ Swing Bridge	22/06/2010	12/12/2018
	Thomson River	225232	Thomson River @ Bundalaguah	03/11/1976	05/06/2016
8	Tanjil River	226216	Tanjil River @ Tanjil South	2/04/1955	04/09/2018
9	Tyers River	226028#	Tyers River @ Pump House	13/04/1990	2/01/1996
10	Morwell River	226408	Morwell River @ Yallourn	2/03/2003	05/09/2018
11	Traralgon Creek	226023B	Traralgon Creek @ Traralgon	01/10/1998	27/11/2018
	Lower Latrobe Wetlands	226611^	Heart Morass @ Rickety Bridge	13/06/2017	20/09/2018
		226602^	Area 2 Site1 @ Dowd Morass Nth	17/06/2003	31/01/2010

*Note: Gauge 226003 was used as a compliance point in the 2007 FLOWS study, but the gauge ended on 09/04/2013, so a different gauge is referenced here

Note. Previous compliance point for Reach 9 (226034) does not have any data available

^ Water level gauge only

*Includes salinity at depth to detect the salt wedge

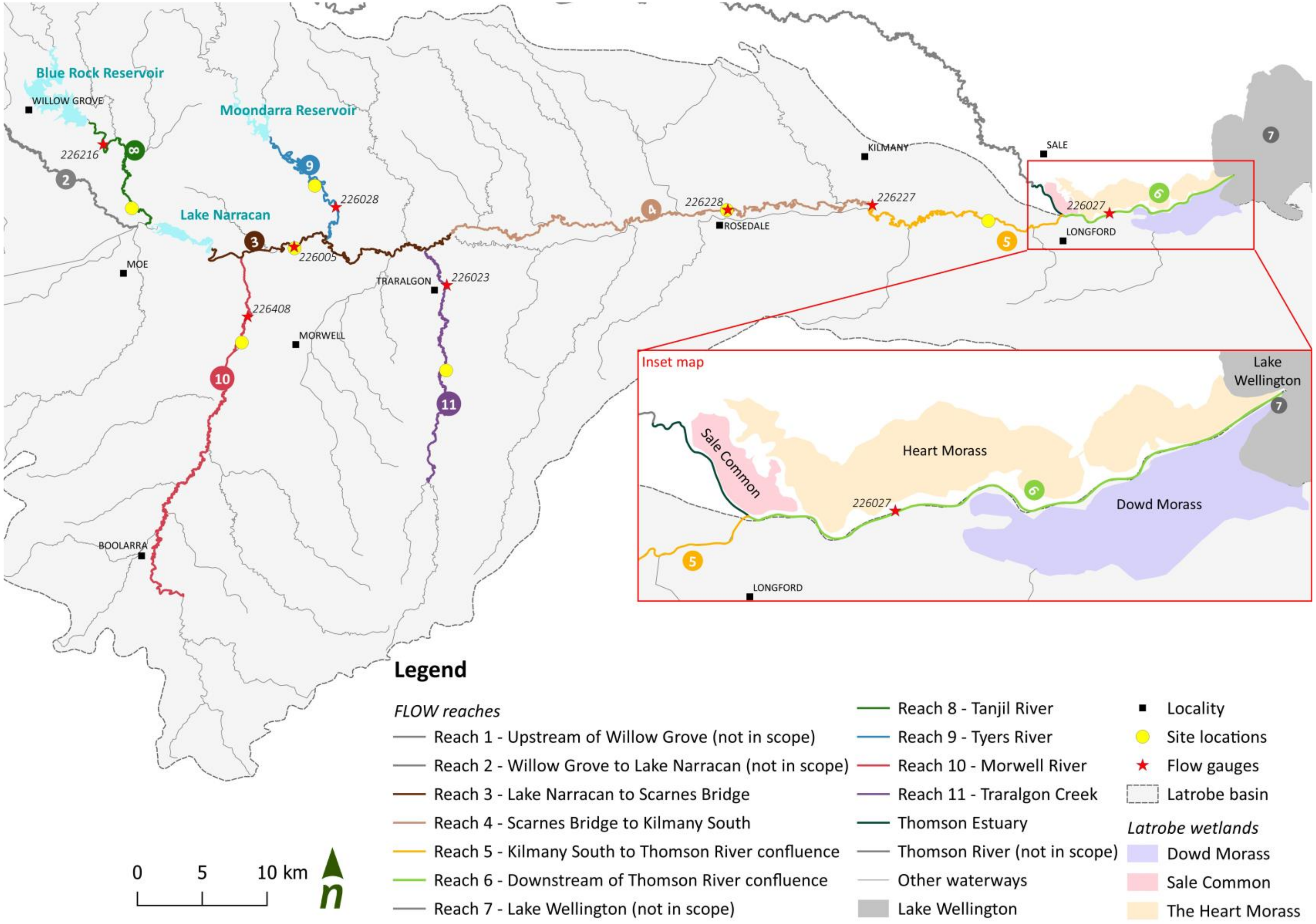


Figure 5. *Flow gauges and field observation sites in the Latrobe River study area*

Hydrological analysis methodology

The FLOWS study process requires hydrological information that enable the Environmental Flows Technical Panel to specify flow components in terms of magnitude, duration, frequency, timing, and rate of change and to assess the degree to which the flow components are provided by the current flow regime. Availability of tailored hydrological statistics reduces subjectivity in the environmental flow assessment process.

Water resource models

The hydrological consideration of surface water requires daily time series of the unimpacted and current flows. The unimpacted flow is a modelled flow regime where there is no impoundment (e.g. dams, weirs), extractions, harvesting nor water diversions or transfers in the system. Unimpacted flows are also referred to the more commonly used term – ‘natural’ flow. Current flow is a modelled flow regime under current levels of water resource development. These time series are derived from the existing REALM models (Latrobe and Thomson-Macalister) through a disaggregation process from monthly to daily time step. The hydrological analysis was completed for river reaches and estuarine reaches under modelled natural and current flows from January 1957 to June 2017.

Concurrent work is being undertaken by DELWP to develop a daily model of the system using the eWater Source software; however, this model will not be complete within the required timeframes for the environmental water requirements study. Daily inputs to the model have been developed and provided as input to the project (GHD 2017). Further information on the water resource models and disaggregation process can be found in Alluvium 2019.

Flow components

The FLOWS method requires recommendations to be made for a number of different flow components (Figure 6, Table 4). Each component has a known or assumed important environmental function. Although the method is generic for Victoria, we have selected components critical for the reaches of the Latrobe River to be included in this study.

Table 4. Hydrological description of the FLOWS method flow components

Flow component	Hydrological description	Relevant period
Summer / Autumn baseflows	Summer / Autumn baseflows are the natural dry period (summer/autumn) flows or ‘baseflows’ that maintain water flowing through the channel, keeping in-stream habitats wet and pools full.	Summer/Autumn
Summer / Autumn Freshes	Summer / Autumn freshes are frequent, small, and short duration flow events that last for one to several days as a result of localised rainfall during the low flow period.	Summer/Autumn
Winter / Spring baseflows	Winter / Spring baseflows refer to the persistent increase in low or base flow that occurs with the onset of the wet period.	Winter/Spring
Winter / Spring Freshes	High flow freshes refer to sustained increases in flow during the high flow period as a result of sustained or heavy rainfall events.	Winter/Spring
Bankfull Flows	Bankfull flows fill the channel, but do not spill onto the floodplain.	More common in the wet period, but occurs in the dry period
Overbank Flows	Overbank flows are higher and less frequent than bankfull flows and spill out of the channel onto the floodplain.	More common in the wet period, but occurs in the dry period

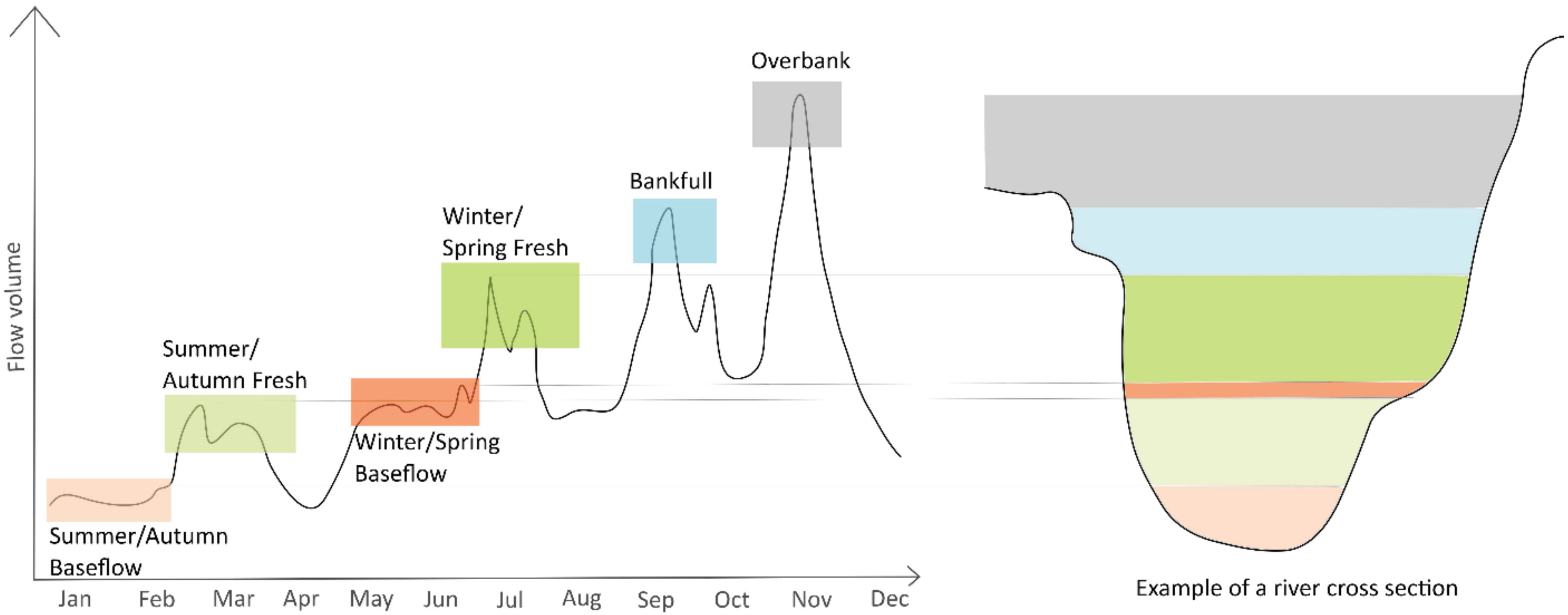


Figure 6. *Notional hydrograph showing commonly used terms to describe the flow regime in studies developing Environmental water requirements (Adapted from Victorian Environmental Water Holder http://www.vewh.vic.gov.au/environmental-water/what-is-environmental-water)*

Hydrological analysis results

Flow variability

Flow duration curves are used to summarise the entire flow distribution and can indicate the range of flows that are impacted by land and water resource development. They do not however allow examination of the extremes of low flows and high flows or indicate seasonal impacts. Flow duration curves for the river reaches are presented in Figure 7 - Figure 10 (below).

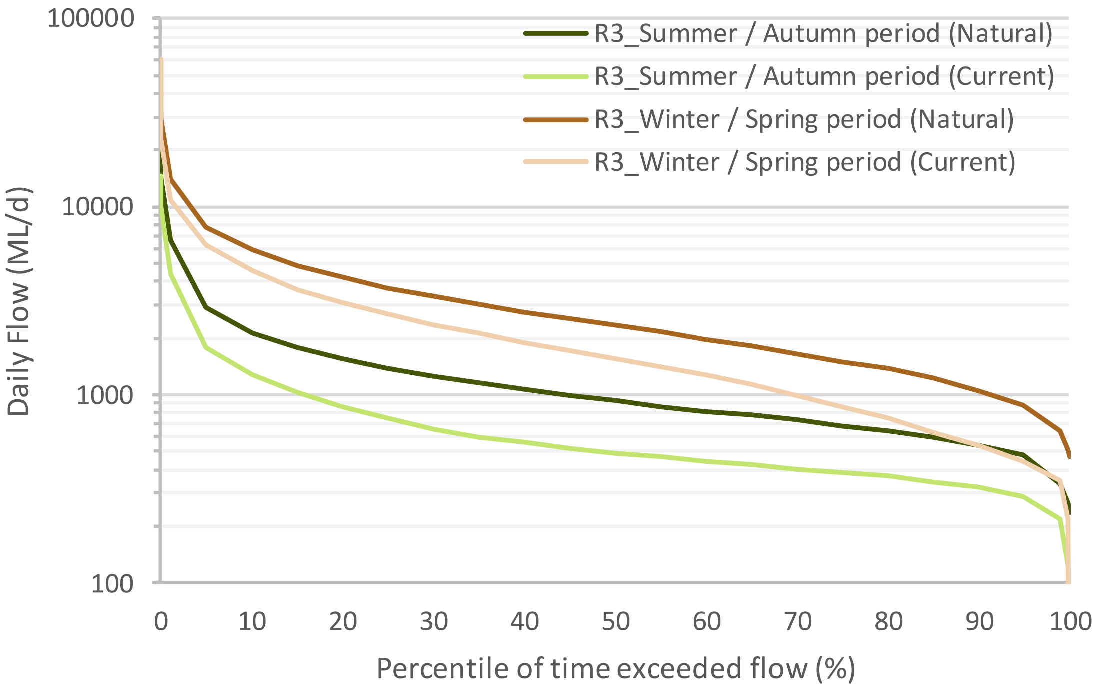
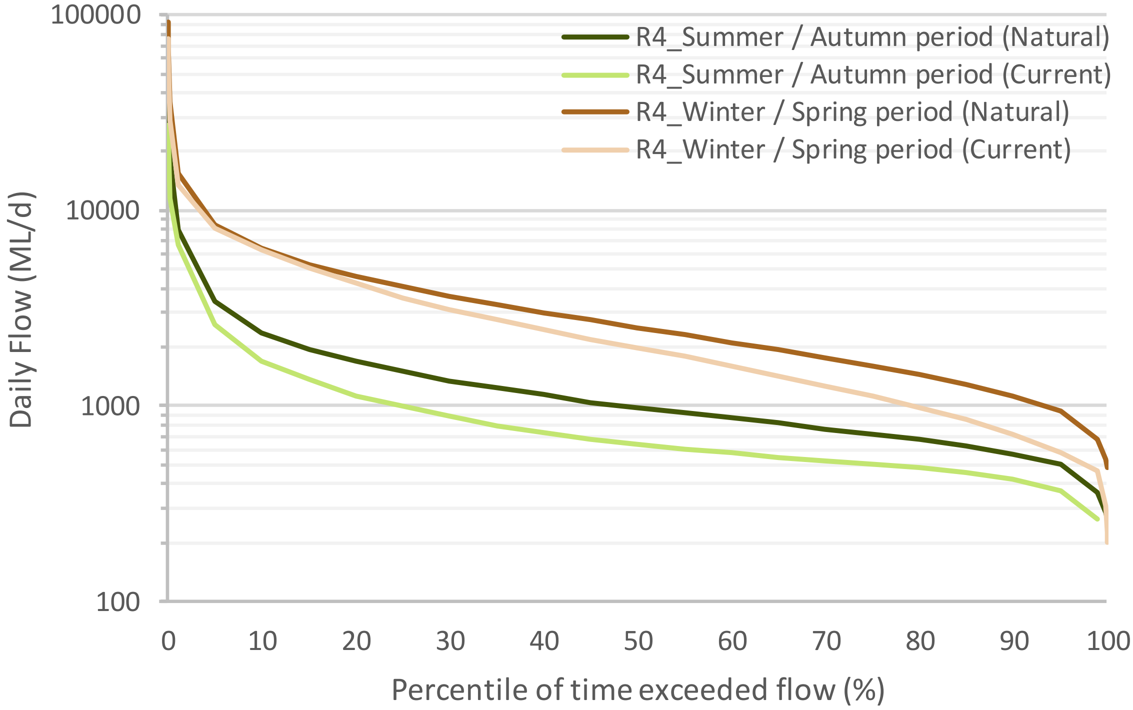


Figure 7. *Flow duration curves of mean daily flow under natural and current conditions: reach 3*



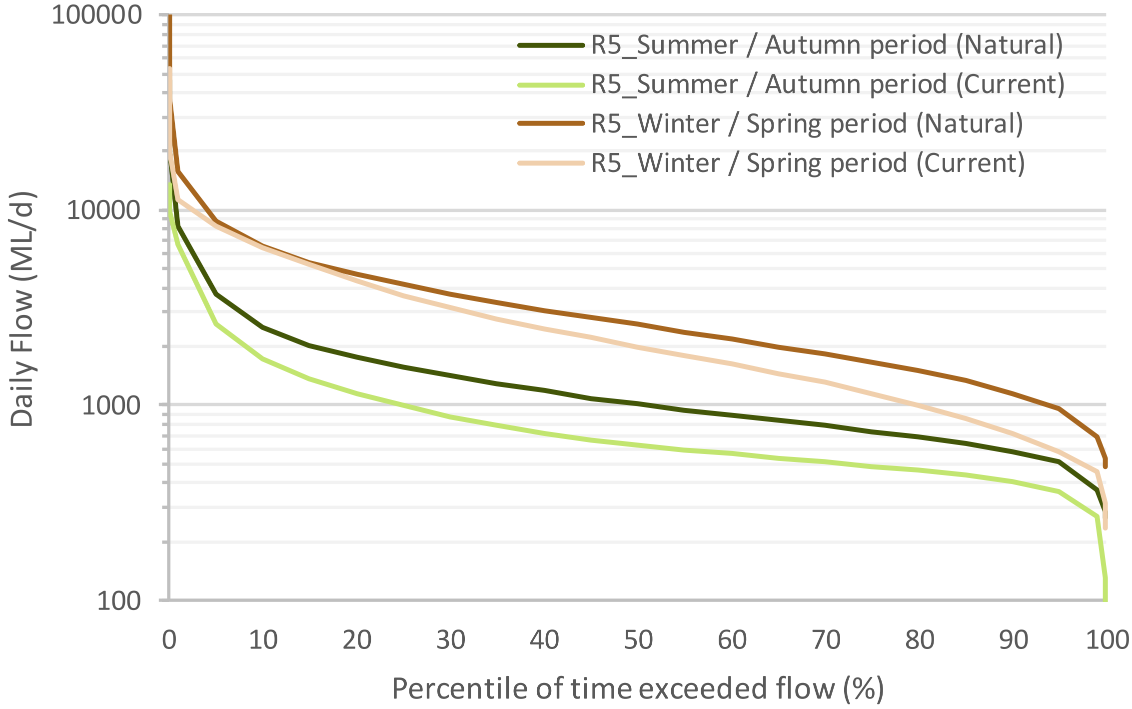
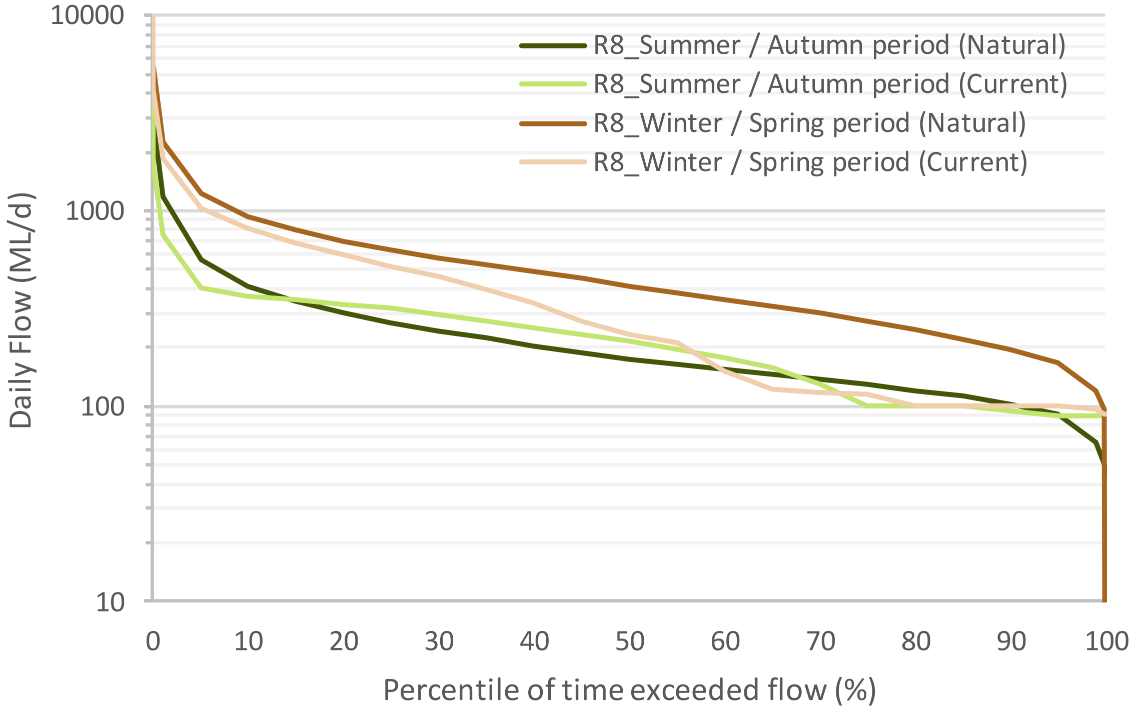


Figure 8. *Flow duration curves of mean daily flow under natural and current conditions, reaches 4 and 5.*



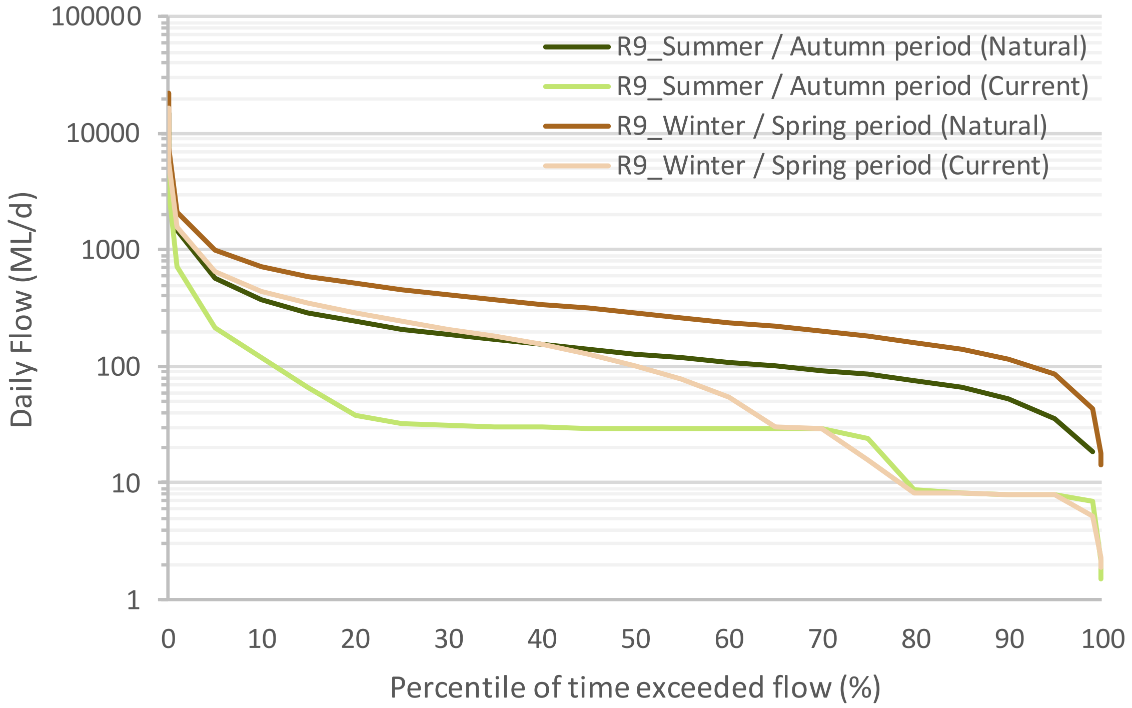
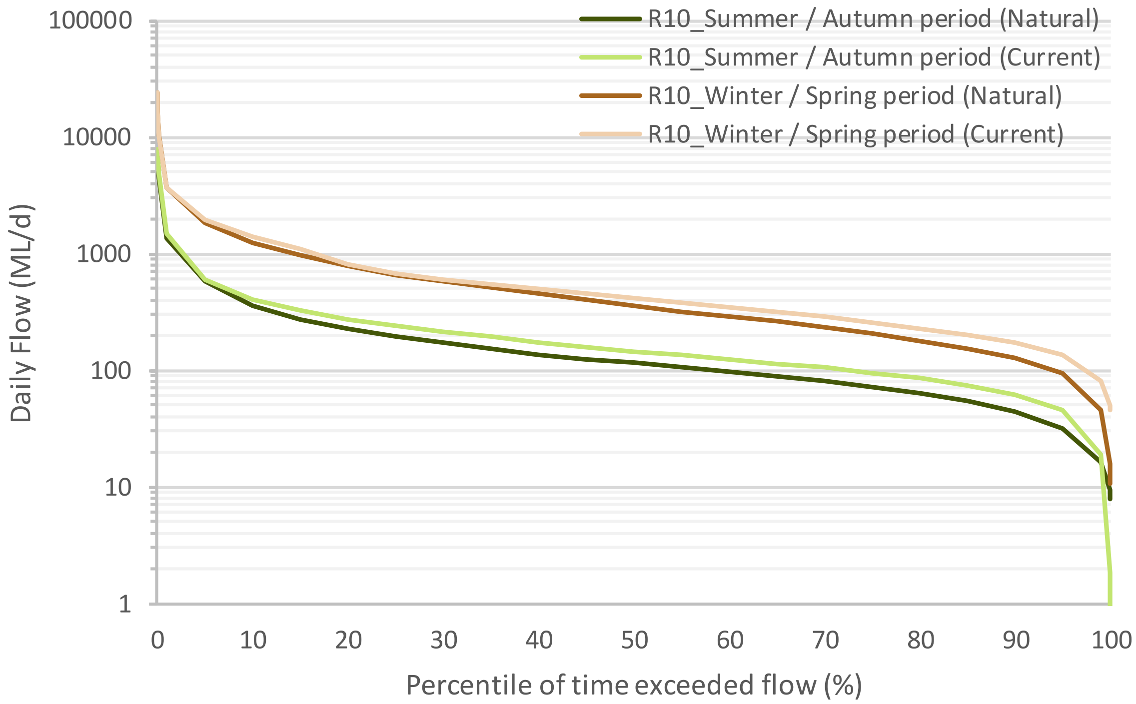


Figure 9. *Flow duration curves of mean daily flow under natural and current conditions, reaches 8 and 9.*



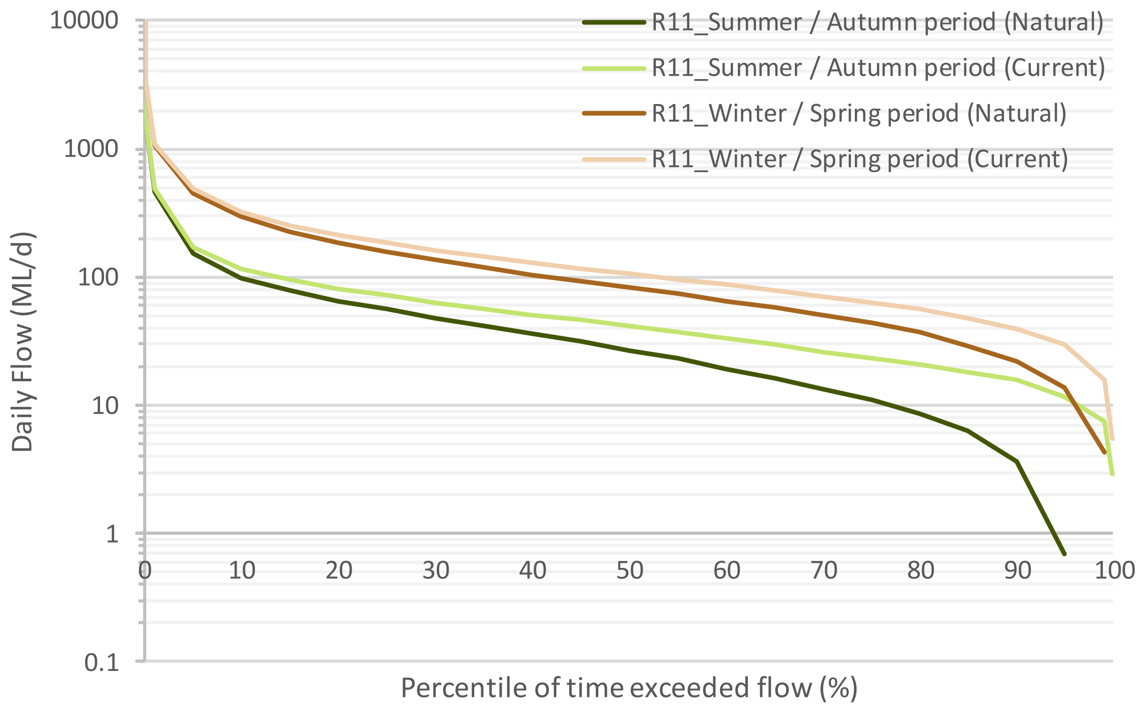


Figure 10. *Flow duration curves of mean daily flow under natural and current conditions, reaches 10 and 11*

These flow duration curves show that regulation and land use change have reduced the entire range of flows immediately downstream of Blue Rock Lake, Lake Narracan and Moondarra Reservoir (Reach 3 -Figure 7, reaches 4 & 5 - Figure 8, and 8 & 9 - Figure 9). Notably, the Tyers River (Reach 9) flow duration curve shows a stepping pattern with constant moderate flows before dropping to constant low flows. This pattern is largely influenced by the passing requirements of Moondarra Reservoir indicating that Tyers River is highly impacted by the Reservoir[2].

Discharges from the mines (Loy Yang and Yallourn) have increased low and moderate flows in Morwell River and Traralgon Creek (Reaches 10 and 11 - Figure 10).

Seasonality

Flow regulation and extraction to meet domestic and agricultural demands can have a varied level of impact on the flow regime temporally throughout the year and spatially across a catchment. Figure 11 shows a comparison of mean daily flows in each reach under natural and current level of development conditions for each month of the year. Across the catchment, mean flows are higher in the months of June to November than in the months of December to May, for the main stem of Latrobe River and tributaries, and for natural and current flow conditions.

Latrobe River main stem reaches (i.e. Reaches 3, 4 and 5), and Reach 9 (Tyers River) showed consistently lower flows under the current conditions than natural for all months of the year. The reduction in flow is consistent with the diversion of water from the system for consumptive purposes. The Morwell River (Reach 10) and Traralgon Creek (Reach 11) showed an increase in flow for all months.

Reach 8 (Tanjil River) was found to have lower (than natural) flow rates in winter, consistent with the storage of water, and higher than natural flow rates in summer, consistent with the release of stored water via the river channel for downstream consumptive use.

Cease to flow frequency-duration

An analysis of flows less than 0.01 ML/d was undertaken to assess cease to flow events, where events were considered independent if 7 or more days apart (Table 5). Negligible frequency or duration of cease to flow events was observed in the modelled current or natural flow time series for the main stem of the Latrobe River (Reaches 3 and 4) and Morwell River (Reach 10).

Table 5. Comparison of estimated cease to flow event frequency and duration under natural and current conditions over 60-year period.

		Natural		Current	
Reach #	Name	Occurrence (60 years)	Mean duration	Occurrence (60 years)	Mean duration
3	Latrobe River from Lake Narracan to Scarnes Bridge	0	NA	0	NA
4	Latrobe River from Scarnes Bridge to Kilmany South	0	NA	5	2.6
5	Latrobe River from Kilmany South to Thomson River confluence	0	NA	0	NA
8	Tanjil River	1	7	0	NA
9	Tyers River	2	4.5	0	NA
10	Morwell River	0	NA	0	NA
11	Traralgon Creek	71	6.8	0	NA

[2] The consolidated *Bulk entitlement (Moondarra Reservoir) Conversion Order 1997* specifies a minimum passing flow in the Tyers River below the Moondarra Reservoir equal to the lesser of 30 ML/day and natural flow at this location, except when inflows to Moondarra Reservoir are less than or equal to 25,000 ML over the previous six months period that the minimum passing flow is reduced to 8 ML/day.

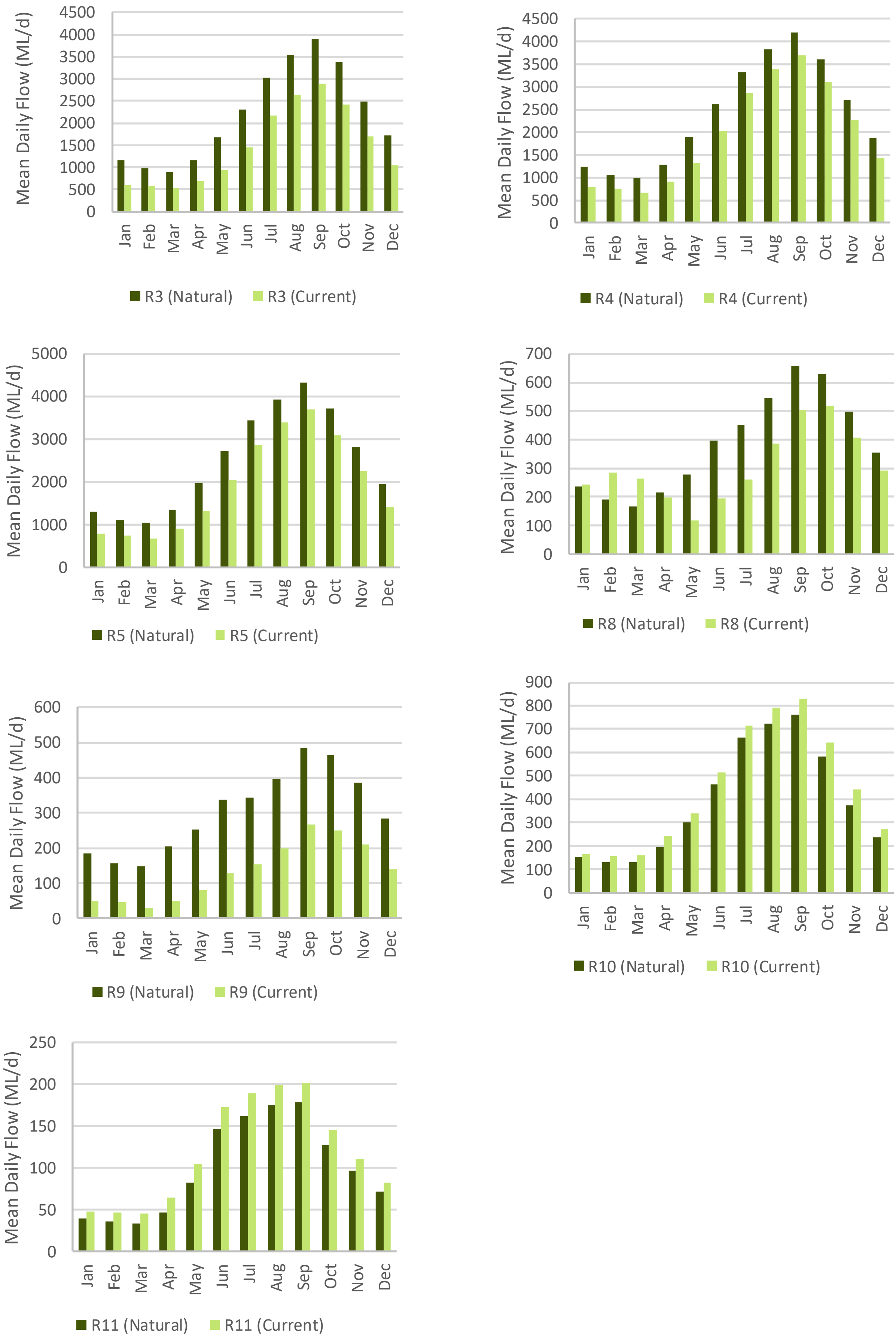


Figure 11. *Mean daily flows (ML/d) per month per reach under natural and current level of development condition over a 60-year period.*

2.2 Surface water – the Latrobe estuary

Located at the interface between the Latrobe catchment and the Gippsland Lakes, the Latrobe estuary is part of the Gippsland Lakes estuarine wetland complex that discharges to the sea at Lakes Entrance. The hydrology and hydrodynamics of the Latrobe estuary have been investigated in the estuary flows study (Water Technology 2013) and the Lower Latrobe and Thomson e-flow response monitoring (Water Technology 2017). The findings of these reports are summarised below.

Given the multiple inflows (Latrobe River and Thomson River) and presence of Lake Wellington, the relationships between flow, water level and salinity in the Latrobe estuary are highly complex and spatially variable. Water Technology (2013) characterised the estuary into three zones, with similar flow, water level and salinity relationships:

- The lower estuary
  Lake Wellington to ~ 0.5km west of the western water control structure "Big Drain" in Dowd Morass.
  River inflows have limited effect on water level and salinity conditions with conditions from Lake Wellington dominating this zone. Typically, saline water is only flushed from the lower estuary when river flows are greater than 4,100 ML/day. Helical flow zones in river bends were identified through hydrodynamic modelling, bringing saline water towards the surface and limiting availability of fresh water for fringing wetlands.

- The mid estuary
  From the Latrobe-Thomson confluence at the Swing Bridge, downstream to about to about 0.5km west of the western water control structure "Big Drain" in Dowd Morass.
  Water levels and salinity are increasingly affected by river inflows in this zone, with saline water less frequently present near the water surface than in the lower estuary. The reach is predominately freshwater although saline water may be present throughout the water column, especially in low flow periods.

- The upper estuary
  The Latrobe and Thomson Rivers above the confluence and Sale Canal.
  Water levels in this zone are strongly influenced by river inflows with predominately fresh water and saline water restricted to deeper water and in extended low flow periods. Differences in riverbed bathymetry mean that the Thomson River is more susceptible to salt wedge intrusion that the Latrobe.

These zones are adopted for this study and are outlined in Figure 12.

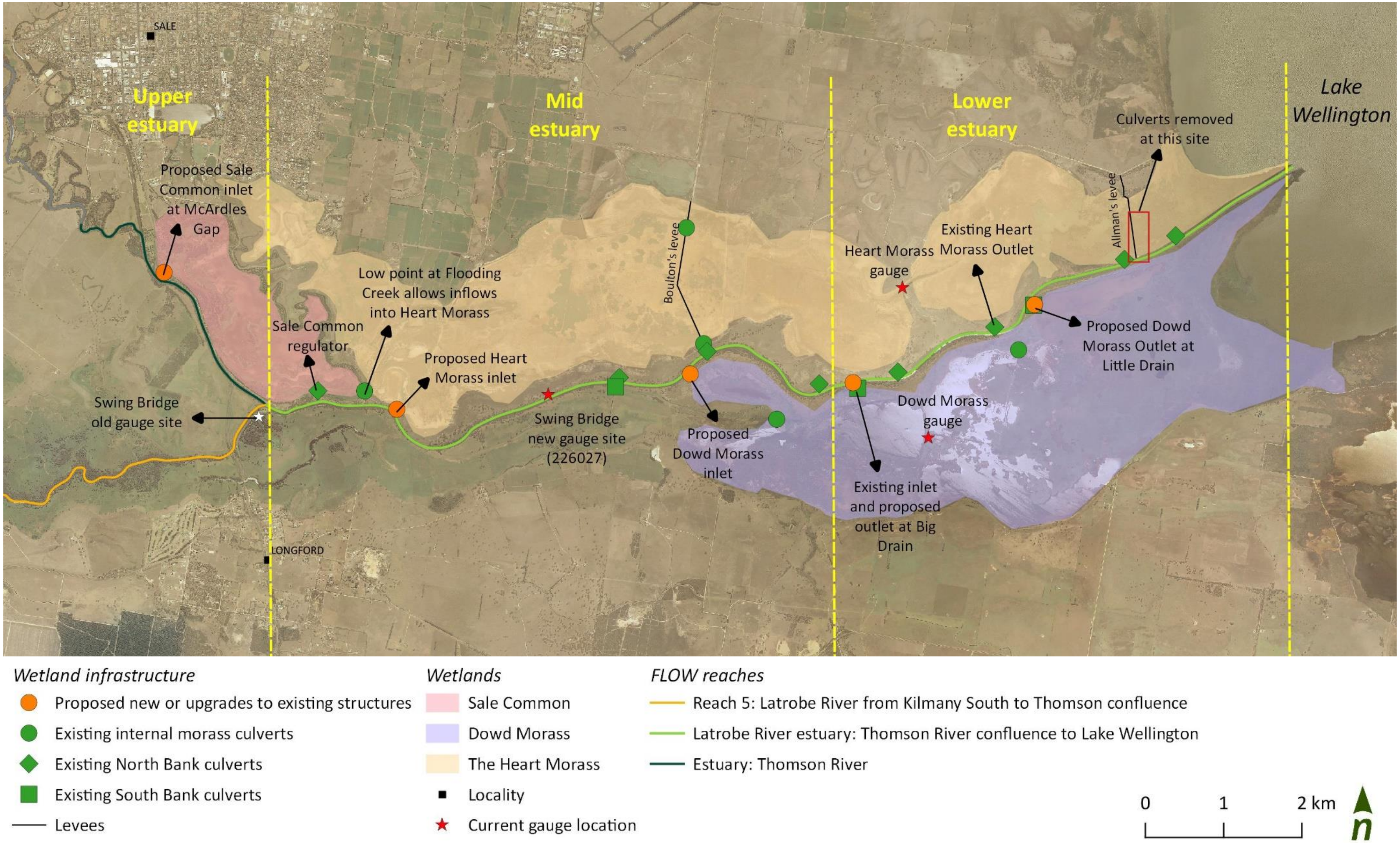


Figure 12. *Latrobe estuary zone delineation and wetland infrastructures (after Water Technology 2013 and Jacobs 2015)*

Flow variability
The relationship between flow and water level in the estuary is variable, which significant influence from Lake Wellington water levels at different times (Figure 13).

Flow duration curves presented in Figure 14 (below) show different influences reducing the entire range of flows under current conditions for tributaries into the estuary (Upper Thomson), upper estuary (Swing Bridge) and mid-estuary (Estuary). The flow duration curve for the Upper Latrobe (Reach 5) are presented in Figure 8 above. Upstream water resource development and land use changes have decreased the flows under current conditions, particularly for the Thomson River base flows. These impacts may have also reduced the current flow regime at the Swing Bridge and mid-estuary.

The Thomson River exhibits a greater difference in water levels from natural to current than the Latrobe and estuary. This greater difference may be due to a number of factors including levels of development, catchment morphology, water resource development and the relative size of storages to the catchment (i.e. Thomson has a large storage compared to a small input catchment, whereas the Latrobe has a smaller storage and a larger input catchment).

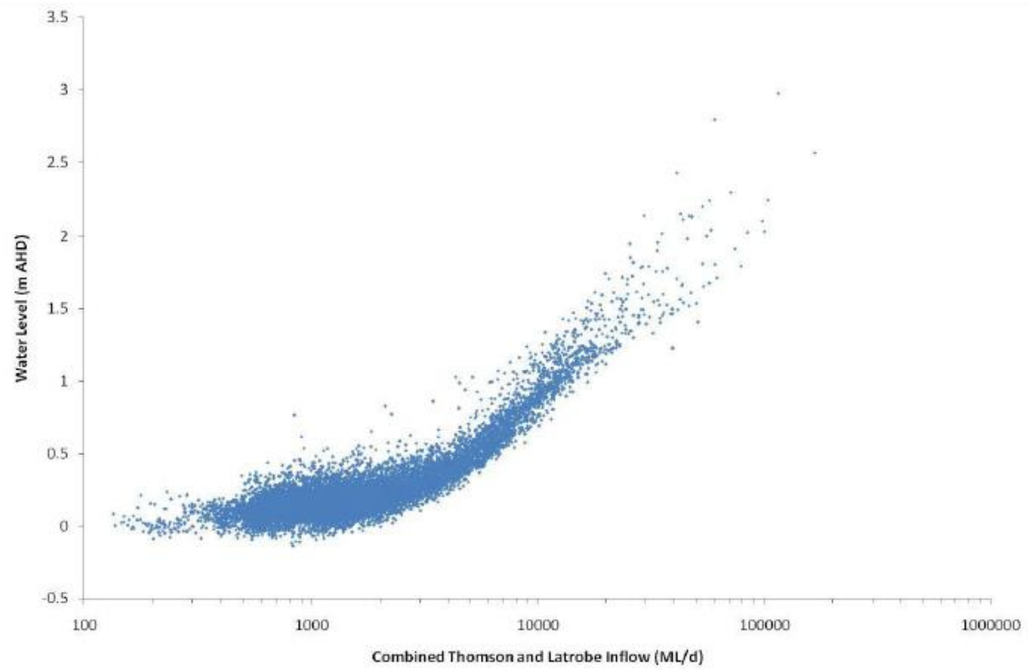
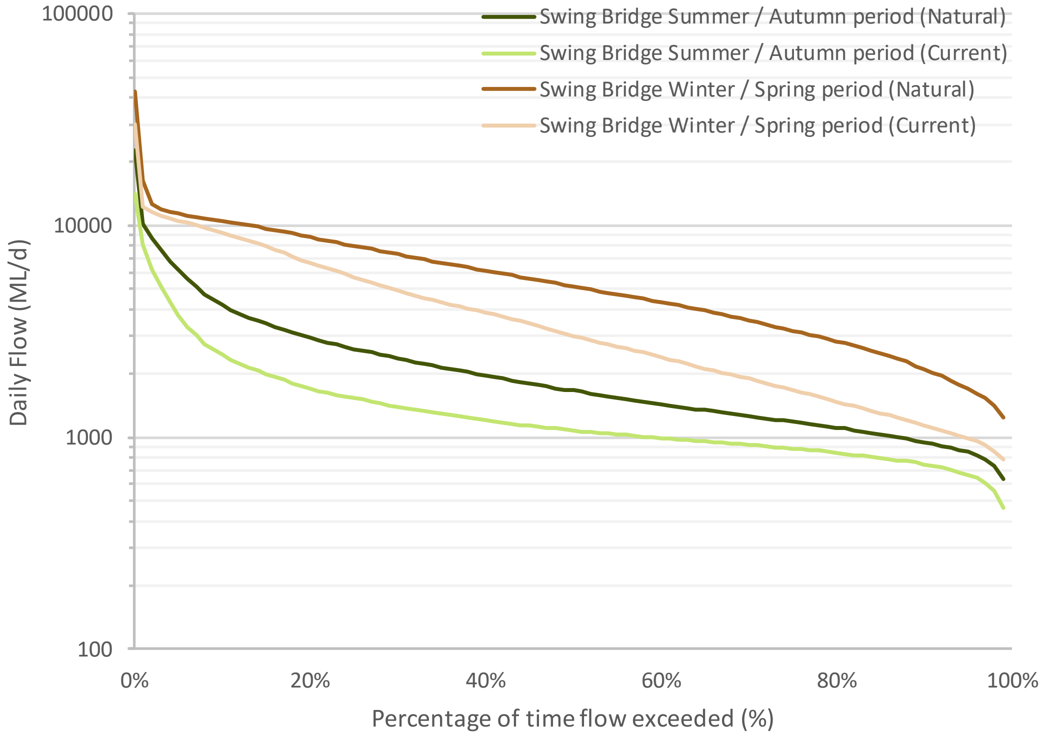


Figure 13. *Relationship between water level and combined estuary inflows from Thomson and Latrobe Rivers at the Swing Bridge (as reported in Water Technology 2013)*



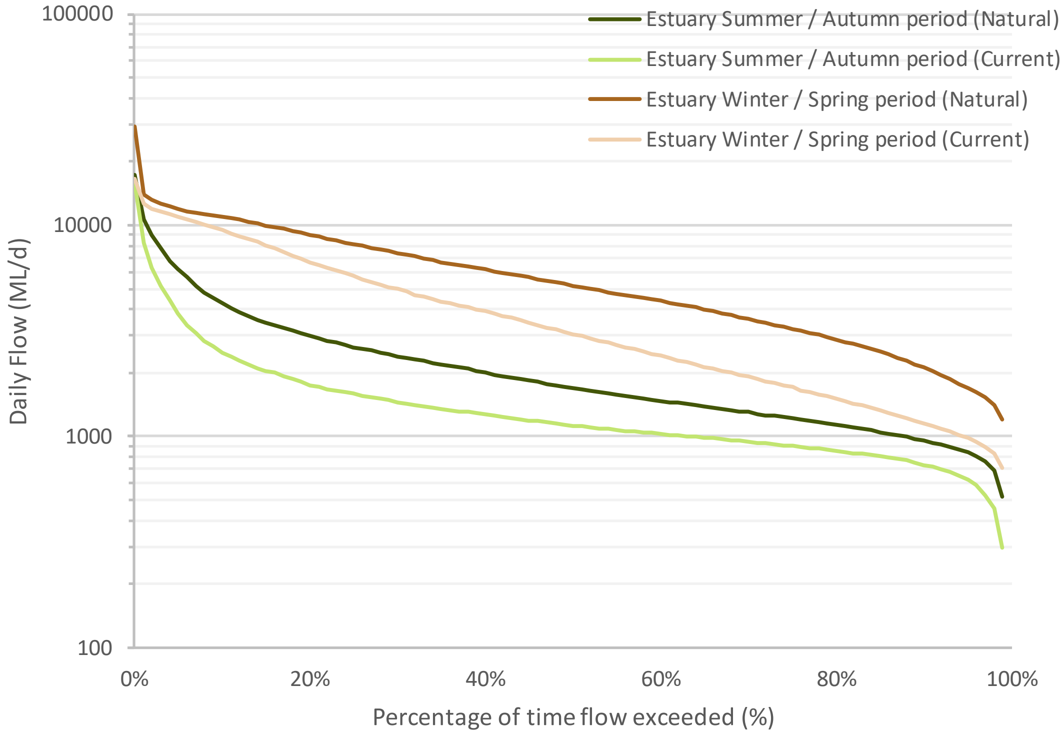


Figure 14. *Flow duration curve of mean daily flow under natural and current conditions: Swing Bridge and lower estuary*

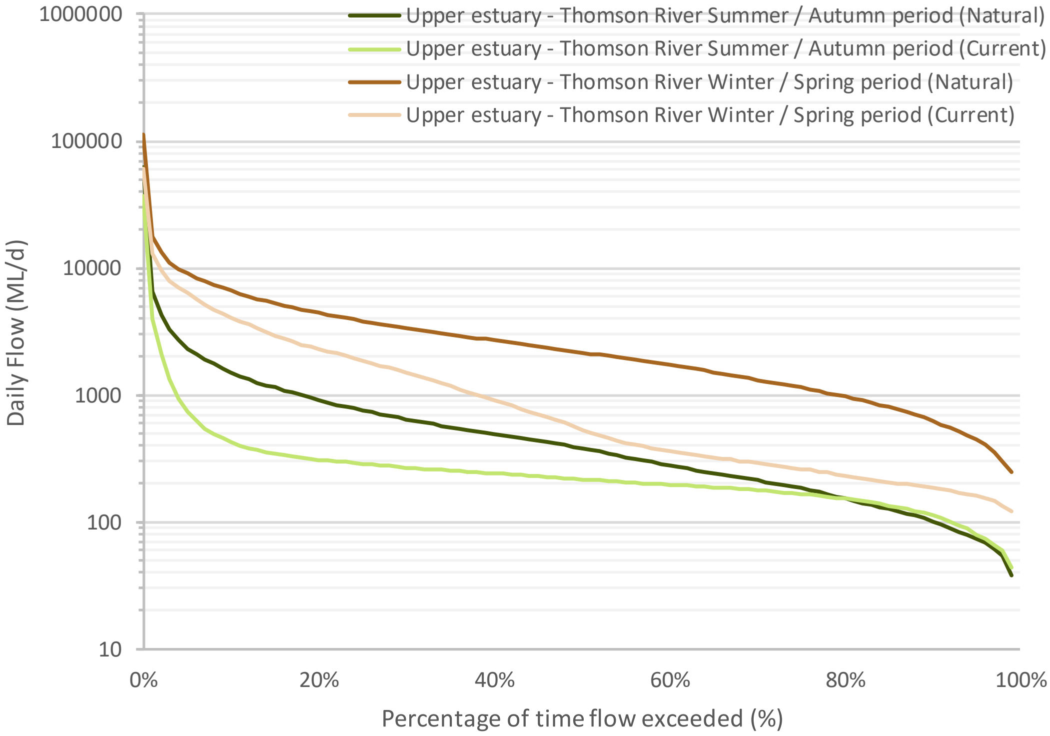


Figure 15. *Flow duration curve of mean daily flow under natural and current conditions: Thomson River*

Seasonality
As discussed above, flow regulation and extraction to meet domestic and agricultural demands can have a varied level of impact on the flow regime temporally throughout the year and spatially across a catchment. Figure 16 and Figure 17 show a comparison of mean daily flows under natural and current level of development conditions for each month of the year.

There are consistently lower flows under the current conditions than natural for all months of the year. The reduction in flow is consistent with the diversion of water from the Latrobe and Thomson systems for consumptive purposes.

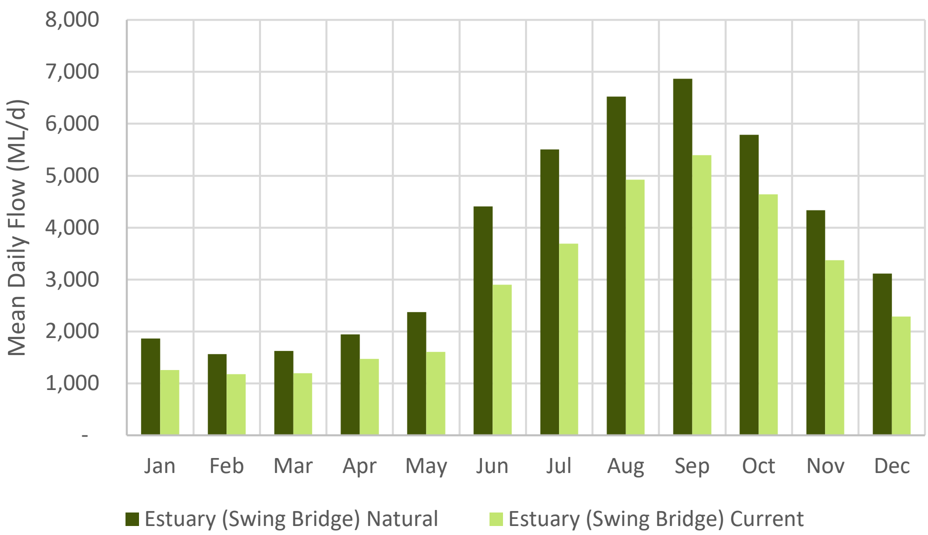


Figure 16. *Mean daily flows (ML/d) per month for the Estuary (at Swing Bridge) for natural and current level of development condition.*

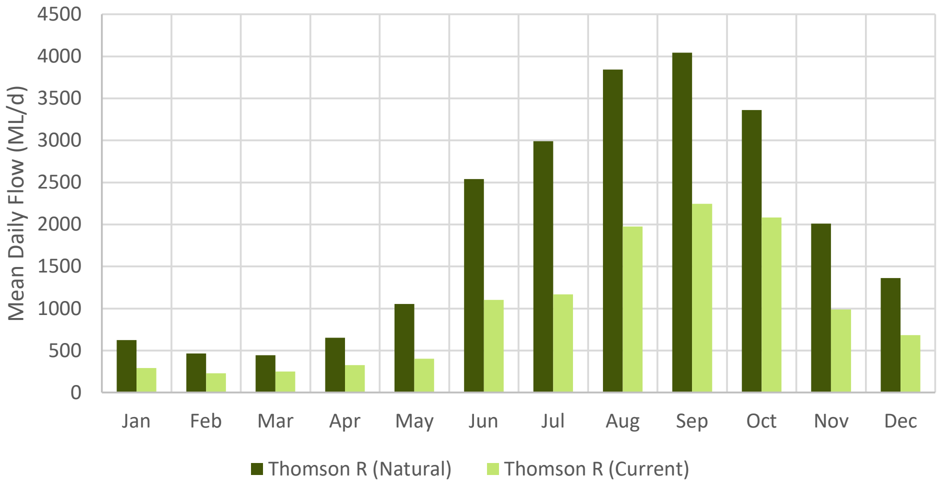


Figure 17. *Mean daily flows (ML/d) per month for the Thomson Estuary for natural and current level of development condition.*

2.3 Surface water – wetlands

The Lower Latrobe wetlands consist of Dowd Morass, Heart Morass and Sale Common and are an important component of the Gippsland Lakes. Since European settlement, the frequency, duration and timing of flooding and drying cycles in the wetlands have varied greatly. These wetlands require a dynamic regime with periodic flooding, timely drawdowns of water levels and complete drying, to maintain and enhance their ecological integrity.

The hydrology and hydrodynamics of the Lower Latrobe Wetlands have been investigated in SKM (2003), Water Technology (2011), Water Technology (2014), Jacobs (2015) and Hale *et al.* (2018). The findings of these reports are summarised below. There is also existing and proposed water management structures in all three wetlands, influencing flows into and within the sites. Infrastructure within the wetlands was originally designed to drain the wetlands for agricultural purposes, instead of maintaining the natural flow regime. This means that active watering of the wetlands was reliant on river heights and hydraulic head difference between the river and wetlands. The water regime in all three wetlands is now to some extent managed by regulators connected to the Latrobe River (VEWH, 2017).

Sale Common

The flooding regime of Sale Common is dependent on the behaviour of Thomson and Latrobe Rivers and the water levels of Lake Wellington (Water Technology 2011). The main sources of unregulated inflows into the wetland can occur through:

- Overbank flows of the Thomson River at McArdles Gap, with flows passing along the depression at Cox's Bridge. Shorter duration events can occur if flows in the Thomson River are above 6,000 ML/d and large flooding events can occur if flows in the Thomson River are above 21,600 ML/d.

- Overbank flows of the lower Latrobe River north bank at locations between the Swing Bridge and the existing water management structure. This will occur if flows in the lower Latrobe River are above 15,000 ML/d.

In 2013, there was an upgrade to the regulating structure that improved the ability to deliver environmental flows into Sale Common wetland from the Latrobe River. This regulator also incorporates a carp screen, preventing adult carp from entering the wetland and allowing re-establishment of wetland vegetation. Detailed designs have also been prepared for a second regulating structure to service Sale Common at McArdles Gap.

Heart Morass
There are three management areas within Heart Morass that are delineated based on hydraulic controls – Western Heart Morass, Central Heart Morass and Eastern Heart Morass (Water Technology 2013; Water Technology 2014). The main sources of unregulated inflows into the wetland can occur through:

- Overbank flows from Flooding Creek and Sale Common into Western Heart Morass when the Thomson River is flooding.

- Overbank flows from the lower Latrobe River entering Central Morass when either Thomson River or Latrobe is flooding and combined with elevated water levels in Lake Wellington.

- Flows from Lake Wellington that overtop Allmans levee (eastern extent of heart Morass); noting that the culverts in this location have been decommissioned.

There are regulating structures long the northern bank of Latrobe River that provide for filling and drainage of the Central and Eastern sections of Heart Morass (depending on operation and river levels).

In 2018, the existing structure located in East Heart Morass was upgraded. It can be closed to hold water in the Morass and opened to drain/flush out the Morass into Latrobe River

A new regulator is proposed to improve water management into Heart Morass. This regulator is proposed near Flooding Creek to provide direct inflows to West Heart Morass from the Latrobe River to fill Central and East Heart Morass. The regulator is designed to fill the whole of Heart Morass from empty up to EL -0.3m in 7 days and raising the whole morass from EL -0.3m to 0.0m in 21 days.

Dowd Morass
The Dowd Morass water regime is complex, and the morass receives water of various salinities through several pathways (SKM 2003; Water Technology 2013; Water Technology 2014; Hale *et al*. 2018):

- Overbank flows from the lower Latrobe River into Dowd Morass located at "a low point in the riverbank adjacent to the western end of the morass about 9 km upstream of the confluence with Lake Wellington" (SKM 2003) . This will most likely happen when Thomson River is flooding.

- Overbank flows from the lower Latrobe River into Dowd Morass at Long Waterhole (an anabranch of the Latrobe River) located around 5 km upstream of Dowd Morass.

- Direct inflows from Lake Wellington entering the eastern section of the Morass known as the Dardanelles, when the water level of Lake Wellington is > 0.35m AHD.

- Multiple culverts along the bank of the Latrobe River, including Big Drain.

The following infrastructure is proposed:

- A new regulator to provide flow diversion into the western areas of the morass.
- The drainage of Morass into the Latrobe River is to be upgraded at existing outlets at Big Drain and Little Drain

In addition, it is proposed that in some circumstances, a temporary pump station would be used to assist in draining Dowd Morass.

Wetland salinity
Similar to the Latrobe estuary, the salinity of Sale Common, Heart Morass and Dowd Morass are highly dependent on the water quality of the water source and are highly influenced by the saline waters from Lake Wellington. Several studies have investigated the risk of salinity intrusion or increase in salinity of the wetlands that potentially impact on the existing ecological communities (Water Technology 2011; Water Technology 2013; Hale 2018). Hale (2018) found that more saline waters from Lake Wellington have intruded into Dowd

Morass over the past decade and are predicted to have longer and higher number of incidences of salt intrusions in the future as sea level increases with ongoing climate change.

Wetland watering regime
Wetland watering regime components are detailed in Table 6. Wetting flows and drawdown may be provided through active management (i.e. opening regulators) or passively (i.e. overbank flooding or evaporation respectively); however, overbank flooding is required to produce significant flushing flows (push water into and out of the wetland and fill it).

Table 6. Hydrological description of the watering regime components for wetlands

Watering regime	Hydrological description
Wetting flow	Inundation event or events sufficient to fill or partially fill the wetland
Flushing flow	Inflow sufficient to push water into and out of the wetland and fill it
Drawdown	A period of receding water levels resulting in large areas of the wetland surface drying out

Table 7 shows the historical achievements of water regime recommendations for the Lower Latrobe Wetlands, as detailed in the 2018-19 Seasonal watering proposal (WGCMA, 2018).

Hydrologically, Dowd Morass and Heart Morass have a good history of wetting flows with nine and seven years of the last 14 (including this year) receiving adequate wetting flows, respectively. Largely due to its smaller size, Sale Common has a more variable water regime. This variable water regime has been observed over the past three years through managed and natural inflows and natural drawdown.

Flushing flows typically only occur with major flooding in the Latrobe River causing overland flows into Dowd and Heart Morass. A full flushing flow has therefore not been achieved since 2011/12. Minor flooding of the Latrobe River in September 2017 was not adequate to provide a flushing flow. Due to positioning of the inlet structure at Heart Morass it is not possible to achieve a flushing flow without a natural overbank flow. Sale Common has also not received a flushing flow since 2011/12, when flood waters overtopped levee banks and inlet infrastructure.

Outside of drought conditions or through active pumping of remaining water bodies, Dowd Morass cannot be completely drawn down due to levees positioned throughout the wetland. As a result, Dowd Morass has only received partial drawdown in the last six years. A complete draw down of Heart Morass is also rare due to the risk of acid sulphate soil activation in the deepest parts of the wetland. The last successful drawn down of all areas (except for these deepest portions) was observed in 2015/16.

Table 7. Historical achievement of water regime recommendations in the Lower Latrobe Wetlands. Source: WGCMA, 2018.

Water regime component	Year													
	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17	17/18
	Sale Common													
Wetting Flow				N		A	N	N	A/N	N	N		A/N	A
Flushing flow				N				N	N					
Drawdown			N		N	N			N	N	N	N	N	N
	Heart Morass													
Wetting Flow		A		N			N	N	N	N	N		A/N	A
Flushing flow				N				N	N	N			N	
Drawdown			N		N	N			N	N	N	N	N	N
	Dowd Morass													
Wetting Flow				N			N	N	A/N	N	N	N	A/N	A
Flushing flow				N				N	N	N			N	
Drawdown	A				N	N			N	N	N	N	A/N	N

Key

	No significant part of the water regime component provided
	Water regime component partially provided
	Water regime component completely provided

Blank	No data
N	Provided naturally
A	Provided through active management

2.4 Climate variability

Water resources in the Latrobe system are climate dependent. Therefore, an understanding of climate variability and climate change is an important part of this study. The following three climate scenarios have been considered for this study:

1. Historical (1957 – 2016)
2. Baseline Climate (post 1975)
3. Step Change Climate (post 1997)

The Baseline and Step Change climate scenarios were developed in line with DELWP's Guidelines for Assessing the Impact of Climate Change on Water Supplies in Victoria (DELWP 2016). The development of the climate scenarios adopted flow duration curve decile scaling of each relevant data sets. The breakpoint in the scaling for the current climate was 1 July 1975 and for the step change climate was 1 July 1997.

The data used to inform the flow recommendations is based on the historic modelled unimpacted (natural) flow data. The intent of using this data is to understand the conditions under which environmental values have adapted to and thresholds that should not be exceeded. The Baseline and Step Change scenarios are discussed further below.

Assessment of water requirements for climate conditions (drought, dry average and wet years)

The flow recommendations have been developed for four prevailing climatic conditions: drought, dry, average and wet years. These climatic conditions can be used in combination with other factors to prioritise environmental watering actions as part of a seasonally adaptive management approach. The recommendations for wet years, when water resources are abundant, maximise recruitment and connectivity, and conversely the recommendations for drought years, when water is scarce, aim to avoid critical loss and maintain key refuges.

By categorising different climate years, flow recommendations can be developed and delivered appropriately, in response to future climate variability. That is, the environmental water recommendations for a given year will be appropriate and feasible as they are relative to the climate conditions (and therefore water availability).

The four climatic conditions used in this study have been defined based on the modelled unimpacted **annual inflows to Blue Rock and Lake Narracan and Baseline Climate**. Climate conditions are defined based on water years, starting in June to align with flow recommendation periods (i.e. Winter / Spring starts in June). Modelled data (as described in section 2.1) is used to define these climate conditions as it provides a constant level of water resource development over time, and therefore differences between different years can be largely attributed to climate variability (rather than resource use). The estimated long-term average inflow to the system (for Blue Rock Reservoir and lake Narracan) for the baseline climate is approximately 496,000 ML.

Definitions of the four climatic conditions, along with the resultant number of years for each condition are detailed in Table 8 and Figure 18.

Table 8. Climatic condition definitions and resultant climate condition classification

Climatic condition	Definition (based on modelled annual inflows to Blue Rock and Lake Narracan)	Number of years (1957-2017 inclusive)
Drought	<50% of average annual inflows	3
Dry	50% - 75% of average annual inflows	11
Average	75% - 125% of average annual inflows	30
Wet	>125% of average annual inflows	16

Climate change

Most parts of Victoria, including the Latrobe Basin are projected to experience ongoing reductions in annual rainfall, with corresponding reductions in available runoff as a result of climate change (Table 9). Median projections from a range of climate scenarios and global circulation models predict a reduction of 4.5% in annual rainfall from current conditions to 2065, with more conservative estimates (90th percentile) as high has 16.7%. The corresponding predicted runoff reductions are 16.3% (median) and 41.5% (90th percentile) (DELWP 2016). It should be noted that these estimates do not consider changing physical conditions within the catchment that would likely occur as a result of climate change, hence the actual reduction in runoff may be higher than the predictions provided.

Table 9. Change in average annual runoff relative to the current climate baseline across all seasons (DELWP, 2016).

	Average annual runoff (mm) (1975-2014)	Change relative to current climate baseline (%)					
		2040			2065		
		10th percentile	50th percentile	90th percentile	10th percentile	50th percentile	90th percentile
		Low	Medium	High	Low	Medium	High
Latrobe basin	186	8.7%	-10.7%	-31.3%	0.1%	-16.3%	-41.5%
Victoria	93	8.7%	-8.5%	-24.7%	1.5%	-15.9%	-43.8%

When considering shortfalls and environmental water management, including surface water availability, modelled climate change scenarios will be considered and used to understand some of the implications of climate change on environmental water management and environmental outcomes. For this study, the Step Change (post 1997) climate has been adopted as a climate change scenario. This is included in a separate supplementary report under development.

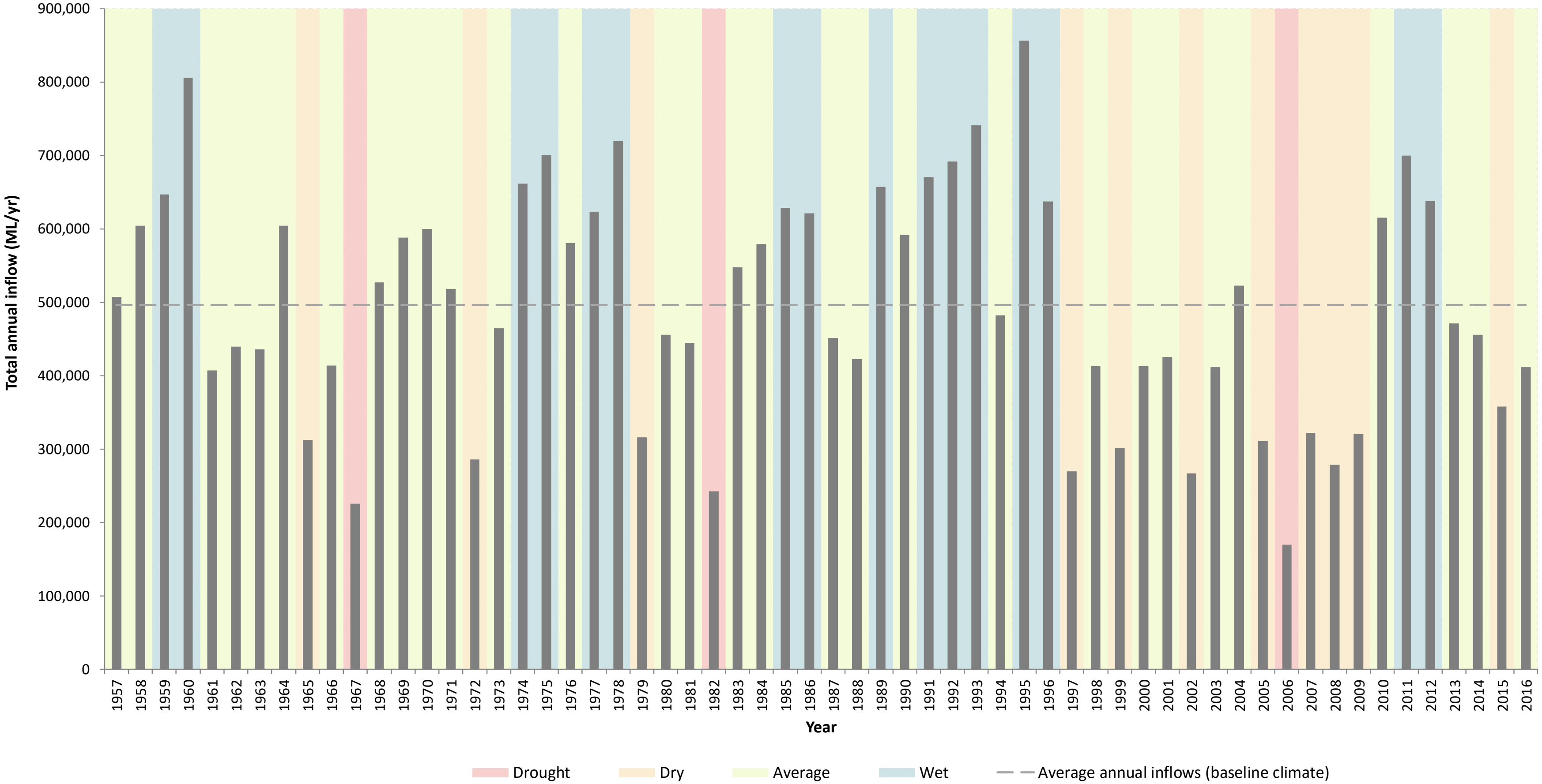


Figure 18. *Total annual inflow to Blue Rock and Lake Narracan and resultant climate condition classification for complete water years*

2.5 Groundwater – surface water interactions

An assessment of groundwater – surface water interactions has been undertaken to inform the system understanding and the environmental water requirements.

Groundwater and surface water systems interact in most catchments, in one of two primary ways:

- Gaining streams – streams gain groundwater through the streambed when the water table elevation is higher than the stream elevation (Figure 19); or
- Losing streams – streams leak to groundwater through the streambed when the water table elevation is lower than the stream elevation (Figure 20).

For most streams, the interaction between groundwater and surface water will change from gaining to losing along the stream length (i.e. spatially) and at different times of the year (i.e. temporally).

Many reaches in the Latrobe study area are gaining streams, including: Tanjil River, Tyres River, the lower reaches of the Latrobe River and the associated wetlands.

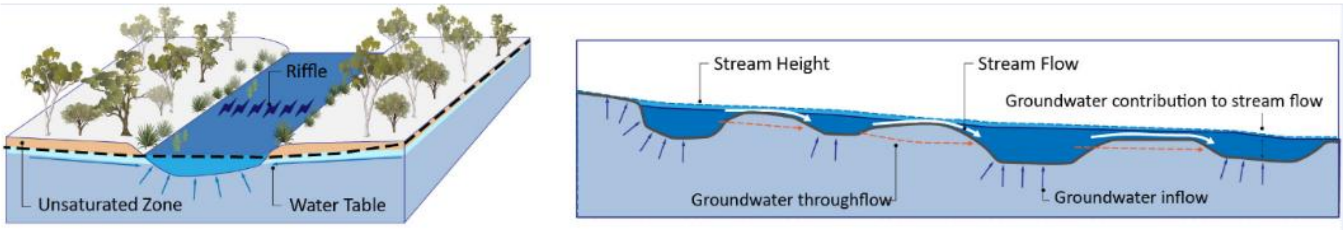


Figure 19. *Schematic representation of a permanent, gaining stream*

The Latrobe River Reach 3 has been characterized as a losing stream. These conditions are also likely to occur for the other river reaches (classified as dominantly gaining), at least for sometimes of the year after high rainfall events.

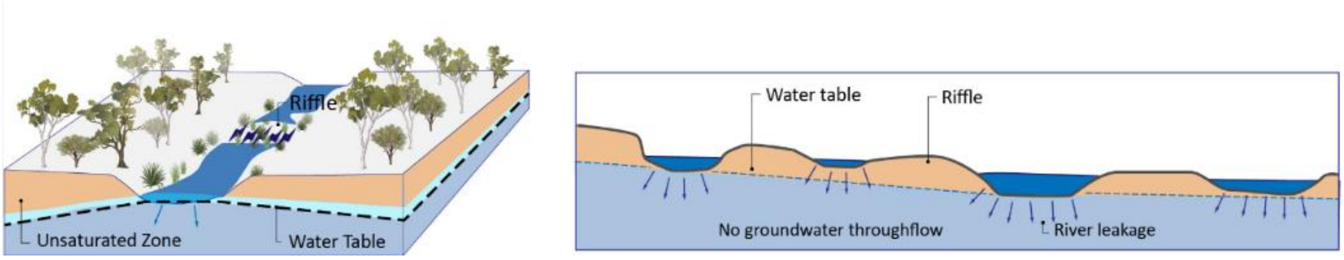


Figure 20. *Schematic representation of a losing stream*

The nature of groundwater and surface water connection is described for the study area below, based on:

- Topography
- Geology
- Hydrogeology (including aquifers, groundwater levels and flow directions)
- Previous groundwater and surface water studies

Full details of this assessment can be found in Appendix C.

Reach 3 - Latrobe River from Lake Narracan to Scarnes Bridge
Reach 3 of the Latrobe River is dominantly losing in nature, which may be a result of reduced water table levels associated with the depressurisation of the deeper aquifers.

Baseflow accounts for 24% of average daily streamflow; however, the reach was classified as an overall losing stream, with the largest losses occurring when the stream flows were the highest (GHD 2013). The Latrobe River was estimated to lose ~26.8 GL/year baseflow overall on this reach on average. The losing behaviour could be associated with the effects of coal mines depressurisation of the Tertiary aquifers which sub crop in the shallow subsurface in this western end of the Latrobe Valley. There is minimal seasonal fluctuation in baseflow due to the influence of the upstream Blue Rock Reservoir & Lake Narracan.

Reach 4 - Latrobe River from Scarnes Bridge to Kilmany South
This reach of the Latrobe River progresses from low to high gaining along its length. The groundwater contribution is greatest during the winter-spring period.

There are variable baseflow conditions along the upper half of this reach (up to Rosedale), with the river overall gaining at 4.3 GL/year on a long-term average annual basis. For the lower half of the reach (Rosedale to Kilmany South) the river was classified as gaining, with 55.1 GL/year groundwater contribution to streamflow (GHD 2013).

Reach 5 - Latrobe River from Crooks Lane to Thompson River Confluence
No previous groundwater and surface water interaction studies have been undertaken for this river reach, but analysis of groundwater bore and river gauge data at Kilmany South shows the groundwater levels are elevated relative to the river levels and this suggests gaining river conditions at this location.

Reach 8 Tanjil River

Groundwater is likely to contribute to the Tanjil River reach. Groundwater contributions to rivers are usually most important during dry, low flow conditions. However, given the upstream reservoir is likely to help maintain river flows during drier periods, this reach is likely to be less sensitive to changes in groundwater baseflow, than it may have been under natural conditions.

Reach 9 Tyres River
Groundwater is likely to contribute to the Tyres River reach. Groundwater contributions to rivers are usually most important during dry, low flow conditions. Similar to the Tanjil River, the Tyres River is also regulated by an upstream reservoir (the Moondarra Reservoir) and hence doesn't experience the same flow variability that it may have under natural conditions. Therefore, this reach is likely to be less sensitive to changes in groundwater baseflow, than it may have been under natural conditions.

Reach 10 Morwell River
Groundwater is likely to contribute to the Morwell River in the upper reaches, with groundwater contributing 72% of average daily streamflows (SKM 2012). Groundwater and surface water interaction is likely to be negligible in the lower reaches, with groundwater contributing 16% of average daily streamflows (GHD 2013), with little variability (either seasonally or inter-annually). The range of depth to water table readings for three shallow bores near Hazelwood Mine suggest the aquifer is disconnected from the river, in the vicinity of the Hazelwood Mine, in-part due to mine depressurisation effects (GHD 2018).

Figure 21 shows a schematic cross-section across the Hazelwood mine pit and the Morwell River. The cross section has been developed to demonstrate the groundwater and surface water interaction, in areas where mine depressurisation effects have influenced the interaction, such that losing stream conditions have been artificially developed. The cross-section shows that the water table elevation has been depressed in this area, due to the pumping of large volumes of groundwater from the underlying coal-bearing aquifers (necessary to undertake open cut mining). Although there is no publicly available groundwater monitoring data available, GHD (2018) reported groundwater levels for the (mine owned) monitoring bore H2324_S01, located approximately 570 m from the Morwell River. The groundwater levels are deep (17.2 to 23.5 mbns) due to depressurisation effects and have led to losing stream conditions and potentially disconnection between the stream and the water table aquifer.

Whilst the schematic depicts conditions near the Morwell River/Hazelwood Mine, it is reasonable to assume that similar conditions may occur at Traralgon Creek/Loy Yang Mine.

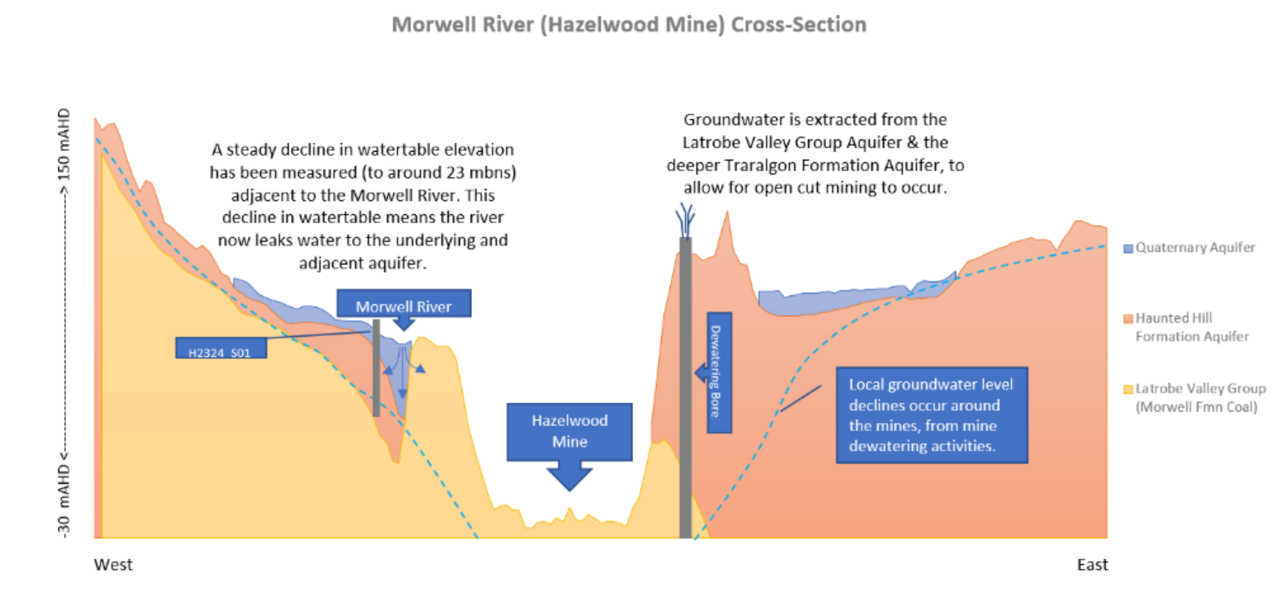


Figure 21. *Schematic west to east cross-section, across the Hazelwood mine*

Reach 11 Traralgon Creek

Groundwater is likely to contribute to the Traralgon Creek in the upper reaches, where mine depressurisation effects are absent. Groundwater contributes 71% in the upper reach (SKM, 2012).

Groundwater and surface water interaction is likely to be negligible in the lower reaches, if the same deep water tables are occurring around Loy Yang mine, that have been observed at Hazelwood mine. GHD (2016) noted that the highest rate of potentiometric surface declines for the deep coal bearing aquifers were around the Hazelwood and Loy Yang Mines. As noted in the section above, three water table monitoring bores around Hazelwood mine indicate significant groundwater declines and hence it is reasonable to assume that similar depressurisation effects could be occurring around the Loy Yang Mine (and therefore Traralgon Creek).

Latrobe River estuary

This reach sits low in the landscape, upon a well-developed alluvial aquifer. Beverley et al. (2015) undertook a baseflow assessment in this reach, which suggests groundwater contributes 41% average daily stream flow. The Latrobe estuary is likely to gain groundwater.

Sale Common

Groundwater fluxes to the Sale Common are likely to be small relative to the other sources of water to the wetland and hence are not likely to be critical. However, the groundwater flux may act to extend the saturation of the wetland during drier periods and provide fresher water to fringing wetland vegetation.

Jacobs (2015) developed a conceptual model for the Sale Common and highlighted that the relatively flat topography is likely to lead to a low water table gradient, which in-turn would result in only small fluxes of groundwater to the Sale Common. Jacobs (2015) concluded that it was likely that the wetland operates in a variably gaining/losing nature, with wetland losing conditions during flood events when water levels in the wetland are higher than groundwater and wetland gaining conditions during dry periods when the water level in the wetland is below the groundwater elevation.

Heart and Dowd Morass

The contribution of groundwater flow to the Heart and Dowd Morass are likely to be small relative to the inflows from the adjacent rivers. However, the fresh groundwater inflows may still provide environmental benefits, such as maintaining saturation of the wetlands (which could limit the potential for acid sulfate soil generation) and sustaining less salt tolerant plants from the repeated inundation of more salty water, if the plants roots had access to fresher groundwater.

The Heart Morass is considered a gaining wetland, at an average groundwater discharge rate of 0.5 ML/day (Jacobs, 2015).

The Dowd Morass gains only a negligible flux of groundwater (SKM, 2003, cited in Jacobs, 2015). The latest depth to groundwater levels for shallow monitoring bores show groundwater levels vary from slightly artesian to 4.5 m below ground surface. The depth to groundwater appears to increase with distance from Lake Wellington. Fluctuations observed in the Dowd Morass water levels can also be observed in the depth to water level in the monitoring bore, which suggests good hydraulic connection between groundwater and surface water for the Dowd Morass at this location (Figure 22).

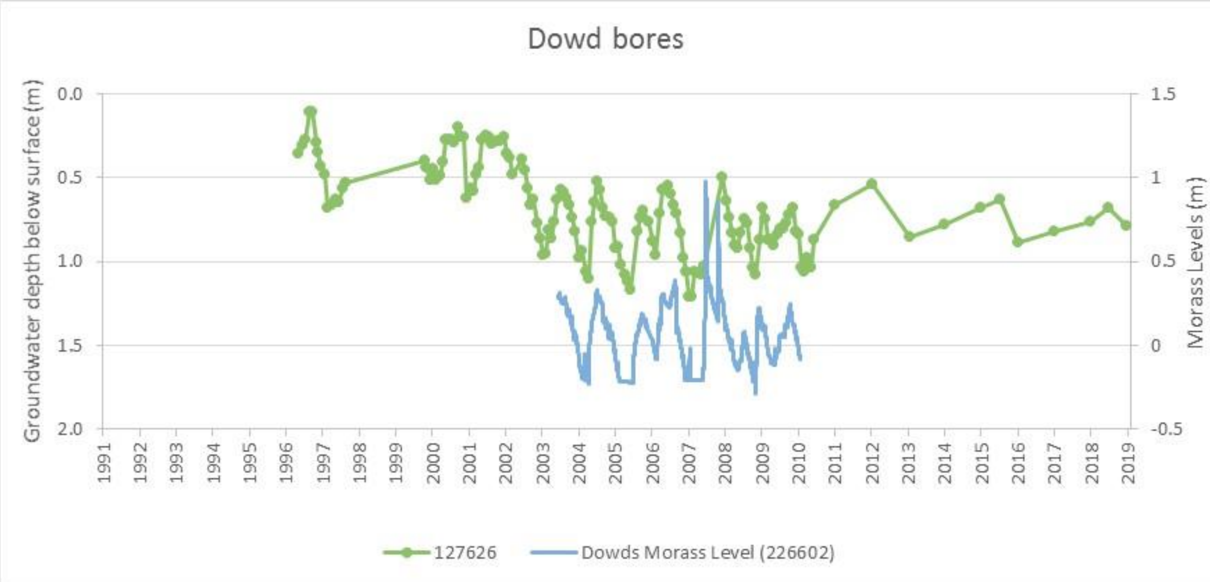


Figure 22. Groundwater and surface water levels at Dowd Morass

3 System changes, issues and values

3.1 Changes in the system

Traditional owners

Gunaikurnai people are the traditional owners of Gippsland, and the Latrobe system. Waterways and wetlands in the region contain important ceremonial places and for thousands of years the Latrobe River provided resources such as food and medicines to the Gunaikurnai people.

European settlement

In the early 1840s the Latrobe River was named after Charles La Trobe, the first Governor of Victoria, and the area was occupied by pastoral runs. Land clearance for grazing and dairying occurred in the 1870s and the area began to develop with expansion of the rail network to Sale.

Opening of the Gippsland Lakes

Since 1889 the Gippsland Lakes system has been linked to the sea by an artificial entrance, where the town of Lakes Entrance is now located. The Lakes and Latrobe and Thomson estuaries are still responding to the effects of this opening, with a shift of the fresh-salt water interface moving upstream into the lower reaches of the inflowing rivers. Reduced river flows from the combined impacts of climate change, the Millennium Drought and extraction have exacerbated this shift. As a result, the Latrobe estuary now supports varied estuarine-dependent species. As a result of these changes, the estuary differs from most typical estuaries in that it is immediately upstream of a saline to brackish lake (Lake Wellington), rather than the ocean.

Power generation and other industry

From the 1920s, power generation became a major industry for the region, with the Yallourn, Morwell and Hazelwood Power Stations constructed between the 1920s to 1960s. Maryvale Paper Mill also began making paper in 1938. During this time, the natural flow regime in the Latrobe basin became highly modified, with many large industrial water users in the basin. There are no significant amounts of flow regulation in the forested upland areas of the Strzelecki and Great Dividing Ranges and consumptive water extraction is relatively low in these upstream tributaries, providing important freshwater flows downstream.

1840s	European discovery and settlement in the Latrobe Valley
1870s	Melbourne to Sale railway constructed, land cleared for grazing
1889	Gippsland Lakes opened
1908	Moe River Drain / North Canal constructed
1920s	Yallourn Power Station construction
1930s	Maryvale Paper Mill constructed
1950s	Morwell Power Station construction
1958	Moondarra Reservoir constructed
1961	Lake Narracan Reservoir constructed
1960s	Hazelwood Power Station construction
1978	Saline inundation of the lower Latrobe floodplain
1984	Blue Rock Reservoir constructed
1989	*Water Act 1989*
1990s	Loy Yang Power Station construction
1998	Saline inundation of the lower Latrobe floodplain
2004	*Our Water Our Future* – EWR established
2007	Latrobe environmental Flows study
2010	Lower Latrobe Wetlands Environmental Entitlement created
2011	Gippsland Regional SWS
2012	Morwell River diversion collapse
2013	Blue Rock Environmental Entitlement created
2014	Hazelwood Mine fire
2016	*Water for Victoria;* LVRRS commenced
2017	Hazelwood Power Station decommissioned
2018	Upgrade Heart Morass inlet infrastructure
	Environmental flows update (this project)

Key: Important events | Major hydrology changes | Policy updates and technical studies

Figure 23. *Timeline of major events and changes in in the Latrobe catchment.*

Floodplain drainage, meander cut-offs and reinstatement

Meanders had been cut-off from the Latrobe River from the 1890's through to the 1970's to reduce waterlogging and improve floodplain drainage, reduce the occurrence of floodplain inundation and increase agricultural production. Moe River Drain/North Canal was also constructed around 1908. Prior to European settlement, the Yarragon and Trafalgar area was a wetland with no defined waterway, however the area is now highly productive given the relatively fertile soils and high rainfall. It has been estimated that almost 77 meander cut-offs were constructed on the Latrobe River. These cut-offs have adversely impacted floodplain wetlands and instream habitat. In a 10 km reach of the river bordering Yallourn Coal Mine, meander cut-offs since European settlement have resulted in sinuosity decreasing from 1.66 to 1.34, a 19% reduction in channel length (Alluvium, 2008). The West Gippsland CMA has reinstated selected meanders of the Latrobe River. The meander reinstatement lengthens the waterway, slows down flow and leads to more frequent floodplain inundation.

Flow regulation

Along with expansion of coal mining and other industrial activities, agriculture and commercial forestry expanded throughout the region, with urban centres developing to accommodate workers and their families. To manage the increased water demands, the Latrobe system was regulated with the construction of Moondarra Reservoir, Lake Narracan and Blue Rock Reservoir throughout the 1950s-1980s. Areas below the large storages of Blue Rock Reservoir and Moondarra Reservoir are now regulated with high levels of consumptive water use. Proportions of surface water diversions are detailed in Figure 24. The major industrial water users in the basin include electricity generators and Australian Paper. In 2015–16, these entities accounted for more than half the surface water diversions in the Latrobe basin, they also returned 37,135 ML to the system.

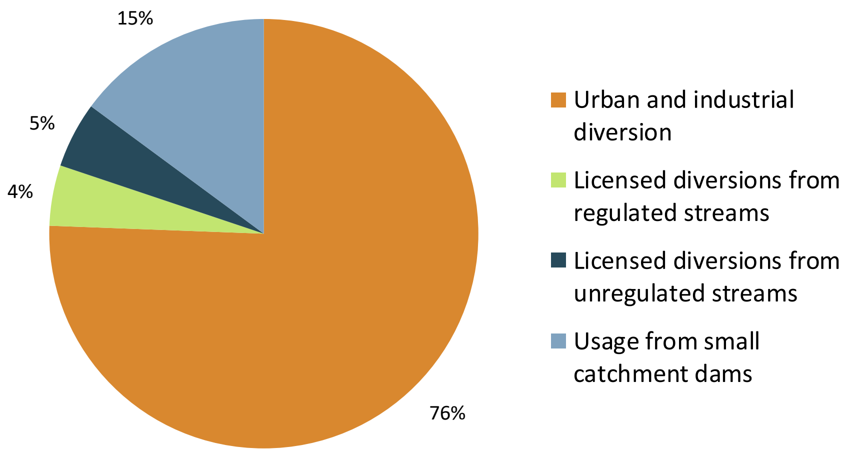


Figure 24. *Proportions of surface water diversions in the Latrobe basin in the 2015-16 water year (DELWP 2017). Total diversions: 153,100 ML*

Environmental water

As described above (Section 2.1), water can be set aside for the environment through water entitlements, passing flows and other regulatory limits on the water allocated to consumptive users.

In the Latrobe system, passing flows set aside water for the environment through conditions on bulk entitlements. These conditions specify minimum passing flow requirements at offtakes and immediately downstream of reservoirs to be provided for environmental purposes. These passing flows are specified as 'or natural' which means they are heavily influenced by climate variability.

A limit, called a permissible consumptive volume, has been placed on allocation of water to consumptive users in the Latrobe basin. Because this 'above cap' water is only available to the environment after all other users have taken their share, its volume varies with climatic conditions and reduces significantly when conditions become drier.

River regulation and water extraction from the Latrobe, along with the impacts of the Millennium Drought and climate change has meant that the frequency of small-medium sized floods that would naturally inundate the

Lower Latrobe Wetlands has reduced. The importance of these floodplain wetlands led to the creation of the Latrobe Environmental Entitlement (Lower Latrobe Wetlands Environmental Entitlement) in 2010. The entitlement formalised access to unregulated flows in the Lower Latrobe River and allows water to be diverted to the wetlands to meet environmental objectives. Action 6.21 of the Gippsland Sustainable Water Strategy sought to determine how the water could be used to best meet the needs of the wetlands.

The remainder of the Latrobe Environmental Water Reserve is made up of the Blue Rock Environmental Entitlement 2013, which was made available from the unallocated share of the Blue Rock Reservoir owned by the Government. The creation of this entitlement fulfilled action 6.15 of the Gippsland Sustainable Water Strategy.

Despite the new environmental entitlements, the volume available to the environment has declined because of reduced spills from reservoirs. With current climate conditions and current water sharing arrangements, water availability has decreased by 48 GL/ year compared with historical availability (DELWP 2019).

Hazelwood Mine fire and rehabilitation

A major fire at the Hazelwood Coal Mine in 2014 resulted in significant impacts to the local community. As a result, the Victorian Government established an inquiry into the Hazelwood Mine fire. The inquiry identified major information gaps in the feasibility of the mine operators' proposed rehabilitation plans and the understanding of the cumulative effects of mine closure plans. In response to the Hazelwood Mine Fire Inquiry, the Victorian Government committed to the development of a Latrobe Valley Regional Rehabilitation Strategy (LVRRS). The LVRRS seeks to establish a long-term plan for closure of the existing Latrobe Valley coal fired power stations and accompanying open cut coal mines. As part of this closure planning, the water demand at the mine sites may change. While there may be many potential changes to the Latrobe systems as part of power station closure and rehabilitation, these changes are being assessed through other projects and are considered out of scope for this study.

Land management

Sale common, part of Dowd Morass and the eastern section of Heart Morass are part of the Gippsland Lakes Ramsar site covered by the Ramsar Convention as Wetlands of International Importance. Sale Common was used for multiple purposes until the 1960s when it was reserved as a nature conservation reserve. It is currently managed by Parks Victoria. Dowds Morass was privately owned until the 1970-80s when it was transferred into Crown Land. It is currently managed by Parks Victoria as a State Game Reserve.

The western and central sections of the Heart Morass are in private ownership and have been subject to past grazing and vegetation clearing for agricultural purposes. The land was purchased by Wetlands Environmental Taskforce (WET) Trust in 2006, 2010 and 2013. Conservation and restoration works have been undertaken since the land purchase, under a Memorandum of Understanding between Bug Blitz, Field & Game Australia, Watermark Inc., and the West Gippsland Catchment Management Authority. The eastern part is managed by PV as a State Game Reserve.

3.2 Issues and opportunities

Riparian vegetation

Riparian vegetation provides an important habitat corridor for wildlife, provides shading for aquatic biota and assists in maintaining stream stability and water quality. Environmental watering alone will not be sufficient to maintain good riparian vegetation health. PAG members identified adjacent land use as a major influence on riparian vegetation condition, with impacts of agriculture, grazing, deer (Sambar) and recreation noticeable in some areas.

Exotic species

Invasive species are one of the biggest threats to the environment. Exotic species in the Latrobe catchment that may require complementary management include, but are not limited to:

- exotic vegetation such as willows, blackberry, and various exotic grasses, including Reed Canary Grass

- introduced fish species such as European carp species. Increasing flow variability can allow native fish populations to build and potentially reduce exotic fish which thrive in altered and low flow regimes
- invasive fauna such as rabbits and foxes and deer.

Barriers to fish passage

Fish need to be able to move freely between habitats and reaches for spawning, feeding and dispersal. Waterways have been modified and barriers to fish passage, such as dams, weirs and road culverts have been constructed. Unrestricted fish movement is a key characteristic of a healthy waterway and while environmental flows can assist in fish movement, physical barriers can limit their effectiveness. It is important to identify where any natural or man-made fish barriers exist. PAG members suggested that objectives could be considered in scenarios with and without fish barriers. The existing storages on the Latrobe River system including Narracan, Moondarra and Blue Rock together with several smaller weirs including Wirilda Park weir on the Tyers River provide significant barriers to fish passage.

Wetland infrastructure

The water regime in all three of the Lower Latrobe wetlands is now to some extent managed by regulators connected to the Latrobe River. However, greater environmental benefits from environmental water could be achieved with upgrades to inlets, outlets, levees, and other wetland infrastructure. Upgrades would mean a lower hydraulic head (and therefore volume of water) is required to achieve environmental objectives in the wetlands.

Groundwater extraction

Many of the waterways within the Latrobe Basin are fed by groundwater and support Groundwater Dependent Ecosystems (GDEs). GDEs are surface environments that rely on groundwater to stay healthy and survive. In the Latrobe Basin GDEs occur in two key areas. The first is at the foothills of the Strzelecki Range where outcropping areas of the Latrobe Group Aquifer provide base flows directly to streams. The second is in the lower catchment where shallow aquifers contribute to the condition of wetlands, estuarine environments and terrestrial flora (WGCMA, 2012).

In parts of the Latrobe Valley, groundwater is extracted by power stations to dewater mine pits and ensure safe operating conditions for coal mining. Mine dewatering has led to lowering of the water table in the shallow (upper) aquifer and depressurisation of the Morwell Formation Aquifer System. In general, groundwater levels within the major middle and lower aquifers underlying the Latrobe Valley have slightly declined since the late 1980s.

Stock access and bank stability

While stock access is not the only factor influencing bank erosion and stability, grazing and trampling can increase bank slumping, with increased nutrient and sediment inputs to the channel impacting on downstream waterways. Riparian fencing and off-stream watering points can reduce stock access and associated impacts on the riparian zone.

Shared benefits

There was support from PAG members to, where possible, deliver flows that have a benefit for a range of users, including for recreational purposes, bird breeding, fishing etc. Increased recreation in the Gippsland Lakes, Sale Common and Heart and Dowd Morass was reported. However, PAG feedback highlighted that in recent years there has been a lower interest in camping and recreational fishing around the Latrobe which was formerly prized for its fish populations. There is also support for considering how Aboriginal Cultural values can be incorporated and culturally significant species can be supported, with improved access for Traditional Owners.

Mine rehabilitation

While there is some uncertainty around how mine rehabilitation might influence the flow regime and availability of water, opportunities for optimisation were also highlighted by PAG members. For example, the potential for environmental water to be held in pit lakes before being released was raised and opportunities for shared benefits and optimisation of environmental water management are being explored.

3.3 Overarching goals and values

This section provides an overview of overarching goals of the rivers, estuaries, and wetlands in the study area (Figure 26).

In 2019-2020, GLaWAC completed an Aboriginal Waterways Assessment for the Latrobe River system. A summary of the values identified through the Aboriginal Waterway Assessment is provided in Figure 27. The cultural values and objectives for the Latrobe system are further discussed in Section 5 below.

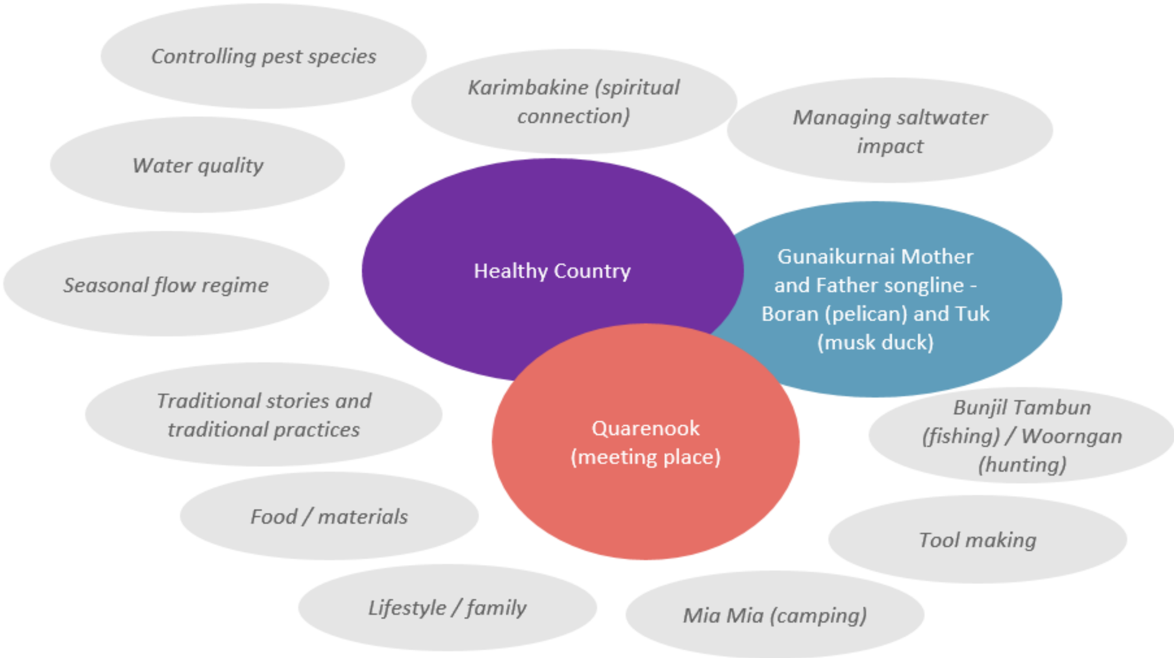


Figure 25. *Summary of values identified through Aboriginal Waterway Assessment [values provided by GLaWAC]*

The environmental values identified by the Project Advisory Group (Figure 27), and a summary of values identified by the Environmental Flows Technical Panel based on available literature and monitoring data are provided below (Figure 28). This information has been used to guide the environmental objectives developed in section 3.

West Gippsland Waterway Strategy 2014-2022

Relevant regional goals

- *Maintain and improve the **habitat and condition** of waterways to support water dependent animals and plants.*
- *Maintain the **ecological character** of significant wetlands and estuaries.*
- *Provide system **connectivity** between rivers, estuaries and wetland..*
- *Maximise the **ecological outcomes from the available environmental water**.*
- *Support community use, participation, advocacy and stewardship in the region's waterways.*
- *Provide appropriate environmental conditions to **support the economic values** of waterways in the region.*

Relevant Long Term Resource Condition Targets

- *All expected **native fish species** (migratory and non-migratory) are found in the reach and their abundance and diversity has increased*
- *The condition and extent of **riparian vegetation** communities is improved.*
- *The ecological character of the **Gippsland Lakes Ramsar Site** and associated fringing wetlands is maintained.*
- ***Quality and quantity of freshwater flows** from the Thomson and Latrobe systems to the Gippsland Lakes and fringing wetlands is maintained and, where possible, improved.*
- *Populations of Australian Grayling are self-sustaining.*
- *Water regime is managed to provide **required base flows** and **flow variability** within and between seasons.*
- *Habitat for birds particularly in terms of the **condition and extent of wetlands** is maintained.*
- *Waterways in the catchment provide **water of suitable quality** to support economic uses including township, rural uses and fishing.*
- *The extent of **freshwater wetlands** (including Seasonal Herbaceous Wetlands of the Temperate Lowland Plain) is maintained and their condition has improved.*

Relevant Management Outcome Targets

- *Condition of the **Lower Latrobe Wetlands** (Dowd Morass, Heart Morass, Sale Common) has improved from baseline level.*
- ***Threats to water regime** (altered seasonality, magnitude and water quality) are reduced through delivery of water to the Lower Latrobe Wetlands and the Thomson and Latrobe Estuary.*
- ***Environmental water outcomes** for the Latrobe River, Lower Latrobe wetlands and Thomson and Latrobe estuary are improved through **planning**, **reporting** and **monitoring**.*
- *Increased **community skills and knowledge** of waterway management issues.*
- ***Wetland water regime** (altered seasonality and magnitude) threats are reduced in priority waterways.*

Strategic management objectives for the Lower Latrobe Wetlands

To provide:

- *Coastal wetland landscapes characteristic of the Gippsland Lakes*
- *A **mosaic of habitats** supported by **spatial variation** in wetting and drying regimes*
- *Selected wetland areas **protected from salinization***
- *Feeding, breeding and sheltering **habitat** for a diverse range of wetland biota, including waterbirds*

Gippsland Lakes Ramsar Site Management Plan – Relevant Resource condition targets:

- *A reduction in the number of years in which **blue-green algal blooms** occur in the lakes to less than five over the 20 years.*
- *Maintain Macleod Morass and Sale Common as **freshwater marshes***
- *Maintain the extent, diversity and condition of **freshwater vegetation communities**.*
- *Maintain extent of **variably saline fringing wetlands***
- *The site supports greater than 20,000 **waterbirds** in three out of five diversity of waterbirds years*
- *Maintain **hydrological and biotic connectivity** between the catchment and the sea.*
- *Maintain sustainable native fish populations of important recreational and commercial fishes.*

West Gippsland Regional Catchment Strategy 2013-2019
Gippsland Lakes and Hinterland Landscape

- *Improved **conservation status** of threatened species and communities in the landscape.*
- *Improved or maintained **environmental condition of waterways, estuaries, wetlands and aquifers.***
- *Improved quality of native vegetation in the landscape.*
- *Increased **native vegetation** extent and connectivity across the landscape.*
- *Improved **water quality** in the landscape system.*
- *Minimised disturbance of acid sulphate soils in the landscape.*
- *Minimised flood damage to the floodplain and its occupants.*
- *Preservation of **Aboriginal cultural** heritage sites.*
- ***Traditional Owners**' knowledge and aspirations are incorporated into the management of the landscape.*
- *Sustainable management of the **Gippsland Lakes system** during the long term transition to a saline system*
- *To maintain, and where necessary improve, the ecological character of **Gippsland Lakes Ramsar site** and promote wise use.*

Figure 26. *Summary of relevant overarching goals to guide objective setting*

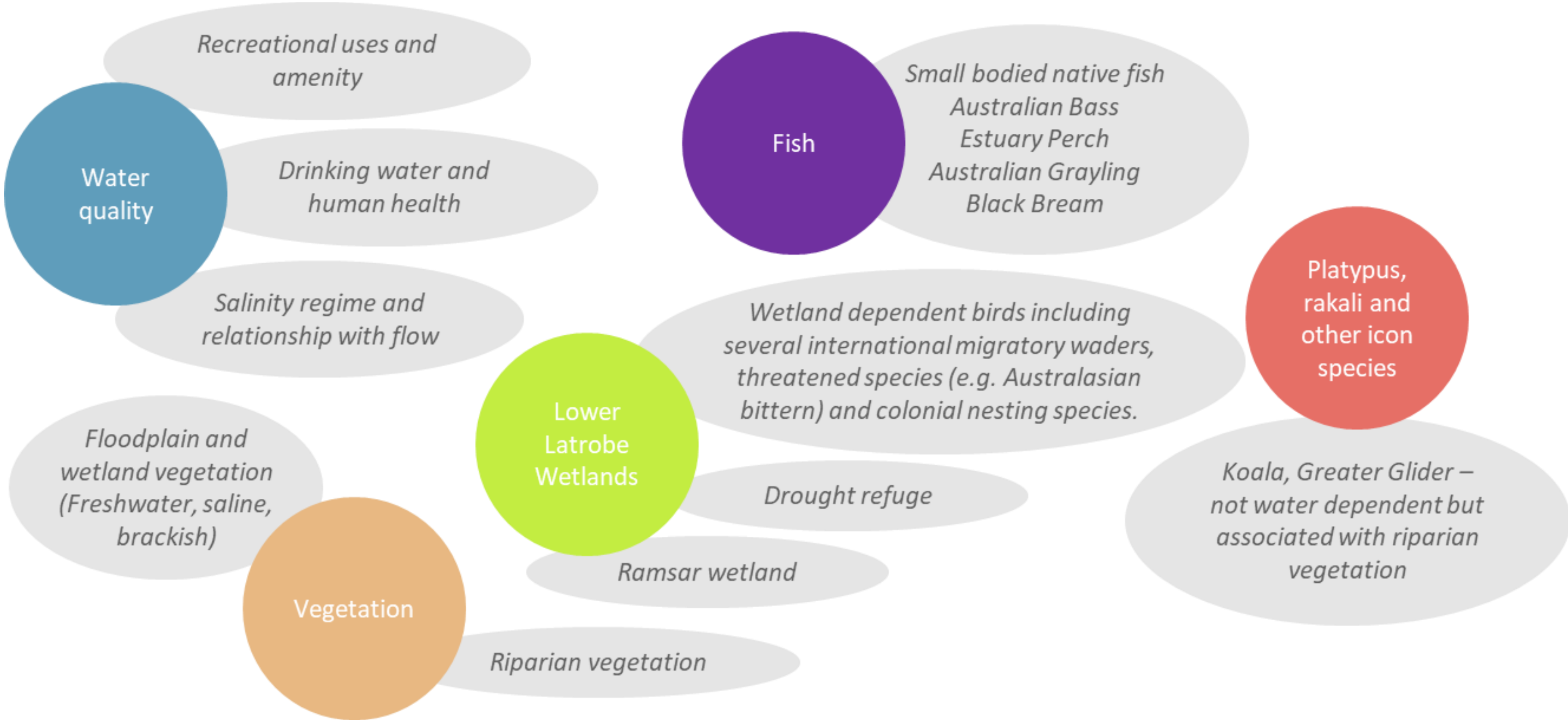


Figure 27. *Summary of values identified during Project Advisory Group Meeting*

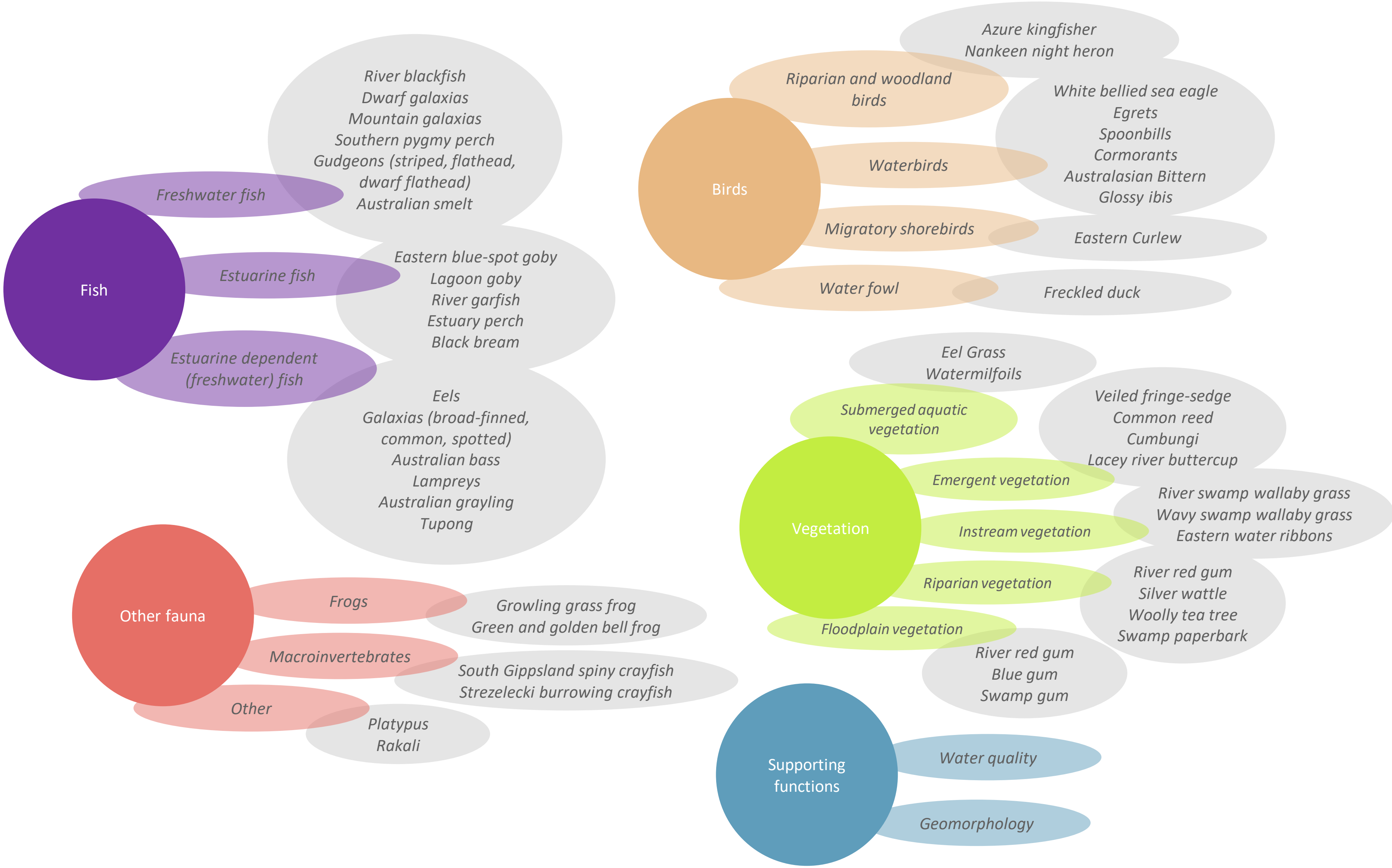


Figure 28. *Summary of values identified by the Environmental Flows Technical Panel.*

4 Environmental objectives

4.1 Approach to objectives

Environmental objectives were reviewed and updated based on the previous environmental water studies in the study area.

The objectives reflect the environmental values of the Latrobe system considered important by both waterway managers and the community. Objectives were determined in the context of the current water resource management, likely environmental conditions, including the likely trajectory of the system over the next 50 years, and the social and economic values of the region.

The objectives are intended to be applied over the next ten years, as environmental water investigations are generally updated every ten years, and this also aligns with timeframes for reviewing Sustainable Water Strategies.

Each environmental objective includes three components:

- the value (functional group of species of interest)
- the desired measurable outcome (e.g. abundance, recruitment, extent)
- a desired trajectory for that outcome (e.g. maintain, improve)

These objectives can be measured as part of an environmental water monitoring and evaluation program, which would include setting specific targets for these objectives and collecting baseline data so that the relative trajectory (i.e. maintain or improve) can be assessed.

The following sections on each environmental value includes:

- Description of the presence and condition of the value, functional groups and species
- Environmental objectives for this study
- Water requirements of (including conceptual models)
- Summary of the objectives, flow functions, and flow components

Specific criteria for these flow functions and flow components are provided in the relevant environmental water recommendations sections.

4.2 Self-sustaining fish populations

Description

The majority of fish in the Latrobe River system are entirely dependent upon access to the estuarine zones, Gippsland Lakes and marine ecosystems downstream. However, while some fish species, including nationally listed species, live in only in freshwaters, all estuarine, freshwater or marine respond to or require freshwater flows for part of their lifecycle.

The fish of the Latrobe River, and the wetlands and estuary of the Latrobe River, can be classified into six groups which have different requirements (Lloyd et al 2012). These types are classified based on their presence within different parts of the system, their use of the estuary and their migration patterns, all of which affect their environmental flow requirements (Figure 29).

Table 10 shows the species present within the system, their classification and reaches in which they inhabit. Resident Freshwater Fish will be most common in the freshwater reaches of the Latrobe, whereas the Estuarine Dependent (Freshwater) are found in both estuarine and freshwater reaches, often spending long periods in freshwaters, and the Estuarine Residents species are largely restricted to the estuary of the system.

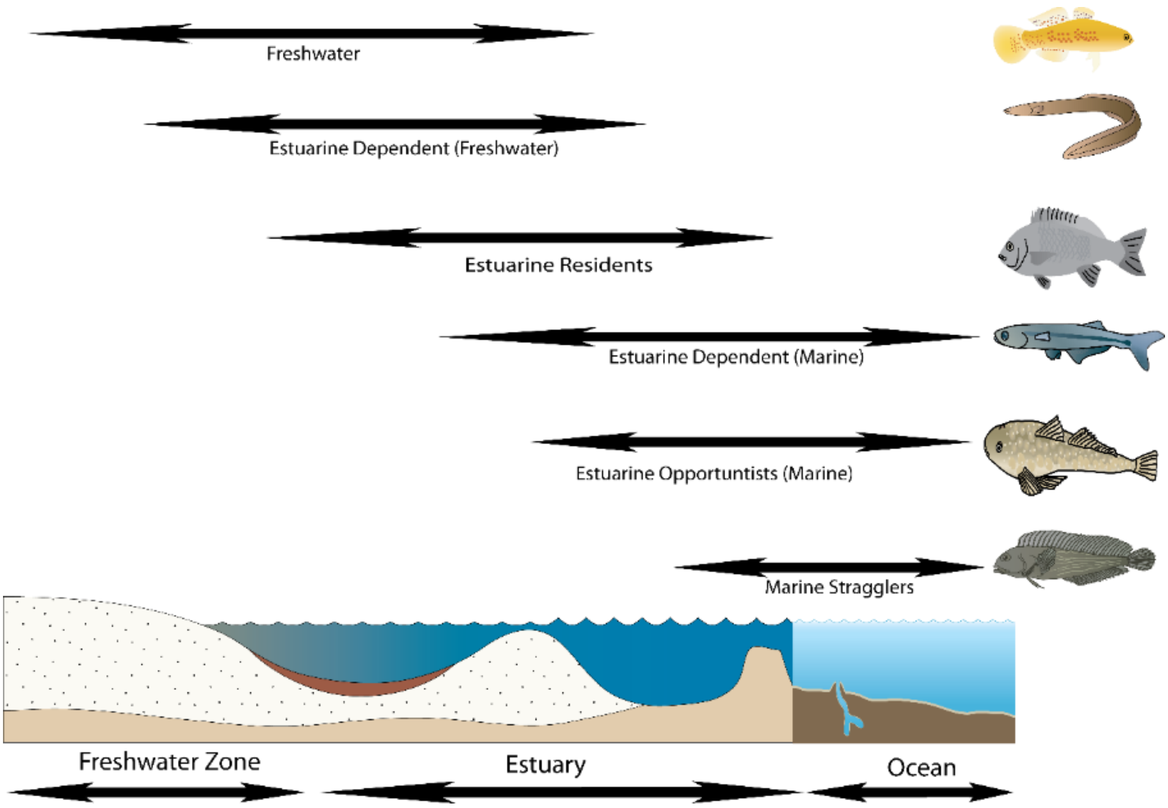


Figure 29. *Fish groups within the Latrobe River based on Lloyd et al (2012) classification.*

The first three groups (Resident Freshwater Fish; Estuarine Dependent (Freshwater); and Estuarine Residents) will be more closely assessed in this study as these groups are more significantly reliant on freshwater inflows than the other three groups. The Estuarine Dependent (Marine), Estuarine Opportunists (Marine) and Marine Stragglers species are less dependent upon freshwater inflows for their life cycle, although freshwater is important to all species to some degree as freshwater inflows also bring nutrients and organic matter into the estuary increasing its productivity (Lloyd et al. 2012).

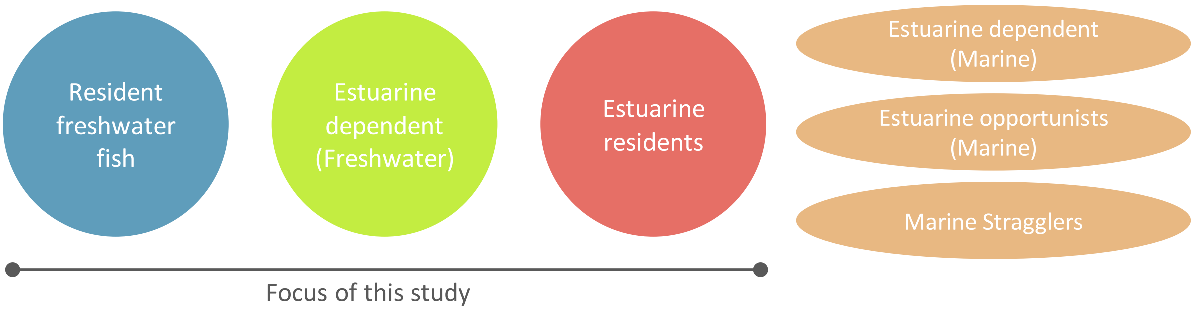


Table 10. Fish of the Latrobe River, estuary and wetlands (EarthTech 2007; Warry et al 2010; Brizga et al 2013; VBA 2018)

X= recorded recently in VBA records; O = recorded by other authors or known or expected to be present in that reach.

^ FFG listed species in Victoria (FFG Act); ^^{X} = Listed as an Extinct Species under FFG Act; ^^{CE} = Listed as a Critically Endangered Species under FFG Act; ^^{E} = Listed as an Endangered Species under FFG Act; ^^{v} = Listed as a Vulnerable Species under FFG Act; ^^{NT} = Listed as a Near Threatened Species under FFG Act; ^^{DD} = Data Deficient in Victoria (DNRE 2000); ^{v} = Listed as Vulnerable (DNRE 2000); $^{@E}$ = Endangered under EPBC Act; $^{@V}$ = Vulnerable under EPBC Act

Classification	Common Name	Scientific Name	Reach 3	Reach 4	Reach 5	Reach 6	Reach 8	Reach 9	Reach 10	Reach 11	Thomson Estuary	Dowd Morass	Heart Morass	Sale Common
Resident freshwater	River Blackfish	*Gadopsis marmoratus*	X	O	O		X	X	X	X				
	Dwarf Galaxias	*Galaxiella pusilla*^$^{v, @V}$	X	O	O		O	O	X	O				O
	Striped Gudgeon	*Gobiomorphus australis*^^{NT}				X					O	O	O	O
	Southern Pygmy Perch	*Nannoperca australis*	X	O	O		O	O	X	O				
	Flinders Pygmy Perch	*Nannoperca sp 1*	X	O	X	X	O	O	X	X	X	O	X	O
	Flathead Gudgeon	*Philypnodon grandiceps*	X	O	O	X	X	O	X	X	X	O	X	O
	Dwarf Flat-headed Gudgeon	*Philypnodon macrostomus*	O	O	O	O	O	O	O	O	X	O	O	O
	Australian Smelt	*Retropinna semoni*	X	O	X	X	X	X	X	X	X	X	X	X
Estuarine Dependent (Freshwater)	Southern Shortfin Eel	*Anguilla australis*	X	X	O	X	X	X	X	X	X	O	X	O
	Longfin Eel	*Anguilla reinhardtii*	X	O	X	X	X	X	X	X	X	O	X	O
	Climbing Galaxias	*Galaxias brevipinnis*	O	O	O	O	O	O	O	O	X	O	O	O
	Common Galaxias	*Galaxias maculatus*	X	O	O	O	O	O	O	X	X	O	O	O
	Spotted Galaxias	*Galaxias truttaceus*	O	O	O	O	O	O	O	O	X	O	O	O
	Macquarie Perch	*Macquaria australasica*^$^{E, @E}$	X											
	Australian Bass	*Macquaria novemaculeata*	O	O	X	X	X	O	O	O	X	O	X	X
	Shorthead Lamprey	*Mordacia mordax*	X	O	O	O	X	X	X	X	X			
	Non-parasitic Lamprey	*Mordacia praecox*	X	O	O	O					X			
	Australian Grayling	*Prototroctes maraena*^$^{v, @V}$	X	O	O	O	O	O	O	X	X			

Classification	Common Name	Scientific Name	Reach 3	Reach 4	Reach 5	Reach 6	Reach 8	Reach 9	Reach 10	Reach 11	Thomson Estuary	Dowd Morass	Heart Morass	Sale Common
Estuarine Resident	Black Bream	*Acanthopagrus butcheri*				X					X	O	O	O
	Tamar River Goby	*Afurcagobius tamarensis*				O					X	O	O	O
	Yellow-eye Mullet	*Aldrichetta forsteri*			X	X					X	O	O	O
	Port Jackson Glassfish	*Ambassis jacksoniensis*				O					X			
	Bridled Goby	*Arenigobius bifrenatus*				X					X	O	O	O
	Smallmouth Hardyhead	*Atherinosoma microstoma*				O					X	O	O	O
	Australian Anchovy	*Engraulis australis*				X					X	O	O	O
	Glass goby	*Gobiopterus semivestitus*				O					X	O	O	O
	River Garfish	*Hyporhamphus regularis*			X	X					X			
	Estuary Perch	*Macquaria colorum*			X	X					X	O	X	O
	Sea Mullet	*Mugil cephalus*				O					X	O	O	O
	Tupong (Congolli)	*Pseudaphritis urvillii*	X			O	O	O	X	X	X	O	O	O
	Eastern Blue-spot Goby	*Pseudogobius* sp. 9				O					X	O	O	O
	Lagoon Goby	*Tasmanogobius lasti*				O					X	O	O	O
Marine Opportunist	Luderick	*Girella tricuspidata*				X					X			
	Tailor	*Pomatomus saltatrix*				X					X			
	Trevally	*Pseudocaranx* spp.			X	X					X			
Alien Species	Goldfish	*Carassius auratus*	X	O	O	X	X	O	X	O	X	O	O	O
	Goldfish/Carp Hybrid	*Cyprinidae Carassius x Cyprinus HYBRID*	X	O	O	O	O	O	O	O	O	O	O	O
	European Carp	*Cyprinus carpio*	X	X	X	X	X	O	X	X	X	O	X	X
	Eastern Gambusia	*Gambusia holbrooki*	X	X		O	O	O	X	X	X	O	X	O
	Oriental Weatherloach	*Misgurnus anguillicaudatus*	O	O	O	O	O	O	O	O				
	Redfin	*Perca fluviatilis*	X	X	X	X	X	X	O	O	X	O	O	X
	Rainbow Trout	*Oncorhynchus mykiss*	X	O	O	O	X	O	O	O	O			
	Brown Trout	*Salmo trutta*	X	O	O	X	X	X	X	O	X			

Resident Freshwater fish are restricted to the freshwater reaches of the river system for their entire life cycle and are generally not migratory or at least only undertake local movements to find mates, foods or new habitats. Important freshwater species in the Latrobe River and its estuary include:

- River Blackfish
- Dwarf Galaxias
- Southern and Flinders Pygmy Perch
- Gudgeons (Striped Gudgeon, Flathead Gudgeon, Dwarf Flathead Gudgeon)
- Australian Smelt.

Many exotic fish are present within the Latrobe River; however, most are found in the freshwater reaches. Eastern Gambusia is able to inhabit highly saline environments. The system has a large range of exotic carp species, including Goldfish, Carp (as well as Carp-Goldfish Hybrids), Eastern Gambusia, Redfin Perch, Rainbow Trout and Brown Trout are quite common in the freshwater reaches (Table 10). Exotic fish competition, predation and other impacts on native fish. Gambusia, Redfin and Trout exert significant predation pressure on native fish (Lintermans 2007).

The **Estuarine Dependent (Freshwater) species** generally live in freshwater but migrate to the estuary (or sea) to breed and are dependent upon the estuary for one part of their life stage. The Australian Grayling migrates up from the estuary to mature and breeds in freshwater just above the estuary with larvae returning to the estuary by drifting with the flow downstream.

The important estuarine dependent (freshwater) species in the Latrobe River and its estuary include:

- Australian Grayling
- Tupong
- Eels (short-finned Eel and Long-finned eel)
- Some galaxias (Broad-finned Galaxias, Common Galaxias, Spotted Galaxias)
- Australian Bass
- Lampreys (Pouched Lamprey, Short-headed Lampreys).

These species are generally migratory as they need to use freshwater or the estuary for breeding and the other habitat to complete other parts of their lifecycle.

Estuarine Residents are those fish which largely live in the estuary and complete their whole life cycle within the estuary (although can travel into the freshwater and out to sea on occasions) and are generally dependent upon some aspects of freshwater inflows to survive.

The important estuarine resident species in the Latrobe River and its estuary include:

- Estuary Perch
- Black Bream
- River Garfish
- Eastern Blue-spot Goby
- Lagoon Goby.

Objectives

The objectives for fish and the relevant reaches are provided below.

Table 11. Environmental objectives for fish in the Latrobe system

	Objective	Riverine reaches (3,4,5, 9,10)	Riverine reaches (8,11)	Upper estuary	Mid Estuary	Lower estuary	Sale Common	Heart and Dowd morass
Estuarine dependent / Migratory fish	Maintain abundance and improve recruitment of Australian grayling populations	✓		✓	✓	✓		
	Maintain abundance of eel populations	✓	✓	✓	✓	✓	❖	❖
	Improve recruitment of small-bodied migratory fish including Tupong, Broad-finned Galaxias and Common Jollytail	✓	✓	✓	✓	✓	❖	❖
	Maintain abundance and improve recruitment of Australian Bass populations	✓		✓	✓	✓	❖	❖
Resident freshwater fish	Improve recruitment of small-bodied freshwater resident fish such as Dwarf Galaxias, Pygmy Perch, Australian Smelt, Flathead Gudgeon and Dwarf Gudgeon Maintain abundance of resident freshwater fish, including Dwarf Galaxias, Pygmy Perch, Australian Smelt and Gudgeon *Dwarf Galaxias absent from estuary	✓	✓	✓*	✓	✓	❖	❖
	Improve recruitment of River Blackfish	✓	✓					
Estuary resident fish	Maintain abundance and improve breeding and recruitment of estuarine resident species (Estuary Perch, River Garfish, Black Bream, Eastern Blue-Spot Goby and Lagoon Goby)	*Reach 5 only*		✓	✓	✓	❖	❖

❖ Objectives relevant to lower Latrobe wetland are not directly used in development of watering regime.

Water requirements

The fish community and the life history of key species, together with other organisms, can be very useful in determining the environmental flow requirements of rivers, wetlands and estuaries. The aspect of their life history, such as life span, spawning season, incubation, duration, migration, and habitat requirements all contribute to our understanding of how a flow regime can be built up for a community of fish and aquatic animals. The flow requirements of each group of fish can be quite different with each species having specific flow and or habitat requirements, but they are generally tolerant of a range of conditions and collectively meeting the requirements of several groups will ensure a robust water regime recommendation (Lloyd et al. 2006 & 2012a, Koehn & O'Connor 1990, McDowall 1980).

Flow interacts with the various habitat types to meet the habitat and flow requirements of fish; within the Latrobe River system these habitats include riverine pools, riffles, runs, woody debris, undercut banks, rocks & boulders (in upper tributaries), freshwater swamps, and estuarine wetlands. These habitats are created and maintained by adequate flow regimes.

The requirements for each key species within the Latrobe River system are shown in Table 12, with key species requirements explained further below:

Resident freshwater fish

Resident Freshwater Fish rely solely upon habitats within the freshwater sections of the catchment mainly stream channels or nearby wetlands (Table 12), the key species for this study are the following.

River Blackfish (*Gadopsis marmoratus*) are relatively long lived (at least 4 years and up to 7 years) they breed each year in November to January. Sticky demersal eggs are laid on hard substrates (large woody debris or rocks), large eggs which hatch after 7 - 10 days. The larvae remained "tethered" by their large egg sacs for a further 21 days as the larvae mature (Allen et al. (2002); Koehn & O'Connor (1990); Treadwell & Hardwick (2003)). Blackfish will require freshes to provide conditions suitable for reproduction. These conditions are created when in-stream bars are inundated to deliver terrestrial carbon (energy & food) into the system and provide habitat for spawning adults and juvenile fish. These flows should occur in late winter, spring and early summer to create extensive habitat across the stream to enable energy and food resources to be swept into the stream channel which enable fish to build condition to allow spawning (Pusey and Arthington 2003; King 2004). Inundation of new habitat will both provide habitat and stimulate invertebrate production and growth. After breeding, this habitat provides conditions for eggs and larvae to hatch and grow. Ideally, long duration flows (7 to 10 days) which cover instream vegetated bars are required to support a range of fish species. Given that many of the small bodied fish and macro-invertebrates (blackfish prey) live only one or two years, then these flows are required in most years.

Dwarf galaxias (*Galaxiella pusilla*) are listed under Victorian (DSE Advisory Listing), Victorian (FFG 1988) and Australian Government (EPBC 1999) legislation. Dwarf galaxias are short-lived species, basically only living one year and therefore the right conditions each year to maintain their populations. The species has a strong preference of areas of dense submerged aquatic vegetation. They use this habitat for breeding, feeding and protection from predators. They lay their eggs in separate batches on flooded vegetation, leaf litter or rocks, with the preferred egg site is the underside of leaves or stems. They breed in August to October and their eggs take 10-17 days to incubate and hatch, meaning they need stable conditions for this to occur. Adults probably die after spawning and some fish are likely to use yabby holes to over summer in if their water body dries out.

Two species of pygmy perch (*Nannoperca* spp.) are recorded in the Latrobe system, the southern pygmy Perch and the recently recognised Flinders pygmy perch. Pygmy perch are wetland specialist species, preferring slow moving and still waters which are heavily vegetated. Submerged aquatic vegetation is a critical habitat for these species required for spawning, feeding and protection. They are restricted to relatively fresh water and are not known in saline or estuarine habitats (Allen et al. 2002; Treadwell and Hardwick 2003). While they are generally rare, individual populations can grow quite large in the right conditions. These species do not undergo any long-distance movements for reproduction or other purpose but would move within their local environment to optimise habitat and feeding opportunities. In summer, these fish move out from drying wetlands to seek refuge in permanent habitats (Allen et al. 2002; Treadwell and Hardwick 2003). These fish have very low fecundity (small numbers of eggs are produced by each female) and the eggs are small and non-adhesive demersal eggs with short incubation times. Pygmy perch live a maximum of five years but are mature after their first year. Breeding is in spring (generally September to October) and eggs are laid amongst aquatic vegetation. Their eggs hatch rapidly after 2 – 4 days.

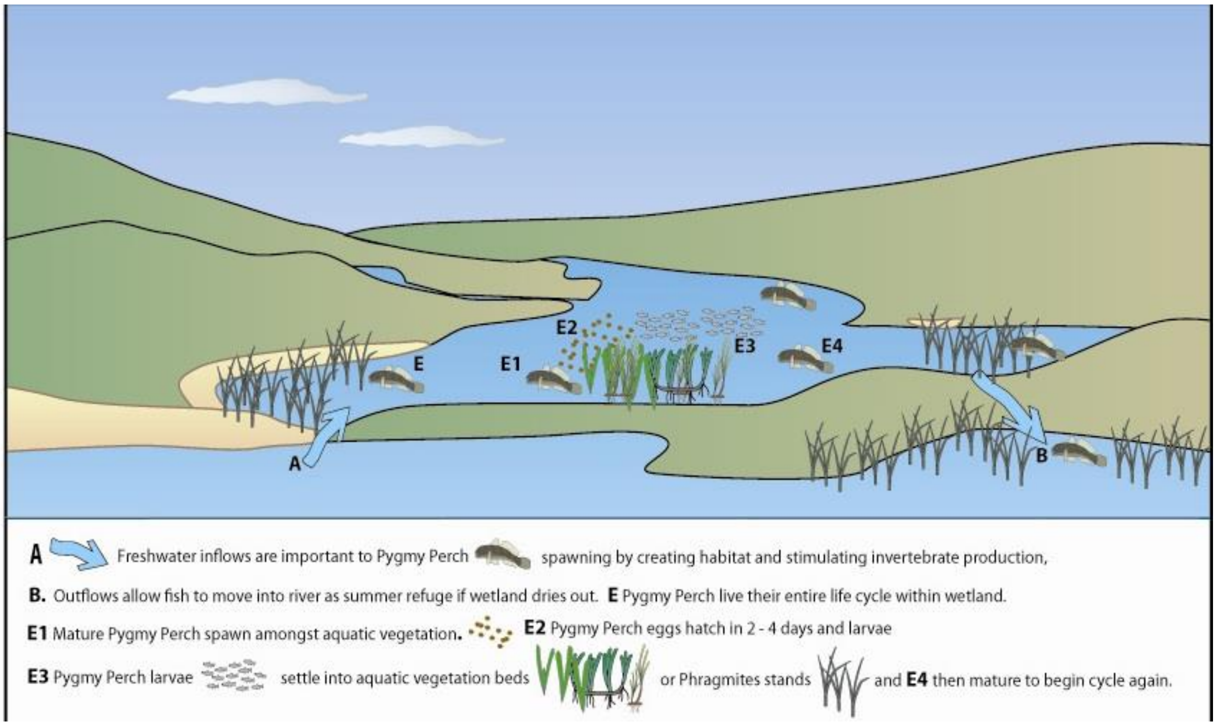


Figure 30. *Conceptual model for the Pygmy perch species (from Lloyd et al 2012a).*

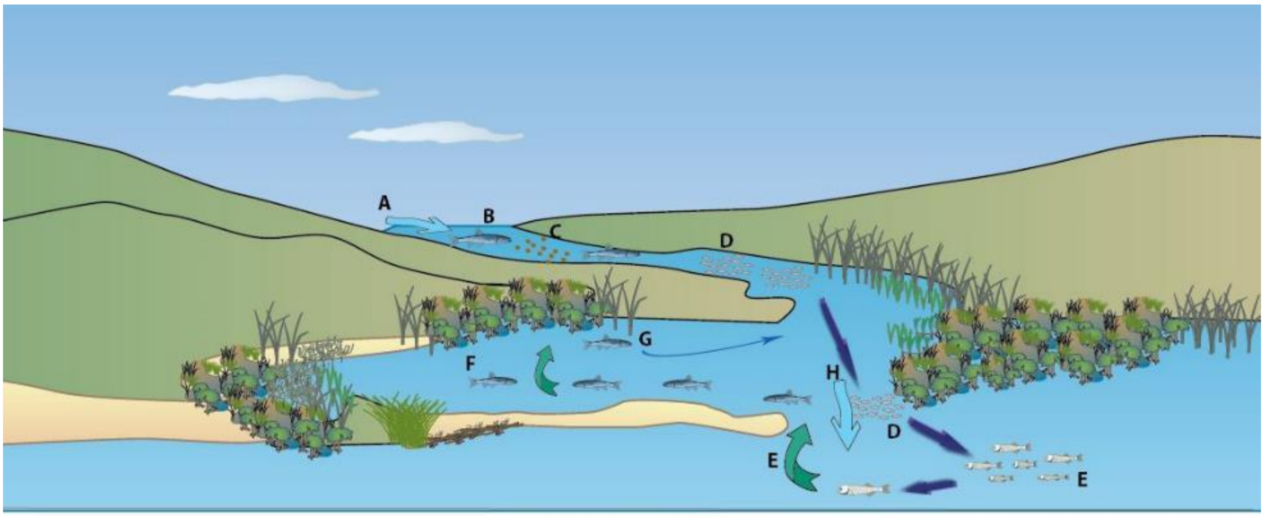
Estuarine Dependent (Freshwater)
Estuarine Dependent (Freshwater) are mostly migratory species and their ecological requirements are listed in Table 12.

Australian Grayling (*Prototroctes maraena*) are an important estuarine dependent representative species as they spend the majority of their time in freshwater but are dependent upon estuaries and coastal zones for early larval development and the development and growth of juveniles returning from the sea. They also require access to the sea (or the Gippsland Lakes) and therefore estuary mouth opening, and closures are important to these fish. In addition, the fish are regarded as vulnerable by the Victoria Flora and Fauna Guarantee Act (FFG Act) and the Australian Government's Environment Protection and Biodiversity Act (EPBC Act).

Australian Grayling spend the majority of their adult life in freshwater, with the adults moving downstream to breed. Grayling larvae are thought to be washed to the sea and return to mature in the estuary (Bishop & Bell 1978a &b; Bell et al. 1980; Berra and Cadwallader 1983; Hall & Harrington 1989).

As adults, Australian Grayling are found in clear, gravel-bottomed streams with alternating pools and riffles, rocky streams and muddy-bottomed habitats. Grayling require a well oxygenated stream, which is promoted by flowing water.

Adults move downstream in February to May to spawn in freshwater (mostly April -May in Victoria), triggered by a high flow event and then juveniles return at the end of their first year to spend time in the estuary (May to Oct) before migrating upstream as they grow in October to December for up to 3 years until they mature (Koster, Dawson & Crook 2013; Koster et al. 2017; Amtstaetter, O'Connor & Pickworth 2016; Bishop & Bell 1978a &b; Bell et al. 1980; Berra and Cadwallader 1983; Hall & Harrington 1989). Grayling can swim up riffles having flows of 2-4 m/s, have sustained swimming at 0.6 m/sec but their preferred flow is 0.2-0.35 m/s.



A Freshwater flows provide for longitudinal connections and breeding triggers for adult Australian Grayling **B.** These freshwater fish which use estuaries as juveniles and breed in freshwaters in April - May **C** and larvae are washed out to sea **D** in May to July and juveniles and begin to mature at sea **E.** In May to October sub-adult fish **F** spend time in the estuary before upstream migrations into freshwaters in October to January **G.**

Figure 31. *Australian Grayling Conceptual Model ecological and hydrologic objectives (from Lloyd et al 2012)*

Tupong (*Pseudaphritis urvillii*) are a moderately long-lived species (about 5 or more years) which spawn in spring and early summer (September to December). They live in the lower reaches of coastal rivers and spending significant periods in freshwater. Adults migrate downstream to the estuary for breeding during April to July with juveniles migrating upstream during October to February. Tupong are susceptible to impacts from the presence of instream barriers which stop their migrations, either upstream or downstream, preventing them from breeding or recruiting (Koehn and O'Connor 1990; McDowall 1996; Merrick and Schmida 1984; Lintermans 2007).

Southern Shortfin Eel (*Anguilla australis*) are long lived species (about 32 years) which live most of their life in freshwater but are catadromous fish, swimming to the sea to breed (and then the adults die), before juveniles return. Eels have complex breeding and migratory requirements. They return to the estuary after being spawned at sea as elvers in winter to spring (Jul-Nov) but move upstream over many years and mature as they go upstream, largely moving between Nov - May (McKinnon 2006). Adults migrate to the sea during late spring, summer and autumn (Oct to May). Elvers return to the estuary after being spawned at sea in winter to spring (Jul-Nov) and undertake upstream migrations Nov – May (McKinnon 2006). However, they are very flexible with the timing of these movements as they are long-lived, and they tend to move upstream, growing as they go, exploiting the river's resources over this time to put on condition for their great ocean migration (Gomon and Bray 2018). In the freshwater environment they occur in streams, lakes and swamps, more likely inhabiting slow flowing streams or still waters. They are large animals which eat a variety of fish, crustaceans, molluscs, worms, aquatic plants, terrestrial and aquatic insects (McKinnon 2006; Lintermans 2007, Gomon and Bray 2018).

Common Galaxias (*Galaxias maculatus*) are a widespread and often abundant species in Australia. They are a short-lived species (2-3 years maximum) which live in freshwaters during their adult life, but like other catadromous fish they migrate downstream to breed in the estuary and then return upstream after recruiting in the estuary. They occur in a variety of freshwater habitats, but mostly in still or slow-flowing waters, mainly in streams, rivers and lakes connected to the sea. Some populations are landlocked where the fish breed in tributary streams during floods, but these are rare (Koehn and O'Connor 1990; McDowall 1996; Merrick and Schmida 1984; Lintermans 2007, Gomon and Bray 2017).

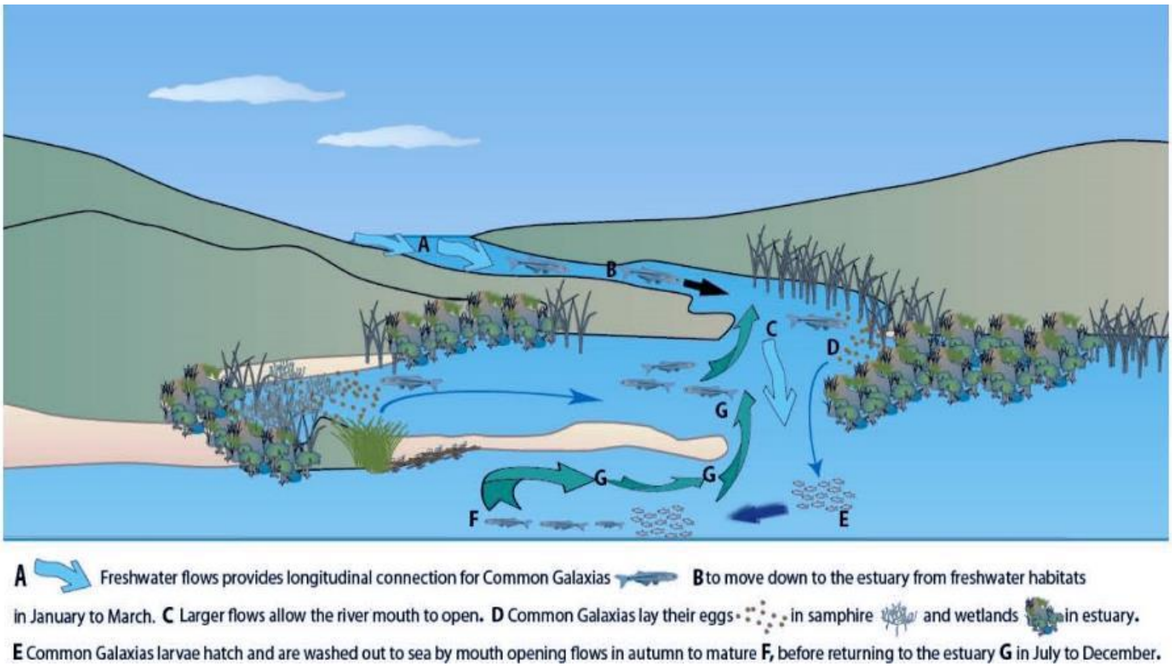


Figure 32. *Common Galaxias Conceptual Model ecological and hydrologic objectives (from Lloyd et al 2012)*

Australian Bass (*Macquaria novemaculeata*) is a native species which distribution extends along the east coast of Australia around to Wilson's Promontory. Australian Bass have high salinity tolerances (up to sea water) but spend most of their time in freshwaters; however, eggs and sperm do not survive in freshwaters. While Australian Bass breed at temperatures between 14-19°C, the adult temperature tolerances are unknown; they inhabit areas of fast flowing waters and are likely to be quite cold tolerant.

The diet of Australian bass varies significantly between habitat and season. Harris (1985) found that almost every available prey type was included in the diet of Australian Bass such as fish (the most important food recorded in Australian Bass); insects; crustaceans; and terrestrial vertebrates (such as skinks, frogs and birds) and plant material.

Australian Bass are long lived species living up to about typically living up to about 20 years , but as long as 47 years has been recorded (Stoessel et al. 2017). They undertake local and moderate distance migration for breeding, finding new habitat and feeding. They breed between July and December and their eggs take 3-4 days to hatch. Adults migrate downstream from April to July and return upstream during August to November. Adults migrate in large schools from freshwater to brackish water to spawn in the upper estuary, but spawning, hatching success and juvenile recruitment are all dependant on flooding (Growns and James 2005). The larvae and juveniles undertake upstream migrations from October to April to recolonise freshwater habitats.

Estuarine residents
Estuarine Residents are largely restricted to the estuary although some species are required to move into freshwater and/or the marine environment for parts of their life cycle.

Estuary perch (*Macquaria colorum*) are a large-bodied fish, usually less than 1.5 kg and relatively long-lived (over 20 years). They predominantly live in estuarine waters but make regularly and sustained forays into freshwater reaches of rivers provided access. The species breeds in July to August in the estuary with fish recruiting in the estuary and then moving upstream to feed and exploit freshwater resources (Koehn and O'Connor 1990; McDowall 1996; Merrick and Schmida 1984; Lintermans 2007).

Black bream are common in and around large structural elements within estuaries. They are considered as the only true estuarine sparid in Australia and have a wide salinity tolerance and may move into the freshwater reaches of estuaries (Kailola et al. 1993). Ecological and hydrologic requirements are shown in Figure 33.

The life cycle of black bream is usually completed within a specific estuary, however, there may be some movement of black bream between estuaries (Butcher and Ling 1958). Spawning period for black bream extends from August to December, though the timing and the period of spawning is thought to vary between estuaries (Kailola *et al.* 1993). Spawning is thought to occur in the upper reaches of estuaries near the interface between fresh and brackish water (Cadwallader and Backhouse 1983; Ramm 1986). Spawning success may also be higher when spring rainfall and river flow is low and when water temperatures is high in October (Hobday and Moran 1983).

Eggs are planktonic and, as a function of their buoyancy (negative in freshwater and positive in saltwater), are most abundant in waters with salinities greater than 15 g/L (Ramm 1986). Nicholson *et al.* (2004) found that bream eggs are neutrally buoyant in salinities 16 – 20 g/L, and therefore float in the halocline. Eggs generally hatch two days after fertilisation, but embryos fail to develop in salinities below 5 g/L (Ramm 1986). Larvae remain in the water column for approximately one month before settling into shallow macrophyte beds at between 10 to 15 mm in length (Ramm 1986). Shallow seagrass/algae beds appear to be important nursery areas for juvenile black bream, as these areas support high abundances of food (Poore 1982). The flow of freshwater into the system will be crucial in establishing salinities and small-scale salt wedge dynamics required for successful reproduction and for the maintenance of seagrass beds for the species to inhabit as juveniles.

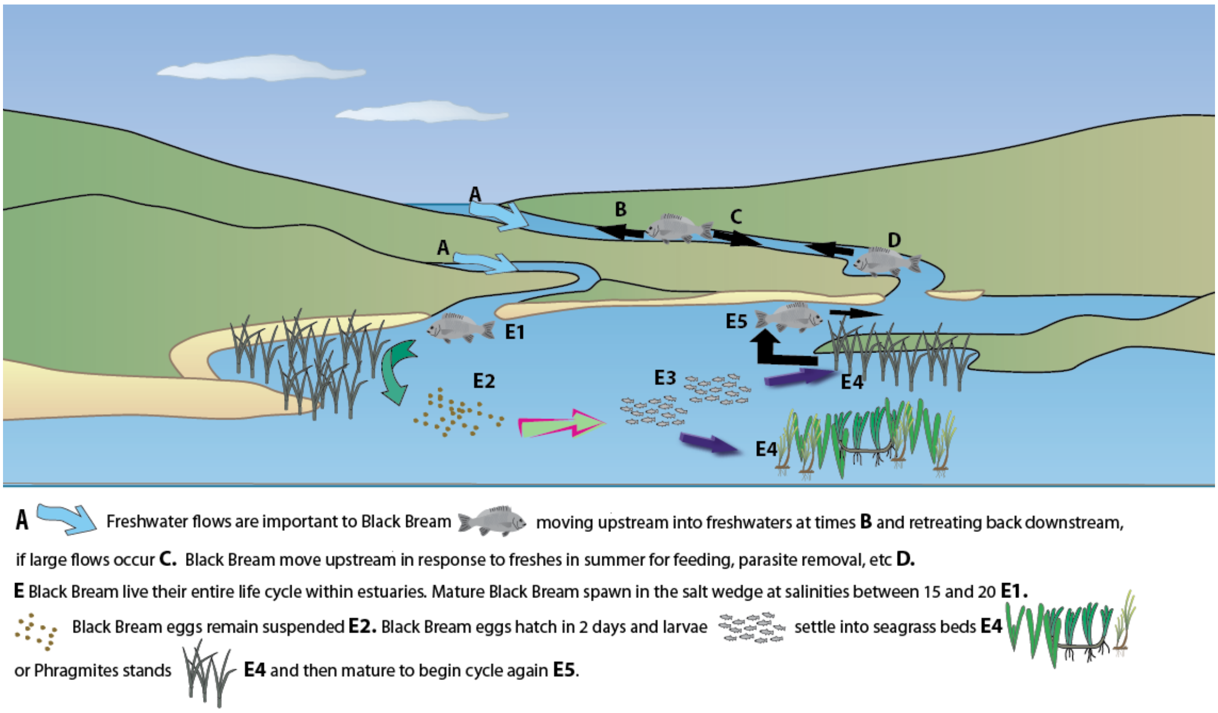


Figure 33. *Black Bream conceptual model, ecological and hydrologic objectives*

Table 12. Ecological requirements of key fish species actually or likely to inhabit the Latrobe River system

These are based on current knowledge but these can only be considered as approximate until further research is conducted on these species [derived from www.fishbase.org (Froese and Pauly 2018), Allen et al. (2002); Koehn & O'Connor (1990); Lloyd (1987); Merrick & Schmida (1984); McDowall (1980); Treadwell & Hardwick (2003); Lloyd et al. (2006 & 2012a); Growns (2004); McKinnon (2007); Raadik (2014)]

Fish Species						
Common Name	Scientific Name	Life Span	Spawning Season	Incubation Duration*	Migration	Other
Resident freshwater fish						
Australian Smelt	*Retropinna semoni*	1-2 years	Sept - Nov	9-10 days	Active movers between habitats and along anabranches	Aquatic vegetation required as a substrate for laying eggs
Dwarf Galaxias	*Galaxiella pusilla*^v, @V	1 year	Aug – Oct	10-17 days	Local	Frequently associated with aquatic vegetation and eggs are laid in separate batches on flooded vegetation, leaf litter or rocks – preferred egg site is the underside of leaves or stems. Adults probably die after spawning. May use yabby holes to over summer.
River Blackfish	*Gadopsis marmoratus*	4–7 years	Nov - Jan	7 - 10 days (plus 21 days "tethered" larvae)	Local	Hard substrate required – hollow logs as a substrate for laying eggs
Southern Pygmy Perch	*Nannoperca australis*	2-5yrs	Sept – Nov	2-4 days	Local	Aquatic plants for spawning and habitat Vegetation or rocks instream habitat required
Flathead Gudgeon	*Philypnodon grandiceps*	4-7 years	Oct - Feb	4-6 days	Local only	Hard surfaces required as a substrate for laying eggs
Dwarf Flathead Gudgeon	*Philypnodon macrostomus*				Local	Hard surfaces required as a substrate for laying eggs

Fish Species						
Common Name	Scientific Name	Life Span	Spawning Season	Incubation Duration*	Migration	Other
Estuarine dependent (freshwater)						
Australian Grayling	*Prototroctes maraena*^v, @V	Males 1-2 years Females 2-3 years	Apr – May (maybe as early as Feb or go as late as June)	10-21 days in freshwater (< 2 ppt)	Larvae washed to sea/estuary in May to July Juveniles spend May to Oct in estuary/sea Juveniles migrate from sea upstream Oct - January	Demersal non-adhesive eggs Fry slender and buoyant Spawning occurs after high flow – full moon to last quarter Eggs develop in slow water to 5m deep Need high O_2 Can swim up riffles at flow of 2-4m/s sustained swimming 0.6m/sec Prefer 0.2 to 0.35 m/sec
Tupong (Congolli)	*Pseudaphritis urvillii*	>5years	Sept - Dec	Unknown (likely to be short - 3 or so days)	Adults migrate downstream to estuary for breeding April to July. Juveniles migrate upstream Oct – Feb.	Congolli are susceptible to impacts from the presence of water flow barriers
Common Galaxias / Common Jollytail	*Galaxias maculatus*	2-3 years	April -June	Normally take 10-16 days between flow events or tides (in estuary	Downstream to estuary in Autumn.	Aquatic/riparian/intertidal macrophytes required as a substrate for laying eggs
Climbing Galaxias	*Galaxias brevipinnis*	2-4 years (Uncertain)	May-June	Unknown – perhaps 5-7 days (same as *G. olidus*)	Larvae are washed downstream to the sea in winter. Juveniles return upstream in spring and early summer.	Prefer rocky streams with flowing water and good riparian vegetation however have are also found in habitats with silt substrates.
Spotted Galaxias	*Galaxias truttaceus*	2-4 years (Uncertain)	May-June	28 days at 12 degrees	Downstream to estuary in autumn & winter. Larvae swept to sea Juveniles return from sea upstream in spring and early summer (Oct – Jan)	LWD, undercut banks, boulders and good riparian vegetation however have are also found in habitats with silt substrates. Pools are also used extensively. Highly salt tolerant and occurs in turbid water – prob very tolerant of poor WQ. Can swim at 3.3m/sec for 1 hour – prefer 0.2m/sec
Australian Bass	*Macquaria novemaculeata*	~18 years [and up to 47 years]	July – Dec	3-4 days	Local and moderate distances Adults Migrate downstream April to July and return upstream August to November. Larvae/Juveniles migrate upstream Oct to Apr	Adults migrate from freshwater to brackish water to spawn in the upper estuary dependant on flooding in large schools.

Fish Species						
Common Name	Scientific Name	Life Span	Spawning Season	Incubation Duration*	Migration	Other
Short-finned Eel	*Anguilla australis*	32 years	June - Mar	Unknown as it occurs in the marine environment	Adults migrate to sea during late spring, summer and autumn (Oct to May). Elvers return to the estuary after being spawned at sea in winter to spring (Jul-Nov) and undertake upstream migrations Nov - May	Flow requirements really need to consider preservation of adult habitat – rivers and lakes. Breeding is cued by non-flow factors and occurs at sea.
Long-finned Eel	*Anguilla reinhardtii*	41 years	Mar – May	Unknown as it occurs in the marine environment	Adults migrate to sea during spring and summer and elvers return into estuaries in autumn and migrate upstream in subsequent years	Flow requirements really need to consider preservation of adult habitat – rivers and lakes. Breeding is cued by non-flow factors and occurs at sea.
Estuarine residents						
Smallmouth Hardyhead	*Atherinosoma microstoma*	1 year	Sept - Feb	4-7 days	Local only	Breeding probably occurs in estuary or lower reaches of rivers
Black Bream	*Acanthopagrus butcheri*	29 years	Nov – Jan	2 days	Between sea and estuary	Breeding in estuary at specific salinities. Tend to inhabit areas where rocky riverbeds, snags or structures provide cover but can be found in open waters over sand or mud substrates. Larvae and small juveniles require seagrass beds in shallow estuarine waters
Estuary Perch	*Macquaria colorum*	20 years +	July to August	2-3 days	The adults move downstream prior to spawning. The species breeds in July to August in the estuary with fish recruiting in the estuary and then moving upstream to feed and exploit freshwater resources	A large-bodied fish, usually less than 1.5kgand relatively long-lived (over 20 years). They predominantly live in estuarine waters but make regularly and sustained forays into freshwater reaches of rivers provided access. (Koehn and O'Connor 1990; McDowall 1996; Merrick and Schmida 1984; Lintermans 2007).
Eastern Blue-spot Goby	*Psuedogobius sp.*	2-3 years	Oct-Jan	4 days	Local only	Need hollow in log or burrow under rock or wood as a substrate for laying eggs.

* Time that eggs take to develop into larvae (eggs require inundation at least for this period)

^ FFG listed species in Victoria (FFG Act); ^X = Listed as an Extinct Species under FFG Act; ^CE = Listed as a Critically Endangered Species under FFG Act; ^E = Listed as an Endangered Species under FFG Act; ^v = Listed as a Vulnerable Species under FFG Act; ^NT = Listed as a Near Threatened Species under FFG Act; ^DD = Data Deficient in Victoria (DNRE 2000); v = Listed as Vulnerable (DNRE 2000)

@E = Endangered under EPBC Act; @V = Vulnerable under EPBC Act

4.3 Healthy and diverse water dependent vegetation

Vegetation communities and broad objectives

Hansen et.al. (2010) describe the benefits of riparian and wetland vegetation and objectives to retain or improve vegetation on waterways with the following points:

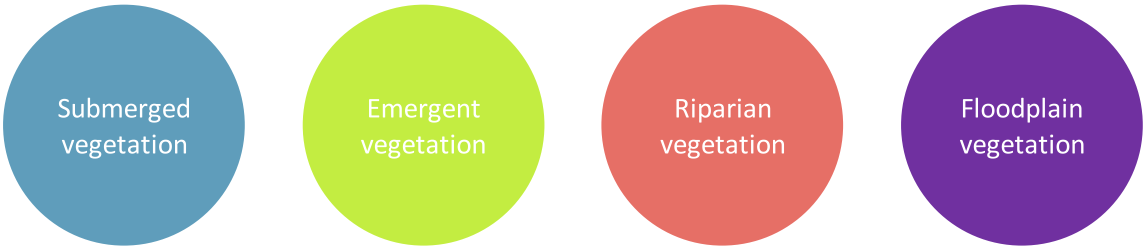
- Improve water quality (reduce excess nutrient and contaminant inputs to waterways)
- Reduce streambank erosion and sediment inputs
- Increase shading and moderate water temperature
- Provide wood, leaf litter and other resource inputs to streams (i.e. facilitate resource transfers between the terrestrial and aquatic environment)
- Increase in-stream biodiversity
- Improve the structure and composition of wetland and riparian vegetation communities, and increase terrestrial biodiversity
- Increase lateral and longitudinal connectivity of biota and other material

To achieve these benefits and objectives for riparian vegetation heath we can target the flows to support the waterway vegetation.

The water dependent vegetation in the study area occupies a range of habitat niches with different environmental conditions which can deliver different ecological outcomes. These habitat niches are:

- instream pools and permanent water wetlands
- shallow semi-permanent water and exposed but frequently inundated benches/lower bank
- channel banks
- adjacent floodplain and broader floodplain.

Assemblages of plants grow in the different habitat niches responding to the environmental conditions by forming groups with different functions and environmental tolerances. The assemblages occupying the habitat niches interact and provide support for each other to deliver ecological outcomes. The different plant groups used in the study to define the ecological objectives and water requirements are:



These groups are shown on a river cross-section along with their water requirements in Figure 34 and Figure 35 below (page 76&67). These plant groups are consistent with the broad groups (Submerged, Amphibious and Terrestrial) described by Dodo (2010). Defining groups in this way aligns them to the waterway/wetland habitat niches and enables hydrological regimes to be aligned accordingly. Water regimes for the vegetation groups are informed by Frood and Papas (2016) who have attributed water regimes and salinity ranges for wetland (and some riparian) EVCs. Further detail for the water requirements of individual species is obtained from VicFlora (2016) and Roberts & Marsden (2011).

An overview of the vegetation condition for the study reaches and wetlands is provided in Appendix D.

Rare and Threatened species

There are few water dependent rare and threatened species recoded in the study area. Table 13 shows the species recorded within 200 m of the waterways in the study area (NatureKit, 2018). These species are associated with seasonally inundated shallow wetland habitats with *Cycnogeton microtuberosum* also occurring in slow flowing waterways up to 1200 mm deep.

Table 13. Rare and threatened species recorded within study area *(NatureKit, Nov 2018)*

Scientific name	Common name	FFG	Victorian Advisory List	EPBC	Reach
Amphibromus fluitans	River Swamp Wallaby-grass			Vulnerable	6, 11, Sale Common
Amphibromus sinuatus	Wavy Swamp Wallaby-grass		Vulnerable		6, Heart Morass
Cycnogeton microtuberosum	Eastern Water-ribbons		Rare		6, Sale Common, Heart Morass
Fimbristylis velata	Veiled Fringe-sedge		Rare		6, Sale Common, Heart Morass
Ranunculus amplus	Lacey River Buttercup		Rare		6, Heart Morass

Ecological Vegetation Classes (EVCs)

Native vegetation in Victoria is classified into different Ecological Vegetation Classes (EVC). These are communities of plants which can be defined through a combination of floristics, lifeforms and ecological characteristic and through an inferred fidelity to particular environmental attributes (DELWP, 2018). An EVC can be expressed by different floristic communities and, depending on the aligned habitats, different niches may be present.

A summary of the predominate EVCs in the study area is shown in Table 14. EVCs of the Lower Latrobe Wetlands are shown in Table 15.

Submerged aquatic vegetation

This is aquatic vegetation which can survive near permanent inundation of 500 mm or more. These are found in permanent waterway pools or wetland habitats. Species observed in this group include amphibious species such as; *Potamogeton ochreatus, Cycnogeton procerum (syn.Triglochin procerum)*. These species generally require a period of low or cease to flow events to occur every 2-3 years in spring/summer to expose damp substrate for seed germination to occur. Some species such as *Vallisneria australis* requires permanent water pools to persist.

The waterway sites visited had no or very low levels of submerged aquatic vegetation. This reflects the absence of channel bed topography (benches, sand/gravel bars) for the submerged aquatic vegetation to grow on or no periodic water drawdown enabling recruitment. The Tanjil River site did have these structures and instream vegetation was present.

Stands of this vegetation can be components of or defined as EVC918 Submerged Aquatic Herbland, EVC653 Aquatic Herbland or EVC 537 Brackish Aquatic Herbland. This vegetation provides primary production in the aquatic environments processing nutrients, trapping sediment and providing food and shelter to macroinvertebrates, birds and fish.

Dodo (2010) grouped some species such as *Cycnogeton procerum* with amphibious species which would be more aligned to the Emergent vegetation group. For this study the species which require/tolerate extended periods of inundation and only require short periods of dry conditions for seed germination are included in the Submerged vegetation group.

Objective: Improve condition and extent of submerged aquatic vegetation to provide structural habitat for macroinvertebrates and various fish species.

Emergent vegetation
The emergent vegetation group comprises herbs, grasses and sedges which can survive short to semi-permanent periods of inundation and occupy the shallow semi-permanent water, waterway benches and lower bank habitats. They also grow in floodplain features which remain moist or fill during flood events. They can tolerate changes in water level and will survive periods without inundation. Reproduction usually requires dry conditions for seed to germinate in damp soils.

Sale Common, Heart and Dowd Morasses have extensive areas of emergent vegetation growing in a mosaic of different wetland floristic communities. These wetland areas are experiencing altered hydrology and changes in salinity which is impacting vegetation condition and species composition to varying degrees.

Few native species were observed on the waterway site visits occupying this niche. Species observed in this group include; *Carex appressa, Juncus sp., Persicaria decipiens, Lycopus australis, Phragmites australis, and Typha orientalis*. Exotic species such as *Phalaris aquatica* were commonly dominating this zone along the waterway sites visited.

Emergent vegetation can be a component of riparian EVCs of the dominate species in EVCs such as: EVC653 Aquatic Herbland, EVC821 Tall Marsh, EVC538 Brackish Sedgeland, EVC932 Wet Verge Sedgeland.

This niche's habitat was dominated by exotic grasses (*e.g. Phalaris aquatica, Phalaris arundinacea, Paspalum distichum*) and herbs (*Ranunculus repens, Rumex* sp,).

The waterway sites visited were missing key common emergent species from this group such as, *Bolboschoenus sp, Poa labillardierei* and *Schoenoplectus tabernaemontani*. This indicates low prevalence of channel benches or stable areas within the channel for the emergent species to establish.

Two main waterways processes could be responsible for this low diversity and cover of emergent vegetation.

- Changes in sediment transport due to increased flow efficiency clearing the channel of sands and gravels. This would be the result from historic straightening of the waterway (meander cut-off works),
- Unnatural hydrology where levels fluctuate beyond the ecological tolerance of the species resulting their failure to survive under that regime.

Objective: Improve condition, extent and diversity of emergent macrophyte vegetation in the waterways to provide structural habitat and channel/lower bank stability to low and moderate flows.

Riparian Vegetation
This is the terrestrial vegetation occupying the channel bank and adjacent floodplain which can only tolerate very brief (flood event) inundation. This vegetation requires soil moisture to persist and flows which inundate the channel banks will support its health.

In the study area this changes from the Riparian forests and woodlands in the upper areas of the catchment to swampy and floodplain woodlands in the middle to lower reaches below. The remnant riparian vegetation in the study is highly modified, quite narrow and in a few instances not expressed by representative species of the modelled EVC. The channel banks in reaches 3, 4, 5, 6, 10, 11 have minimal physical variation to support a diversity of species. This indicates changes from the natural state for these sites and is reflected in low vegetation diversity observed on site. Reach 6 (Latrobe River estuary) where natural levees have formed along the waterway have developed as a narrow band of riparian vegetation on the slightly elevated ground.
Reach 9 (Tyers River) is in a mostly undisturbed state and shows the expected diversity.

EVCs modelled for the riparian zone include: EVC16 Lowland Forest, EVC18 Riparian Forest, EVC53 Swamp Scrub, EVC56 Floodplain Riparian Woodland, EVC82 Riverine Escarpment Scrub, EVC126 Swampy Riparian Complex.

Species observed in this group includes; *Acacia dealbata, Acacia melanoxylon, Calystegia sepium subsp. roseata, Leptospermum lanigerum, Kunzea ericoides, Melaleuca ericifolia, Melicytus dentata, Eucalyptus ovata, Eucalyptus camaldulensis, Eucalyptus tereticornis.*

Eucalyptus tereticornis (Gippsland Red-Gum) is the dominant riparian canopy tree in the lower reaches especially the Latrobe River estuary.

The channel banks in reaches 3, 4, 5, 6, 10, 11 and are mostly dominated by exotic grasses e.g. *Phalaris* sp, with Blackberry and Willows.

Regeneration of many riparian species requires a disturbance event to open a space for seed to germinate or for flooding/fire to stimulate seed germination. Flows that move fill or spill from the channel create these disturbances and enable regeneration and improvements in vegetation extent while providing moisture to enable growth. Species such as Red Gums are reliant on these flow events to establish the conditions required for their reproduction and establishment of new plants. Natural regeneration was not observed at many sites and ensuring bank full and overbank flows will encourage reproduction of the riparian plants.

Objective: Improve condition, extent and diversity of riparian vegetation as part of endangered EVCs and provide shade and stability to the waterway channel.

Floodplain vegetation
This is the vegetation which relies on interseason overbank flows for adequate water. This vegetation has been largely cleared from the study area and replaced with pasture or other agricultural plants. Species observed include; *Eucalyptus camaldulensis, Eucalyptus tereticornis, Eucalyptus ovata, Melaleuca ericifolia*, *Melicytus dentata, Persicaria decipiens*.

EVCs modelled for the flood plain areas include: EVC53 Swamp Scrub, EVC56 Floodplain Riparian Woodland, EVC126 Swampy Riparian Complex, EVC334 Billabong Wetland Aggregate and EVC681 Deep Freshwater Marsh.

The floodplain depressions (billabongs) are likely to support the instream and emergent species above when conditions suit. Reach 5 has areas of Floodplain Riparian Woodland which are supported by overbank flows.

Regeneration of the floodplain vegetation is associated with flood events. Events that fill the floodplain in late winter to spring and drawdown naturally over the summer will provide the best results.

Objective: Improve condition and extent of floodplain vegetation especially where part of endangered EVCs.

Summary of objectives
The following objectives have been proposed for vegetation in the Latrobe system:

- Improve condition and extent of submerged aquatic vegetation to provide structural habitat for macroinvertebrates and various fish species.
- Improve condition, extent and diversity of emergent macrophyte vegetation to provide structural habitat and channel/lower bank stability to low and moderate flows.
- Improve condition, extent and diversity of riparian vegetation as part of endangered EVCs and provide shade and stability to the waterway channel.
- Improve condition and extent of floodplain vegetation especially where part of endangered EVCs.
- Maintain mosaics of vegetation communities in the lower Latrobe wetlands.

The following water quality objectives are also important for submerged and emergent vegetation:

- Limit surface water salinity to enable growth and reproduction of emergent vegetation
- Limit surface water salinity to enable growth and reproduction of submerged aquatic macrophytes

Table 14. Ecological Vegetation Classes (EVCs) in each study reach relevant to environmental water management

EVC name	Estuarine Wetland	Lowland Forest	Riparian Forest	Grassy Dry Forest	Herb-rich Foothill Forest	Damp Forest	Wet Forest	Cool Temperate Rainforest	Swamp scrub	Plains Grassy Woodland	Floodplain Riparian Woodland	Riverine Escarpment Scrub	Swampy Riparian Woodland	Swampy Riparian Complex	Valley Heathy Forest	Plains Grassland	Plains Grassy Forest	Billabong Wetland Aggregate	Deep Freshwater Marsh	Plantation
EVC #	10	16	18	22	23	29	30	31	53	55	56	82	83	126	127	132	151	334	681	
	Bioregional Conservation Status																			
Gippland Plain	*LC*	*V*	*V*	*LC*	*V*	*E*	*D*		*E*	*E*	*E*	*E*	*E*			*E*	*V*		*V*	
Highland Southern-fall		*LC*	*LC*	*LC*		*LC*	*LC*							*V*	*V*					
Strzelecki Ranges					*E*	*E*	*D*	*E*		*E*			*E*				*E*			
Lower Latrobe wetlands – Sale Common									✓		✓								✓	
Lower Latrobe wetlands – Heart Morass									✓		✓								✓	
Lower Latrobe wetlands – Dowd Morass	✓								✓		✓								✓	
Reach 3 – Latrobe River from lake Narracan to Scames bridge		✓							✓	✓	✓	✓						✓		
Reach 4 – Latrobe River from Scames bridge to Kilmany South									✓	✓	✓							✓		
Reach 5 – Latrobe River: Kilmany South to Thomson River confluence									✓		✓							✓		
Reach 6 – Latrobe River Estuary: Latrobe River from Thomson River confluence to Lake Wellington, and Thomson River	✓								✓	✓	✓							✓		
Reach 8 – Tanjil River		✓	✓								✓			✓	✓					
Reach 9 – Tyers River		✓	✓	✓		✓			✓											
Reach 10 – Morwell River		✓			✓	✓	✓	✓	✓	✓			✓				✓			✓
Reach 11 – Traralgon Creek		✓				✓	✓		✓				✓				✓			✓

EVC681 Deep Freshwater Marsh is EVC grouping which DELWP has used to map complex wetland areas. Different EVCs can coexist in these areas and can change their extent depending upon water availability and periods of inundation or changes in water quality. DEWLP have listed 40 EVCs which can be components of Deep Freshwater marsh. Table 15 shows wetland EVCs identified in the Lower Latrobe Wetlands by Frood et at (2015). The wetland EVCs are often seen as transitions between different communities and some have multiple floristic communities forming them. They occupy niches (often seasonally varying in area) determined by water depth and period of inundation, substrate material and salinity.

Table 15. Lower Latrobe River Wetland EVCs identified by Frood et al (2015)

EVC #	Name	Sale Common	Hearts Morass	Dowds Morass
EVC 306 *	Aquatic Grassy Wetland	✓		
EVC 653 *	Aquatic Herbland	✓	✓	
EVC 308	Aquatic Sedgeland	✓	✓	
EVC 334	Billabong Wetland	✓	✓	
EVC 934	Brackish Grassland		✓	
EVC 539 **	Brackish Lake Bed Herbland		✓	✓
EVC 656	Brackish Wetland Aggregate		✓	✓
EVC 948	Damp Melaleuca Scrub		✓	✓
EVC 949 *	Dwarf Floating Aquatic Herbland	✓	✓	
EVC 952	Estuarine Reedbed		✓	✓
EVC 953	Estuarine Scrub		✓	✓
EVC 56	Floodplain Riparian Woodland	✓	✓	✓
EVC 172	Floodplain Wetland Aggregate	✓	✓	✓
EVC 810	Floodway Pond Herbland	✓		
EVC 55	Plains Grassy Woodland			✓
EVC 125	Plains Grassy Wetland		✓	
EVC 819	Spike-sedge Wetland			✓
EVC 918 ***	Submerged Aquatic Herbland			
EVC 53	Swamp Scrub	✓	✓	✓
EVC 821	Tall Marsh	✓	✓	✓
EVC 990	Unvegetated (open water / mud flat)	✓	✓	✓
EVC A116 ****	Wet Sedgy Herbland		✓	✓
EVC 932 *	Wet Verge Sedgeland	✓		✓

* Limited distribution
** Presence inferred
*** Historic records
**** Provisional EVC

Water requirements

The different plant groups used in the study (submerged, emergent, riparian, floodplain vegetation) have different water requirements. This is shown conceptually in Figure 34, including the different flow components that can meet these water requirements.

The water requirements for the different plant groups are described below. The water regimes for the vegetation groups are informed by Frood and Papas (2016) who have attributed water regimes and salinity ranges for wetland (and some riparian) EVCs. Further detail for the water requirements of individual species is obtained from VicFlora (2016) and Roberts & Marsden (2011).

The Resource Condition Targets in the Gippsland Lakes Ramsar Site Management Plan include target #7 to: *Maintain extent, diversity and condition of native vegetation communities: swamp paperbark (Melaleuca ericifolia) woodland and common reed (Phragmites australis) emergent macrophyte beds.*

The planned watering regime needs to ensure that the conditions support the ongoing growth and regeneration of the Phragmites and Melaleuca plants in the wetlands. The extent of these will adjust over time in response to the water levels as reported in Frood et al (2015). The water regime in the wetlands is designed to ensure the Ramsar plan LACs are not exceeded.

Based on this information, the flow functions, flow components and timing are summarised in Table 16.

Submerged vegetation
Requires water or saturated soils throughout the year to survive and so low flows are required. In some instances, cease to flow events will assist in regenerating the plants and ensuring their ongoing occupation and expansion through the site. Threats to this vegetation include changes to hydrology with frequent reduced flow lowering water levels to stress the aquatic plants.

Emergent vegetation
These plants can grow in permanent shallow water but will be stressed by extended periods of time in depths >50cm. They require moist soils to grow and recruit new individuals and so low/high flow freshes through the year will support a diversity of niches in the waterway to support a variety of species. Threats to this vegetation include stock access, changes to seasonal flow with increased low flow from storage release, urban or industrial sources and stormwater pulses from catchment drainage changes. Weeds such as Willows and Spiny Rush are a constant threat. Young germinates are sensitive to inundation longer than 2-3 weeks which can kill them off reducing the regeneration from a flow event.

In wetland environments prolonged inundation sees decline in these species with sexual recruitment generally requiring damp soils. Filling of wetlands in winter-spring followed by a natural drawdown through summer provides conditions for growth and recruitment.

Riparian vegetation
These plants require a variety of wet and dry niches in the waterway to support a diversity of shrubs and trees. High flow freshes and bank full events cause some disturbance to provide spaces for recruitment and rejuvenation. Threats to this vegetation include stock access, reduced frequency high freshes leaving the upper bank vegetation stressed, and weeds especially Blackberries and woody weeds.

Floodplain vegetation
This vegetation requires full floodplain inundation via overbank flows to receive adequate soil moisture for floodplain depressions to persist in the environment. Threats to this vegetation include water diversions reducing frequency of overbank events, agricultural practices and stock impacts.

This vegetation often requires a summer drawdown or dry period to enable sexual reproduction to occur. Most wetland species have mechanisms (underground energy stores, bulbs, tubers etc) to survive a dry period.

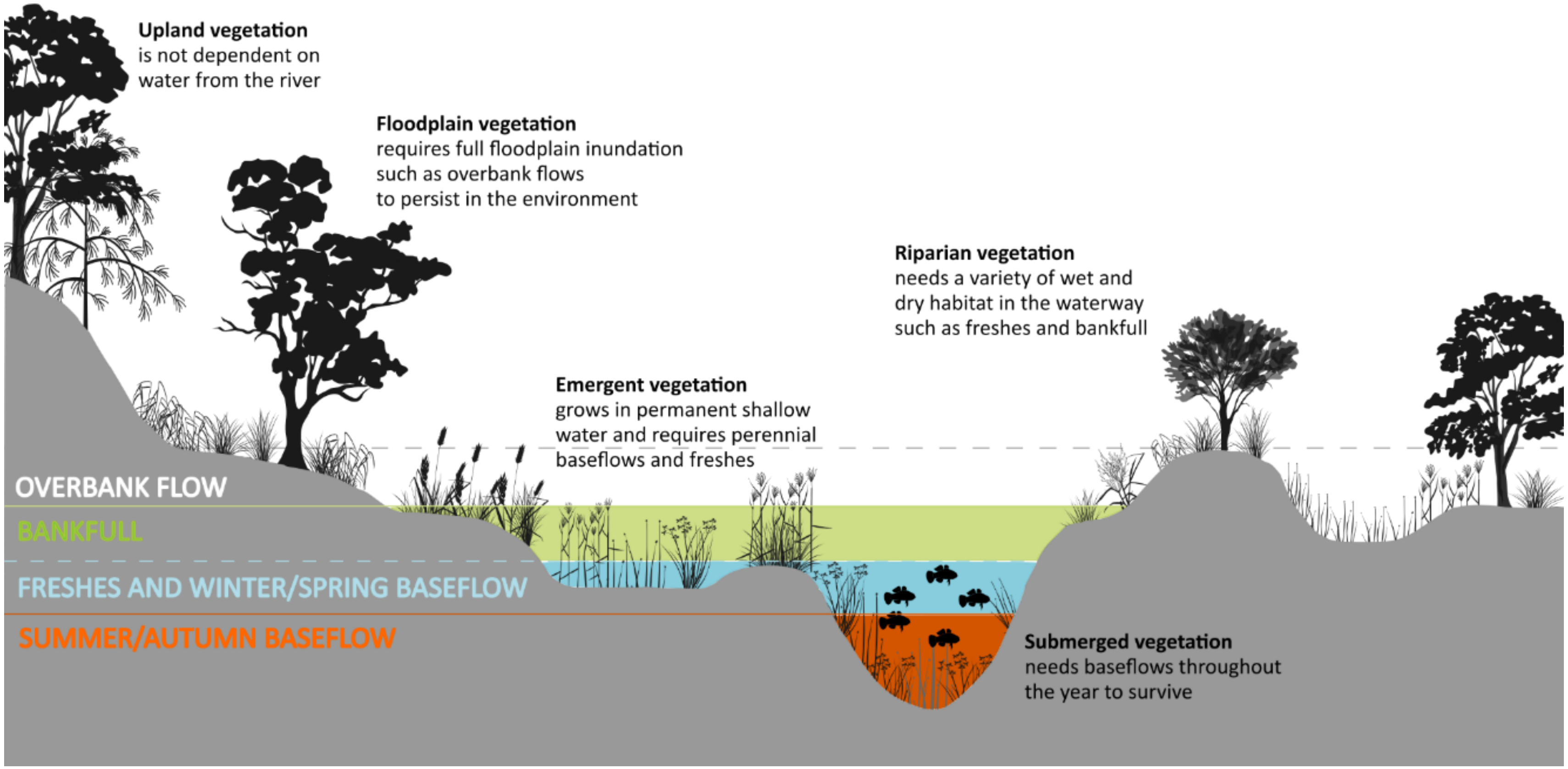


Figure 34. *Conceptual diagram of vegetation groupings and flow components*

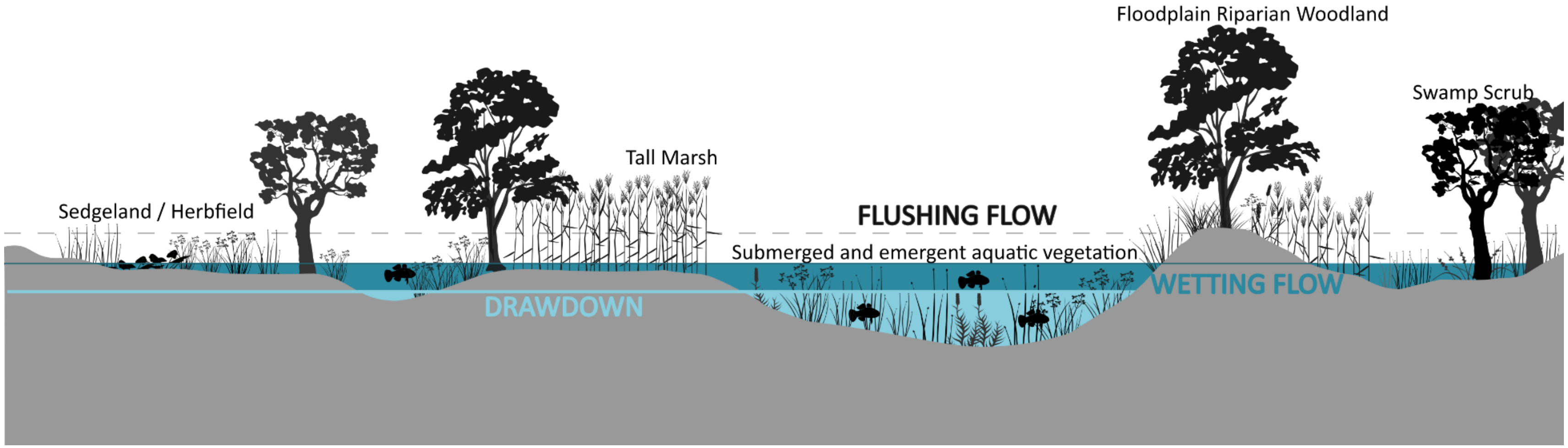


Figure 35. *Conceptual diagram of vegetation groupings and flow components in wetlands.*

Table 16. Flows required for healthy and diverse water dependent vegetation in rivers and estuary

<table>
<tr><th>Environmental objective</th><th>Relevant reaches</th><th>Flow function</th><th>Flow component</th><th>Timing</th></tr>
<tr><td rowspan="3">Improve condition and extent of submerged vegetation</td><td>River reaches and upper estuary</td><td>Maintain adequate depth of permanent water in channel</td><td>Base flow</td><td>All year</td></tr>
<tr><td>River reaches</td><td>Cease to flow with seasonal drawdown in late summer/autumn to promote recruitment</td><td>Cease to flow</td><td>1 every 2-3 years</td></tr>
<tr><td>Thomson River and Sale Canal</td><td>Maintain water quality to support health of Vallisneria sp beds</td><td>Base flow</td><td>All year</td></tr>
<tr><td rowspan="4">Improve condition, extent and diversity of emergent macrophyte vegetation on banks and shorelines to provide structural habitat</td><td rowspan="4">River reaches and estuaries</td><td>Maintain adequate depth of permanent water in stream channel to limit terrestrial encroachment into aquatic habitats.</td><td>Base flow</td><td>All year</td></tr>
<tr><td>Provide disturbance in riparian zone and channel to open recruitment niches for emergent plants.</td><td>Bankfull</td><td>~2 per year*</td></tr>
<tr><td>Support growth on terraces, channel edge and lower bank.</td><td>Fresh</td><td>~6 per year*</td></tr>
<tr><td>Provide a mosaic of spatially and temporally differentially wetted areas within stream channel, benches, lower banks and wetland margins.</td><td>Fresh</td><td>~6 per year*</td></tr>
<tr><td rowspan="4">Improve condition, extent and diversity of all riparian vegetation especially for endangered EVCs</td><td rowspan="4">River reaches
Upper and lower estuaries</td><td>Support growth of riparian vegetation on terraces, channel edge and lower bank</td><td>Fresh</td><td>~6 per year*</td></tr>
<tr><td>Provide disturbance in riparian zone and channel to open recruitment niches for riparian plants. Especially Eucalypt species.</td><td>Fresh</td><td>~6 per year*</td></tr>
<tr><td>Inundate all channel vegetation and support its growth.</td><td>Bankfull</td><td>~6 per year*</td></tr>
<tr><td>Provide mechanism for dispersal of riparian and floodplain seeds.</td><td>Overbank</td><td>Spring</td></tr>
<tr><td rowspan="2">Improve condition and extent of all floodplain vegetation especially for endangered EVCs (e.g. Swamp Scrub River reaches)</td><td rowspan="2">Upper estuary</td><td>Fill floodplain depressions and billabongs to support the growth of seasonal and emergent wetland vegetation.</td><td>Overbank</td><td>Spring/ summer</td></tr>
<tr><td>Inundate floodplain and provide moisture to floodplain species and promote carbon exchange</td><td>Overbank</td><td>1 every 2-3 years</td></tr>
</table>

* Or based on natural regime

Table 17. Flows required for healthy and diverse water dependent vegetation in wetlands

Environmental objective	Relevant reaches	Flow function	Watering regime	Timing
Maintain or restore a self -sustaining mosaic of **submerged and emergent aquatic vegetation** types	All wetlands	Provide habitat inundation for vegetative growth and flowering with seasonal variation of depth within the wetlands.	Wetting flow –partial fill	All year
		Increase oxygenation for germination and recruitment of aquatic vegetation	Drawdown	All year
		Water level fluctuations to provide conditions for reproduction and expansion of Swamp Scrub and Tall Marsh	Drawdown	Summer 2-3 months Areas to dry out in 1 in 2 years
		Encourage seed and propagule dispersal	Flushing flow	Winter / Spring (1 in 2 years)
		Reduce salinity levels to maintain species diversity	Flushing flow	Spring (1 in 2 years)
Maintain or restore the diversity, condition and/or extent of native **riparian vegetation fringing wetlands**	All wetlands	Encourage habitat inundation of riparian vegetation e.g. Floodplain Riparian Woodland (EVC 56)	Wetting flow – fill	Spring to early summer
		Encourage seed and propagule dispersal	Flushing flow	Winter / Spring
Discourage the introduction and spread, or reduce the extent and density, of **undesirable/invasive plant species**	Sale Common	Prolong habitat inundation (reactive management action	Wetting flow – fill	In response to extensive germination of undesirable dominate species (e.g. Juncus Ingens)
		Prolong drying of Aquatic Herbfields to reduce cover of exotic grasses (e.g. *Paspalum distichum)* and aquatic herbs (e.g. *Myriophyllum aquaticum*)	Drawdown	Summer / Autumn (minimum 3-4 months from December to April, every 1 in 3 years)

4.4 Healthy platypus, frog, waterbird and macroinvertebrate populations

The Latrobe River system, and the wetlands and estuary of the Latrobe River have aquatic fauna groups influenced by freshwater flows, including mammals, frogs and crustaceans, and waterbirds.

Aquatic mammals

Description and objectives

Platypus (marsupial) and water-rats (placental) are present within the system although their range and abundance are not well known.

While Platypus are not conservation listed, they are regarded as significant by local communities and will only persist if the correct habitat and food resource conditions exist. As a predatory species, healthy populations of platypus in the stream indicate high levels of macroinvertebrate productivity.

The objectives for platypus, relevant to all freshwater reaches and the upper estuary, are:

- Improve extent of platypus and rakali populations
- Maintain abundance of existing platypus and rakali populations

Water requirements

Platypus require low flows as their preferred habitat which enable foraging for aquatic macroinvertebrates. However, significant periods of cease to flows resulting in drying, will be detrimental to platypus' condition, leading to overcrowding in permanent habitats and potentially reduced population sizes (Serena and Williams, 2010). Fast flows can be tolerated for short periods.

Platypus generally prefer slow flowing waters and conditions which support large macroinvertebrate populations to allow feeding and gaining condition for breeding. Long periods of cease-to-flows are likely to lead to a reduction in the platypus' condition and less reproductive success (Serena and Williams, 2010).

The following conditions provide optimal platypus habitat and conditions (Serena and Williams, 2010):

- water present through summer and autumn for the survival of young
- pools at least 500 mm deep in channels wider than 5 metres, with a minimum of 300 mm in small habitats
- slow flows are generally required from 0.3 m/s to 0.5 m/s (up to a maximum of 1 m/s for short periods)
- water depths below 3m are preferred for feeding, but they can dive up to 9m deep
- large woody debris of >20 snags per 100 m is preferred by platypus
- Inundation of the littoral habitat to enhance aquatic macroinvertebrate populations in spring and summer.

In addition, the upper estuary may provide habitat for platypus and therefore, freshwater conditions in the upper estuary is considered in this study.

Table 18. Water requirements for aquatic mammals

Objectives	Relevant reaches	Flow function	Flow component	Timing
Improve extent of platypus and rakali populations	River reaches	Provide longitudinal connectivity between reaches for local movement	Fresh	Summer / Autumn
		Flow freshes to keep fine sediment from infilling gravel beds and allow large macroinvertebrate populations for food	Fresh	Winter / Spring
	Estuary (upper)	Provide freshwater habitat conditions in the (upper) estuary	Baseflow	Summer / Autumn
Maintain abundance of existing platypus and rakali populations	River reaches	Provide pool habitat for refuge/ permanent habitat	Baseflow	Summer / Autumn
		Support breeding opportunities by avoiding bankfull flows	Bankfull	Summer / Autumn
		Avoid extended high flows events to allow for foraging	Fresh / Bankfull	All year

Frogs

Description and objectives

At least 13 species of frog are present within the Latrobe system and in particularly will form large populations around the freshwater swamps in the Lower Latrobe system. Notable among these are Green and Golden Bell Frog and the Growling Grass Frog, both listed as endangered under the EPBC Act (Table 19).

Table 19. Frogs of the Latrobe River, and the wetlands and estuary of the Latrobe River (VBA 2018)

Common Name	Scientific Name
Common Froglet	*Crinia signifera*
Pobblebonk	*Limnodynastes dumerili*
Pobblebonk	*Limnodynastes dumerilii insularis*
Striped Marsh Frog	*Limnodynastes peronii*
Spotted Marsh Frog (race unknown)	*Limnodynastes tasmaniensis*
Green and Golden Bell Frog	*Litoria aurea*
Southern Brown Tree Frog	*Litoria ewingii*
Lesueur's Frog	*Litoria lesueuri*
Leaf Green Tree Frog	*Litoria nudidigitus*
Peron's Tree Frog	*Litoria peronii*
Growling Grass Frog	*Litoria raniformis*
Unknown Tree Frog	*Litoria verreauxii* (ssp. unknown)
Dendy's Toadlet	*Pseudophryne dendyi*
Southern Toadlet	*Pseudophryne semimarmorata*

The objectives for **Frogs**, relevant to river reaches, estuary (upper and mid) and wetlands, are:

- Maintain refuge habitats for frog populations
- Improve extent of frog populations

Water requirements
Most frogs are stimulated to breed by inundation at temporary (ephemeral) wetlands and stream-side channel sites, and with these conditions preferred over solely permanent waters (Wassens & Maher 2011). The exception to this is the growling grass frog which needs permanent water adjacent to grasslands for feeding and breeding (Heard *et al.* 2010). Hydraulic and water regime diversity is required, with permanent pools and regularly inundated benches and stream margins to support growling grass frog and other frog species.

Slightly saline water has been found to be beneficial to Growling Grass Frogs (Heard et al. 2010) and Green and Golden Bell Frogs (Kearney et. al. 2012) due to increased survival from chytrid fungus and larval survival in each species respectively.

Table 20. Water requirements for frogs

Objectives	Relevant reaches	Flow function	Flow component	Timing
Maintain refuge habitats for frog populations Improve extent of frog populations	Freshwater river reaches	Provide pool habitat	Fresh	Summer / Autumn
		Allow growth and reproduction of macroinvertebrate communities	Fresh	Winter / Spring
		Provide longitudinal connectivity between reaches	Fresh	Winter / Spring
	Upper estuary	Provide habitat with appropriate water quality	Fresh	Summer / Autumn
		Allow growth and reproduction of macroinvertebrate communities	Fresh	Winter / Spring
	Mid estuary	Provide habitat links between wetlands and estuary	Fresh	Spring
	All wetlands	Provide appropriate littoral habitat	Wetting flow – partial fill	Summer
		Allow growth and reproduction of macroinvertebrate communities	Wetting flow – fill	Spring
		Provide connectivity between river and wetlands and between wetlands	Wetting flow – fill	Spring

Turtles

Description and objectives
There is one turtle species recorded in the Latrobe system, *Chelodina longicollis,* which is commonly known as Eastern Snake-necked Turtle and is found in Reach 4 and Reach 10. The environmental water objective for turtles is to Maintain abundance of freshwater turtle populations. This objective is relevant to all freshwater river reaches and the Lower Latrobe Wetlands.

Water requirements
The reproductive success of turtles depends upon seasonal fluctuations in water levels to create conditions for prey populations (macroinvertebrates, fish and other aquatic life) for their diet and reproductive condition (Chessman 1983, 1988; Goodwin and Hopkins, 2005). This also creates a wide area along the channel banks for turtles to leave and return to the water, reducing the risk of fox predation and find suitable nesting habitat (Chessman, 1988; Goodwin and Hopkins, 2005).

The provision of slow flowing habitat through pools will allow turtles to persist over the low flow period and maintain condition for breeding, if suitable rainstorms occur to stimulate eggs laying.

Increasing productivity and feeding opportunities for aquatic fauna and turtles, in particular, will result from inundation of streamside habitat, which will be most effective in spring or summer. This will also help prepare the banks and breeding substrate at nesting time during summer (Chessman 1983, 1988; Goodwin and Hopkins, 2005).

Table 21. Water requirements for turtles

Objectives	Relevant reaches	Flow function	Flow component	Timing
Maintain abundance of freshwater turtle populations	Freshwater river reaches	Provide pool habitat	Baseflow	Summer / Autumn
		Allow growth and reproduction of macroinvertebrate communities	Fresh	Winter / Spring
		Flooding of banks and riparian zone to create conditions for nesting	Fresh	Spring/Summer
	All wetlands	Provide appropriate littoral habitat	Wetting flow – partial fill	Summer
		Allow growth and reproduction of macroinvertebrate communities	Wetting flow – fill	Spring
		Flooding of banks and riparian zone to create conditions for nesting	Wetting flow – fill	Spring/Summer

Birds

Description and objectives

Waterbirds are bird species that depend on water for feeding by swimming, diving or wading, or for the provision of nesting sites. Waterbirds constitute an important component of the Latrobe estuary and wetland ecosystem, with a diverse range of species present in, at times, significant numbers. The waterbirds associated with the Latrobe estuary (Latrobe, Thomson and Lower Latrobe fringing wetlands) include the Azure Kingfisher which occurs along the riparian zone and wetland waterbirds, such as the Darter, Little Pied Cormorant and Little Black Cormorant, Nankeen Night Heron, Egrets, Spoonbills, Terns, and Ibis as well as several species of ducks (such as the Grey Teal, Chestnut Teal and Pacific Black Duck). The majority of these species are not necessarily listed as conservation dependent but are regarded as important by many people.

However, the Caspian Tern is listed as threatened under the FFG Act and the EPBC Act as a Migratory Species, the Nankeen Night Heron which is listed under the EPBC Act as a Migratory Species and 'near threatened' on the DELWP advisory list and the Azure Kingfisher which is listed as 'threatened' on the DELWP advisory list.

The species present, and their abundance, are responding to the variety of wetland types present, their condition and the wetlands watering regimes. In the long-term, abundant and diverse native bird populations are indicative of wetland health (Reid and Brooks 2000). Each species requires suitable foraging, refuge and breeding habitat to be maintained within the wetland complex. To understand the requirements of the bird species, it is necessary to understand when they use the wetlands, and how the birds access the required resources.

In these systems waterbirds can be split into four general groups which include:

- non-breeding summer migrant wader species, which migrate north to breed in autumn and winter
- breeding or foraging species that respond to local flooding events and wetland productivity, which may move on a regional or large scale within Australia
- species seeking summer and drought refuge
- resident species that use the site all year round (Lloyd et al 2012).

There are 4 key foraging microhabitats for Australian waterbirds, these are:

- Deep/Open Water
- Shallow Water
- Reed Beds
- Shorelines/Mudflats

Understanding which birds feed where helps understand what habitats will benefit native birds and how the water regime and vegetation responses will benefit which species in the habitats that are created or supported (Table 22).

The objectives for birds are:

- Maintain or enhance waterbird and threatened fauna breeding, recruitment, foraging and sheltering opportunities in the Lower Latrobe Wetlands
- Maintain the different waterbird functional feeding groups in the wetlands, such as duck and rails, insectivorous guilds, colonial water birds, and shorebirds.
- Maintain abundance of Riparian zone birds in river reaches and the estuary

Water requirements
While Australian waterbirds are generally opportunistic in their patterns of movement, feeding ecology, habitat use, and patterns of reproduction and moulting (Kingsford and Norman 2002), they do respond to water regime changes by migrating locally or regionally. The suitability of habitats depend upon the vegetation present, the characteristics of the wetland (as determined by inflows creating cycles of inundation and drying), and the productivity of the wetlands. The permanent aspects of the fringing wetlands and estuary provide important summer and drought refuge for waterbird species either locally, regionally or from elsewhere in Australia and abroad (Lloyd et al 2012).

Forging habitat is determined by water depth, vegetation communities and physio-chemistry. The objectives for their water regime is likely to be provided from macroinvertebrate, vegetation and water quality objectives established elsewhere in this report.

Breeding requirements are also complex and require a diversity of conditions for successful breeding in waterbirds, these include:

- Inundation of the wetland needs to occur from late winter / early spring.
- Inundation in late winter / early spring must persist for long periods, for example a minimum of 4 months (for rapid breeders e.g. ducks) to 7 months for the successful breeding of most other waterbird species.
- Many waterbird species will not breed in wetlands with highly regulated water regimes which don’t mimic natural systems (Briggs et al. 1997).
- The water regime needs to be predictable with wetting and drying occurring within seasonal context (within and between years) with rapid and/or erratic changes in water levels within a wetland can result in low numbers of the food of many waterbirds in terms of aquatic invertebrates (Briggs et al. 1997).
- Sudden drops in water levels will also result in colonial nesting waterbirds abandoning their nests and young before they fledge (Kingsford 1998, Kingsford and Norman 2002).

In general, waterbirds require the following habitats/water requirements:

- deep/open water
- shallow water (<300 mm)
- reed beds
- shoreline/mudflats
- riparian zone habitats

Table 22. Waterbirds observed in study area [Data source: NatureKit]

Feeding Guild	Common Name	Scientific Name	Reach 3	Reach 4	Reach 5	Reach 8	Reach 9	Reach 10	Reach 11	Thomson Estuary	Sale Common	Dowd Morass	Heart Morass
Open water	Australasian Grebe	*Tachybaptus novaehollandiae*	O							O	O	O	O
	Australasian Shoveler	*Anas rhynchotis*	O					O			O	O	O
	Azure Kingfisher	*Alcedo azurea*	O							O	O		O
	Black Swan	*Cygnus atratus*	O		O			O		O	O	O	O
	Blue-billed Duck	*Oxyura australis*										O	
	Caspian Tern	*Hydroprogne caspia*								O	O		O
	Cattle Egret	*Ardea ibis*	O		O	O				O	O		O
	Chestnut Teal	*Anas castanea*	O		O			O		O	O	O	O
	Common Tern	*Sterna hirundo*											O
	Darter	*Anhinga novaehollandiae*	O							O	O		O
	Great Cormorant	*Phalacrocorax carbo*	O	O			O			O	O	O	O
	Great Crested Grebe	*Podiceps cristatus*									O		O
	Grey Teal	*Anas gracilis*	O		O	O		O		O	O	O	O
	Hardhead	*Aythya australis*	O								O	O	O
	Hoary-headed Grebe	*Poliocephalus poliocephalus*									O	O	O
	Little Black Cormorant	*Phalacrocorax sulcirostris*	O		O			O			O	O	O
	Little Pied Cormorant	*Microcarbo melanoleucos*	O	O				O		O	O	O	O
	Musk Duck	*Biziura lobata*									O	O	O
	Pacific Black Duck	*Anas superciliosa*	O	O		O		O	O	O	O	O	O
	Pied Cormorant	*Phalacrocorax varius*	O									O	O
	Pink-eared Duck	*Malacorhynchus membranaceus*	O									O	O
	Sacred Kingfisher	*Todiramphus sanctus*	O	O			O	O			O		O

Feeding Guild	Common Name	Scientific Name	Reach 3	Reach 4	Reach 5	Reach 8	Reach 9	Reach 10	Reach 11	Thomson Estuary	Sale Common	Dowd Morass	Heart Morass
	Silver Gull	*Chroicocephalus novaehollandiae*	O							O	O	O	O
	Spotted Harrier	*Circus assimilis*										O	
	Swamp Harrier	*Circus approximans*	O					O			O	O	O
	White-bellied Sea-Eagle	*Haliaeetus leucogaster*	O	O				O		O	O	O	O
Reed Beds	Australasian Bittern	*Botaurus poiciloptilus*									O	O	O
	Australian Spotted Crake	*Porzana fluminea*	O										
	Buff-banded Rail	*Gallirallus philippensis*									O		O
	Clamorous Reed Warbler	*Acrocephalus stentoreus*	O					O			O	O	O
	Golden-headed Cisticola	*Cisticola exilis*						O		O	O	O	O
	Little Bittern	*Ixobrychus minutus dubius*										O	
	Spotless Crake	*Porzana tabuensis*					O					O	
Shallow Water	Australian Shelduck	*Tadorna tadornoides*	O			O		O		O	O	O	O
	Eastern Great Egret	*Ardea modesta*	O					O		O	O	O	O
	Intermediate Egret	*Ardea intermedia*										O	
	Laughing Kookaburra	*Dacelo novaeguineae*	O		O	O	O	O	O	O	O		O
	Little Egret	*Egretta garzetta nigripes*									O		O
	Nankeen Night Heron	*Nycticorax caledonicus hillii*		O		O	O				O	O	
	Royal Spoonbill	*Platalea regia*	O					O			O	O	O
	White-faced Heron	*Egretta novaehollandiae*	O			O		O		O	O	O	O
	White-necked Heron	*Ardea pacifica*				O		O		O	O		O
	Yellow-billed Spoonbill	*Platalea flavipes*	O		O	O					O	O	O
Shoreline/ Mudflats	Australian White Ibis	*Threskiornis molucca*	O	O	O	O		O		O	O	O	O
	Australian Wood Duck	*Chenonetta jubata*	O	O		O	O	O		O	O	O	O
	Banded Stilt	*Cladorhynchus leucocephalus*										O	

Feeding Guild	Common Name	Scientific Name	Reach 3	Reach 4	Reach 5	Reach 8	Reach 9	Reach 10	Reach 11	Thomson Estuary	Sale Common	Dowd Morass	Heart Morass
	Black-fronted Dotterel	*Elseyornis melanops*			O			O		O	O	O	O
	Black-tailed Native-hen	*Tribonyx ventralis*											O
	Black-winged Stilt	*Himantopus himantopus*			O						O	O	O
	Cape Barren Goose	*Cereopsis novaehollandiae*								O	O		
	Common Greenshank	*Tringa nebularia*									O	O	O
	Dusky Moorhen	*Gallinula tenebrosa*	O		O	O		O		O	O	O	O
	Eastern Curlew	*Numenius madagascariensis*											O
	Eurasian Coot	*Fulica atra*	O		O			O		O	O	O	O
	Fairy Tern	*Sternula nereis*										O	
	Freckled Duck	*Stictonetta naevosa*											O
	Glossy Ibis	*Plegadis falcinellus*									O		O
	Latham's Snipe	*Gallinago hardwickii*						O			O	O	O
	Little Tern	*Sternula albifrons sinensis*										O	O
	Marsh Sandpiper	*Tringa stagnatilis*									O		O
	Masked Lapwing	*Vanellus miles*	O	O	O	O		O		O	O	O	O
	Purple Swamphen	*Porphyrio porphyrio*	O		O	O		O	O	O	O	O	O
	Red-capped Plover	*Charadrius ruficapillus*										O	
	Red-necked Avocet	*Recurvirostra novaehollandiae*									O		O
	Red-necked Stint	*Calidris ruficollis*										O	O
	Sharp-tailed Sandpiper	*Calidris acuminata*									O		O
	Straw-necked Ibis	*Threskiornis spinicollis*	O		O	O				O	O	O	O
	Whiskered Tern	*Chlidonias hybridus javanicus*									O	O	O
	White-winged Black Tern	*Chlidonias leucopterus*										O	O

Table 23. Flows required for waterbirds in all reaches

Environmental objective	Relevant reaches	Flow function	Watering regime	Timing
Maintain abundance of Riparian zone birds	River reaches Estuary	Flooding of riparian vegetation for foraging habitat	Overbank	Winter / Spring 3 out of 5 years
Maintain or enhance waterbird and threatened fauna breeding, recruitment, foraging and sheltering opportunities Maintain the different waterbird functional feeding groups in the wetlands, such as duck and rails, insectivorous guilds, colonial water birds, and shorebirds.	Estuary	Provide access to fresh drinking water	Fresh	Dry and Winter / Springs
	All wetlands	Stimulation of bird breeding - Nesting for some waterbirds, including rails and waterfowl, and for birds requiring waterbodies next to reed beds (including Australasian bittern, royal spoonbill, several duck species, shorebirds, pied cormorants). Waterbird food supply - foraging along shallow margin for insectivorous guilds with inundation.	Wetting flow – partial fill	July to November, annually
		Waterbird food supply and breeding habitat provision Waterfowl, piscivorous and herbivorous waterbird foraging while inundated Nesting habitat for colonial and other waterbirds in inundated reed bed, and for birds requiring broad waterbodies and deep water next to reed beds Provides access to fresh drinking water for waterbirds. Maintain suitable environmental conditions to continue to support White Bellied sea eagle.	Wetting flow – fill	September to October, annually
		Flooding of fringing vegetation and samphire communities for waterbird and terrestrial avian species foraging habitat. Provides access to fresh drinking water for waterbirds by flushing salts and nutrients. Maintain abundance of Riparian zone birds (including Azure Kingfisher, Nankeen Night Heron).	Flushing flow	July to December for in about three years out of five
		Expose mudflats and submerged and emergent vegetation communities Increase waterbird food supply Facilitate waterbird foraging Stimulate nutrient cycling Expose wetland fringe and create shallows for a many shorebird species and other waterbird species from all guilds.	Drawdown	November to May, three years in five

Macroinvertebrates and Zooplankton

Description and objectives

Macroinvertebrates and zooplankton are important species in their own right, including two listed as endangered species under the FFG Act. They also have roles in nutrient and organic matter processing and in the role of larger invertebrates, such as yabbies, shrimps and insect larvae, in the food chains of fish, frogs, platypus, turtles and waterbirds (Brookes *et al.* 2009).

Many species will be present but not all are recorded or known. Table 24 shows the larger crustaceans recorded in the Latrobe River, and the wetlands and estuary of the Latrobe River. Habitat and hydraulic diversity determine the diversity and abundance of invertebrate, and other aquatic fauna, in aquatic ecosystems. Instream benches, deep holes, undercut banks, woody debris, aquatic vegetation and overhanging vegetation all contribute to habitat diversity, breeding and feeding locations and protection from predators (Brookes *et al.* 2009).

Table 24. Crustaceans found in the Latrobe River, and the wetlands and estuary of the Latrobe River (VBA 2018)

Common Name	Scientific Name	FFG Status
Common Freshwater Shrimp	*Paratya australiensis*	
Common Yabby	*Cherax destructor*	
Gippsland Spiny Crayfish	*Euastacus kershawi*	
South Gippsland Spiny Crayfish	*Euastacus neodiversus*	Endangered
Central Highlands Spiny Crayfish	*Euastacus woiwuru*	
Richards Burrowing Crayfish	*Engaeus laevis*	
Strzelecki Burrowing Crayfish	*Engaeus rostrogaleatus*	Endangered

The objectives for Macroinvertebrates and Zooplankton, relevant to river reaches and the upper estuary are:

- Maintain abundance of macroinvertebrates and zooplankton as a food source for fish, frog and platypus populations
- Improve breeding and recruitment of macroinvertebrates and zooplankton as a food source for fish, frog and platypus populations

Water requirements

Freshwater flows and variations in water levels support the bacteria-rich biofilms on woody debris and rocky substrates, these in turn support macroinvertebrates communities. The mix of algae and bacteria in biofilms changes during long periods of inundation of the substrates, such as sediment, woody debris and rocks on the base of the stream. The longer a surface is inundated the more it becomes dominated by algae, which have a lower nutritional value than the bacteria (Burns and Walker 2000). Water level fluctuations created through the flow components (freshes, low flows and high flows) produce the necessary water level variations to create the food resources at an optimal level for macroinvertebrates.

Flow events in river, wetlands and estuaries provide a period of 'predictable' changes to the environment which can be exploited by many aquatic and floodplain organisms (Lloyd *et al.* 1994). Flow events and inundation of sediments is a major factor in the hatching of invertebrate eggs, and the growth of invertebrate populations (Boulton and Lloyd 1992, Quinn *et al.* 2000; Balcombe *et al*. 2007; Brookes *et al.* 2009).

Flow freshes and high flows inundates benches and engages low lying areas within the river channel which creates hydraulically diverse habitats. Drying results in invertebrates laying desiccant resistant eggs which can hatch on subsequent inundations, proving vital resources to fish, platypus and frogs (Boulton and Lloyd 1992; Balcombe et al. 2007; Brookes et al. 2009). Abundance in freshwater micro zooplankton (rotifers) contribute to spawning success of fish (Boulton and Lloyd 1992). Rotifer abundance and dormant eggs have a negative relationship with salinity in estuary wetlands (Dolan & Gallegos 1992).

The wetting and drying cycle in streams and their riparian zones results in significant carbon and nutrient fluxes which drive ecosystem productivity in these systems (Robertson et al. 1997; Burns et al. 2001). The positive relationship between high flows and Rotifer abundance indicate that the higher river benches and adjoining floodplain are important areas for rotifer egg deposition and storage (Boulton and Lloyd 1992; Balcombe et al. 2007; Brookes et al. 2009).

Organic carbon and nutrients drive microbial production, including the growth of algae, bacteria and fungi, which form the food for zooplankton and many grazing and filter feeding invertebrates. Consequently, this microbial productivity results in increased food availability for vertebrate fauna including fish, frogs, waterbirds and platypus (Brookes et al. 2009).

Table 25. Water requirements for Macroinvertebrates and Zooplankton

Objectives	Relevant reaches	Flow function	Flow component	Timing
Improve abundance of all macroinvertebrates and zooplankton populations	River reaches Upper Estuary	Sustain macroinvertebrate and zooplankton communities during summer as a food source for fish, frog and platypus populations	Fresh	Summer / Autumn
		Create and extend aquatic habitats for macroinvertebrates and zooplankton (including rotifers)	Fresh	Winter / Spring
		Create aquatic floodplain habitats for macroinvertebrates and zooplankton (including rotifers) and stimulate production	Bankfull or overbank	Winter / Spring
	River reaches	Maintain pool habitat	Low flow	Summer / Autumn

4.5 Supporting functions: Geomorphology

Description

Fluvial geomorphology describes the size, shape and diversity of the river channel and the processes by which these elements of the stream system form and change through time. The geomorphology (or physical form) of a river can be described at a range of spatial scales, from the catchment to the microhabitat scale (Sear 1996), which can each correlate with habitat types (Frissell *et al.* 1986). A diversity of habitat types provides the physical basis for a diversity of biota (Treadwell *et al*. 2006, Newson 2002), and consequently is an important factor in providing a healthy river.

Physical features that provide habitat niches include meanders, pools, benches, bars, bank undercuts and variations in substrate. Each of these physical features interacts with flow to create hydraulic habitats (e.g. secondary flow structures at meanders, or areas of slack water on benches) that are preferentially used by different biota (Sagnes, Merigoux and Peru 2008). A diversity of channel form therefore provides a diversity of both physical and hydraulic habitats

While stream geomorphology can have limited inherent value itself, it imparts value by providing essential structural habitat and facilitating ecological processes. A key focus of fluvial geomorphology in environmental flow assessments is linking physical characteristics to the important ecological processes. For example, fish eggs will not incubate if they are covered by sand and finer material after being deposited on gravel.

Primary factors that influence the geomorphic form of the stream system include:

- the frequency, duration, timing and magnitude of water in the stream system
- the volume and size of sediment delivered to and transported through the stream system
- the source and presence of large wood in the system

The Latrobe River basin

As one of the most disturbed river systems in Victoria, the lower Latrobe River has experienced a number of channel changes since the late 1800s. Reinfelds *et al.* (1995) outline these changes, including:

- A 25% reduction in channel length due to artificial meander cut-offs
- Increases in mean channel width
- Incision of up to 1.05 meters
- 67% increase in channel capacity, resulting in a threefold reduction of overbank flow duration
- Channelisation, reducing the frequency of minor flooding and period of floodplain inundation

Grazing impacts

Stock grazing and its associated land clearing activities have had a significant impact on the riparian zone of many Australian waterways (Jansen et al. 2006; Lester and Boulton 2008). In the Latrobe catchment, land use (including stock access to waterways), vegetation clearing, and erosion have all been identified as threats to the values of the system (WGCMA 2012).

Agricultural practices can lead to a variety of changes and disturbances along waterways including loss of vegetation cover (which in turn influences shading, water temperatures and large wood loads) and increased erosion (which has consequences for bank stability, sedimentation and nutrient input rates). These impacts are complex and interdependent as demonstrated in Figure 36.

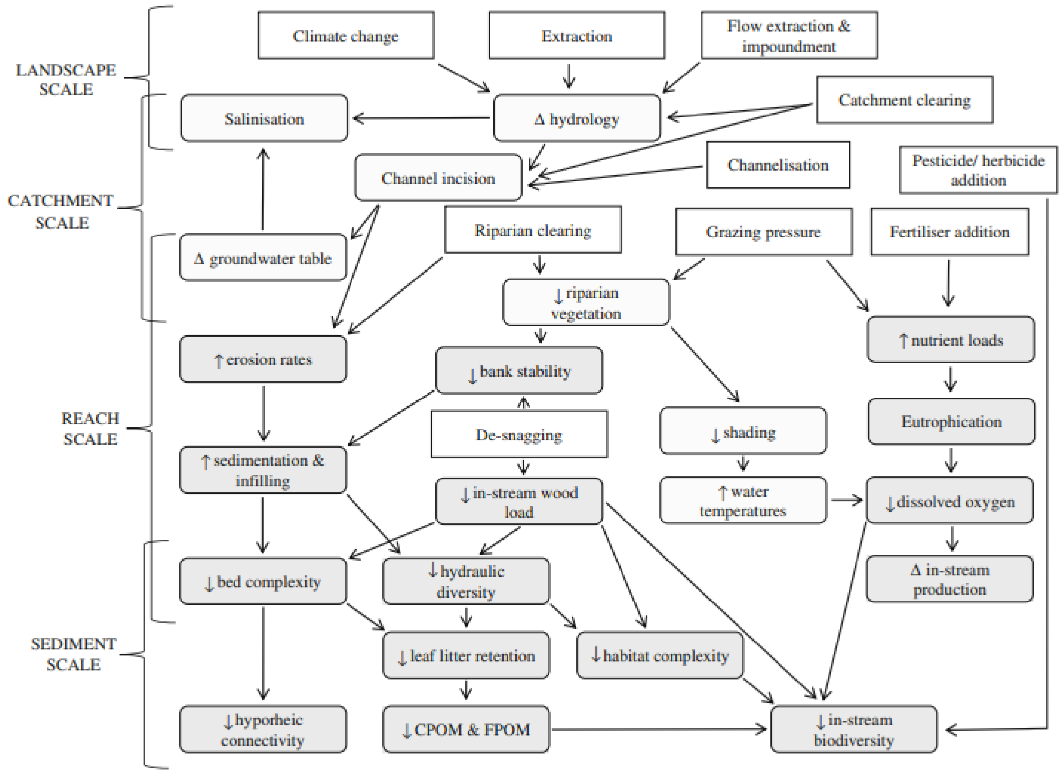


Figure 36. *Agricultural pressures and their impacts (Lester and Boulton 2008)*

One of the largest agricultural impacts on geomorphology is through stock access and while it is not the only factor influencing bank erosion and stability, it does play an important role. Stock grazing reduces ground cover vegetation and exposes more bare ground, while trampling increases soil compaction and potential runoff.

These factors can increase erosion and the delivery of sediment, as well as nutrients into waterways (Jansen et al. 2006; Trimble and Mendel 1995).

Land clearing for agriculture, including within the riparian zone, is another major factor influencing stream geomorphology. Clearing of riparian vegetation following European settlement has been demonstrated to be a major factor in the substantial widening that occurred along many rivers across south-eastern Australia (Rutherfurd et al. 2006). Along the Latrobe River, Abernethy and Rutherfurd (1998) found that well vegetated riparian zones can lead to a reduction in erosion processes through the increased resistance afforded by large woody debris and standing vegetation as well as the stabilising effect of vegetation root masses on streambanks.

Mining impacts
The Latrobe River has been described as a working river because of its high consumptive demands from the industrial, agricultural and energy sectors and urban demand (Earth Tech 2007). Mining activities within the catchment have had a substantial impact on the physical form of the Latrobe and Morwell Rivers. Multiple river diversions to support mine expansion have had substantial impacts on the geomorphic processes in the system. They include:

- The diversion of the Morwell River at Yallourn in 2005. This diversion replaced an underground pipe and accompanying floodway with an unvegetated aqueduct and resulted in the relocation of the confluence of the Morwell River with the Latrobe River (Alluvium 2009).
- The diversion of the Morwell River at Hazelwood in 2009 which replaced a previous pipe and floodway diversion with a meandering channel (Alluvium 2009).
- The diversion of the Latrobe River at Yallourn in 2007. This diversion was an emergency measure after the collapse of the Yallourn coal face which captured the Latrobe River. Downstream of the mine, the Latrobe River ceased to flow for 7 days while the diversion was constructed, part of which follows an historic meander cut-off (Alluvium 2009).

Channelization and large wood removals
The Latrobe River basin has been substantially modified since the late 1800s through channel straightening and meander cut-offs, de-snagging, flow regulation and vegetation clearing. The purpose of these works was to reduce waterlogging and improve floodplain drainage, reduce the occurrence of floodplain inundation and increase agricultural production.

One of the most significance disturbances is the installation of an estimated 77 meander cut-offs in the mid-lower reaches of the Latrobe River between Yallourn and Lake Wellington, with over 80% of the cut-offs undertaken since 1924. Another major disturbance to the Latrobe River is the de-snagging activities which started around 1890s. Historical records reported that major de-snagging started in 1936 and up to three layers of logs had been removed from the riverbed and had reduced the riverbed level by up to 2 metres (Earth Tech 2005). These modifications have led to significant geomorphic disturbances:

- Meander cut-off have caused the channel length to reduce by around 25% and changed the channel sinuosity vary up to approximately 58% (Earth Tech 2005; Hillemacher et. al. 2012; WGCMA 2018)
- As a result of channel straightening, these meander cut-offs had led to accelerated bank erosion, channel incision (deepening and widening of the river) and loss of instream benches and other habitat features.
- Ongoing channel incision has reduced overbank inundation and increased sediment loads, nutrient production and transport down to Gippsland Lakes (Alluvium 2009)
- Ongoing channel incision as a result of the constructed meander cut-offs had led to poor stream condition in the Latrobe River downstream of Lake Narracan (Alluvium 2009), leading to some loss of ecological function (SKM 2009)
- The ongoing channel incision has increased the amount of water required to meet the flow requirements, to provide floodplain inundation for remnant vegetation communities (Alluvium 2009)

Reach descriptions

Latrobe River – Reach 3

This reach of the Latrobe River is immediately downstream of Lake Narracan. The channel is confined through its upper reaches, but the floodplain widens downstream of the Yallourn Mine where the Morwell River and Tyers River enter the Latrobe River (EarthTech 2005). The floodplain through this reach has been cleared for agriculture and has also been subject to mining activities. Native riparian vegetation is largely absent and tree cover consists predominately of willows. The channel is relatively straight although it has not been subject to artificial meander cut-offs like lower reaches of the Latrobe. Where it does display a meandering channel pattern, sandy bars are present on the inside of bends. Channel substrate is silt-clay and some in-channel large wood is present along the reach. Bed load sediment is provided to the reach by the Morwell River with Lake Narracan acting as an effective trap for bed load sediment from the upper Latrobe River and tributaries.

Latrobe River – Reach 4

This reach of Latrobe River has been heavily impacted by grazing on the adjacent floodplain, modified flows from river regulation at Lake Narracan and past river management works such as channel straightening (Earth Tech 2005). The impact of these activities is evident in sections with unstable banks and in the lack of instream channel features such as benches. At the time of the inspection bed substrate was not visible although the previous study found that in this reach, bed material consists largely of clays (Earth Tech 2005).

Latrobe River – Reach 5

Like Reach 4, this reach has been historically impacted by channel straightening. Unlike the upstream reaches however, this reach has been subject to meander reinstatement works. The channel in this reach now meanders through floodplain woodland. Banks are generally stable with some undercutting, consistent with what would be expected in a healthy lowland river. Some in-channel large wood is present throughout the reach.

Tanjil River (Reach 8)

The Tanjil River is regulated through the operation of Blue Rock Reservoir located in its upper reaches. Immediately downstream of the reservoir, the channel flows through a confined reach before entering onto the broader floodplain (Earth Tech 2005). This reach is impacted by floodplain agriculture. The riparian zone is largely cleared of native vegetation. Some isolated willow is present. Bank erosion is evident in places, most likely as a result of stock access to the waterway, lack of native riparian vegetation, and sediment starvation as the reach is immediately downstream of a large dam (which traps sediment from upstream catchment). Channel substrate through the reach is sandy and some limited residual large wood present.

Tyers River (Reach 9)

The Tyers River is regulated through the operation of the Moondarra Reservoir in its upper reaches. A large part of the reach is confined by bedrock and flows through state forest. This part of the catchment is very steep and public access to these areas is low (Earth Tech 2005). Geomorphic form in this reach is largely intact although some vegetation encroachment of the channel may be occurring in response to reduced stream flow. The channel is wide and displays a typical pool riffle sequence with large, deep pools and gravel riffles. Bedrock bars are present along the reach and there are high, large wood loadings through the reach.

Morwell River (Reach 10)

The Morwell River has been heavily impacted by past management activities. The upper catchment is forested, however agricultural activities have had an influence in the downstream reaches. The biggest impact on the Morwell River has been through mining activities with multiple channel diversions. Riparian vegetation is dominated by exotic herbs and grasses as well as some willows. Banks are steep but appear stable and consist of very fine silts.

Traralgon Creek (Reach 11)

Traralgon Creek is an unregulated stream however, it does receive licensed industrial discharges from the operation of the Loy Yang power station and significant stormwater runoff from the urban centre of Traralgon (EarthTech 2005). The reach displays a generally meandering pattern, however, immediately downstream of the Loy Yang discharge point, the channel is relatively straight. Banks are steep and instream benches are present with the predominate substrate composed of fine silts. In the section immediately downstream of the Loy Yang discharge point, rock riffles are present, most likely derived from the mobilisation of quarried rock, installed in the Long Yang discharge channel, during flood events.

Latrobe River Estuary (Reach 6)
The Latrobe River estuary is a levee-backswamp system with the Latrobe and Thomson Rivers situated between natural levees which sit above the Lower Latrobe Wetlands (Water Tech 2013). This reach has been described as sinuous rather than meandering due to the low valley gradient in this area (Erskine et al. 1990). The Latrobe estuary has a cuspate delta, the silt jetties which protrude out into Lake Wellington and are a site of state geomorphological significance. Since the 1950s, bed of phragmites along the shoreline of the jetties have narrowed and erosion has occurred (Water Tech 2013).

The Latrobe estuary has been historically modified by works to improve navigability including channel realignments, de-snagging and dredging. Additionally, sediment inputs from the catchment are likely to have increased as a result of land use change and vegetation loss along the channel banks has likely increased the susceptibility to erosion (Water Tech 2013).

Summary of objectives
The geomorphic objective for the Latrobe system is to provide and maintain habitat to support ecological values and processes. This includes the following functions

- Restore and maintain the extent (area, volume) of available habitat in the Latrobe River and tributary stream channels
- Provide and maintain the diversity of habitat features within the channel including pools, riffles, and benches
- Provide and maintain channel structure including presence of pool depth, presence of large wood, and some undercut banks
- Support related processes including
    - Prevent elevated algae accumulations on riffles and large wood
    - Prevent thermal stratification of pools

These objectives are relevant to all the reaches in the system.

There is an additional environmental objective relating specifically to the geomorphology of the estuarine reach:

- Maintain the silt jetties and the bar at the mouth of the Latrobe River

Water requirements
The diversity and complexity of habitats that support ecological values, such as pools, riffles and benches, are maintained by the geomorphic processes that shape the channel and floodplain. The physical form of a stream depends on its flow regime, the characteristics of its bed and bank sediment, the riparian and instream vegetation, valley controls (such as confinement and valley slope) and the sediment inflow regime. The geomorphic processes and form change over time if any of the factors, for example changes in the flow regime through regulation (Gregory *et al.* 2008), removal of riparian vegetation (Simon & Collison 2002) and interruptions or increases in the sediment supply from upstream (Petts & Gurnell 2005).

Sediment aggradation, transport and deposition is determined by a number of factors, including sediment size (and volume), stream slope and discharge (or flow) (Figure 37). Given the context of a FLOWS study, and limited ability to influence sediment size, volume and stream slope. The focus is to make recommendations for flow components required to maintain and/or improve the extent, abundance and diversity of geomorphic features. Freshes, Winter / Spring base flow, bankfull and overbank flows are the most relevant flow components in terms of sediment mobilisation, transport and deposition as these are the components that account for most geomorphic work (i.e. not Summer / Autumn base flow).

Bankfull flow is particularly important for formation and maintenance of channel form and diversity (US Department of Agriculture 2007; Knighton 1998). It is commonly used as an analogy for the dominant discharge, i.e. the single flow that determines channel features such as cross-sectional capacity (Leopold & Wolman 1957) or the flow considered to do most geomorphic work in terms of sediment transport (Wolman & Miller 1960).

Changes in the frequency and duration of bankfull flow are likely to lead to changes in channel form, potentially leading to the removal of physical features important as habitats. Providing bankfull flows is therefore important to maintain the cross-channel form (i.e. the general size and shape of the channel) and in particular deep pools. Bankfull flows are also important for mobilising sediment trapped in marginal vegetation communities that drive channel contraction.

Smaller and more regular events that have the capacity to mobilise bed load sediment will also be important in the maintenance of channel diversity.

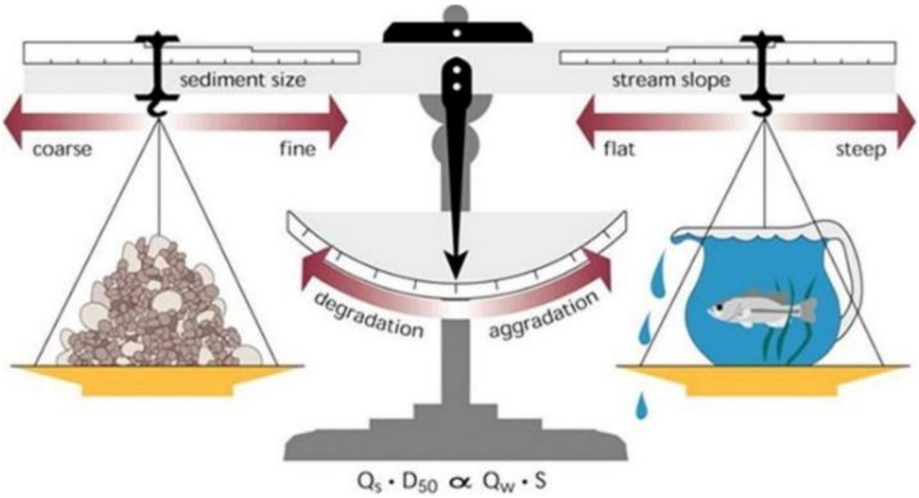


Figure 37. *Lane's balance diagram demonstrating the influence of sediment size (and volume), stream slope and discharge on sediment aggradation and deposition (Lane 1955)*

The flow functions required to meet the environmental objective are:

- Restore and maintain gross channel size and habitat volume
- Provide and maintain channel diversity
- Provide and maintain local habitat
- Provide and maintain floodplain processes

The flow components required to achieve these flow processes are Summer / Autumn freshes, Winter / Spring base flows (high flows), Winter / Spring freshes, bankfull flows and overbank flows. These requirements are summarised in Table 26.

Table 26. Flow requirements to achieve geomorphic objectives for all reaches

Environmental objective	Relevant reaches	Function	Flow component	Timing
Maintain habitat to support ecological values and processes	River reaches	Maintain gross channel capacity through provision of the dominant channel-forming flow events (bankfull events)	Bankfull	Any time
		Maintain gross channel capacity through provision of events capable of mobilising bed load sediment	High flows	Winter / Spring
		Provide flows that establish and maintain high flow benches (scour and deposit sediment on high flow benches)	Freshes	Winter / Spring
			Bankfull	Anytime
		Provide flows that maintain low flow benches through Summer / Autumn (scour and deposit sediment on low flow benches)	Fresh	Summer / Autumn

Environmental objective	Relevant reaches	Function	Flow component	Timing
		Provide flows that maintain pool depth and abrade algae on riffles and large wood through Summer / Autumn, by scouring fine sediment from bed of pools.	Fresh	Summer / Autumn
		Provide overbank inundation to enable exchange of sediment and carbon to and from the river	Overbank Anytime	Overbank
Maintain the silt jetties and the bar at the mouth of the Latrobe River	Lower estuary	Maintain bed load sediment export from the Latrobe River	Bankfull	Anytime

The following criteria should be adopted for the above flow components and objectives.

The **frequency and duration** of events should be indicatively within a band of 80 to 120% of natural to ensure geomorphic processes are maintained.

For the **scour of sediment**, the following criteria can be adopted:

- A shear stress of 1.1 N/m^2 has been adopted for the mobilisation of coarse sands (Reach 3,4,5,8,9,10)
- A shear stress of 0.6 N/m^2 has been adopted for the mobilisation of fine sands (Reach 11)
- A shear stress of 0.1 N/m^2 has been adopted for the mobilisation of non-colloidal silts (Latrobe River estuary)

The criteria for maintaining the bar and silt jetties at the Latrobe River mouth should include:

- Maintain flow velocity that is sufficiently high to transport sediment (silts) through the estuary to the river mouth.
    - Settling velocity for sand is 0.01 m/s
- Ensure salt wedge is displaced into Lake Wellington (to minimise its impact on sediment transport and impacts on phragmites establishment)

Note: We are aware of a potential conflict between the geomorphic objectives including the criteria set out above and water quality objectives for the Gippsland Lakes. The geomorphic objectives seek to establish and maintain bed load sediment transport. Bed load sediment transport is an essential element of functioning alluvial stream systems. However, we are aware of objectives to reduce suspended sediment and nutrient loads to the Gippsland Lakes. Nitrogen and phosphorus is commonly found adsorbed onto the surface of fine suspended sediments. Flow regimes that can transport bed load sediment (as set out in this study), will have the capacity to also transport this fine sediment, with attached nitrogen and phosphorus, to the Gippsland Lakes.

A number of process and objectives have been proposed under this environmental flow study to address this potential conflict including:

1. Provision of overbank inundation to enable suspended sediment to be distributed, deposited and stored on adjoining floodplains
2. The provision of freshes to assist the formation of in-channel depositional benches for the storage of fine sediments
3. The provision of a flow regime that allows and encourages the establishment of fringing emergent aquatic vegetation such as phragmites. This vegetation serves many purposes, some of which are to assist in the trapping and storage of fine sediment and to take up nutrient loads from such stored sediments.

4.6 Supporting functions: Water quality

The environmental objectives relating to water quality for the Latrobe system are:

- Maintain adequate flows to reduce potential of prolonged stratified conditions in pools and promote adequate levels of water quality to allow fish and macroinvertebrate populations to persist.
- Maintain adequate flows to promote levels of water quality to allow fish and macroinvertebrate populations to persist, particularly through avoiding/reducing eutrophication and algal blooms.
- Limit surface water salinity to enable growth and reproduction of emergent vegetation and submerged aquatic macrophytes.
- Maintain freshwater supply to Latrobe Estuary, Dowd Morass, Sale Common, Heart Morass, and also associated freshwater/brackish habitats.

Description

An overview of the condition of water quality across the study area is presented in Appendix E.

Water quality varies naturally across landscapes, with climate, landform, soil type, vegetation and location within a stream system all influencing the water quality at a location. These influences are reflected in Victoria's surface water segments presented in the State Environment Protection Policy (Waters) [SEPP (Waters)]. Each surface water segment has its own set of water quality objectives that reflect the effects of the natural environment. Although the surface water segments in Victoria are largely defined by these natural features, the SEPP (Waters) water quality objectives within each segment also reflect the effects of land use changes within the segment. Accordingly, each of the segments are classified into either 'largely unmodified'; 'slightly to moderately modified'; or 'highly modified'.

In the project area for this flow study, the reaches are all located within two surface water segments: the Coastal Plain of the 'Central Foothills and Coastal Plain' segment (lightly to moderately modified); and the 'Uplands A' segment, draining the southern foothills of the Great Dividing Range (Table 27). Although not part of the SEPP (Waters) delineation, the study reaches within the Coastal Plain can be further divided into those that are part of the mainstem of the Latrobe River and those that are tributaries to the river. The two Uplands A reaches are both tributaries to the Latrobe River. Reaches 8 and 9 can be further distinguished from the other two tributary reaches through their location immediately downstream of substantial reservoirs.

Table 27. Segments and Stream Position of stream reaches in the study area

SEPP (Waters) segment	Reach No. and Name	Stream position
Coastal Plain	Reach 3 – Latrobe River from Lake Narracan to Scarnes Bridge	Mainstem Latrobe River
	Reach 4 – Latrobe River from Scarnes Bridge to Rosedale	
	Reach 5 – Latrobe River from Rosedale to Thomson River confluence	
	Reach 6 – Latrobe River downstream of the Thomson River confluence	
	Thomson River Estuary	
	Reach 10 – Morwell River	Tributary
	Reach 11 – Traralgon Creek	
Uplands A	Reach 8 – Tanjil River	Tributary, below reservoir
	Reach 9 – Tyers River	

Coastal Plains

Water quality data summarised over a period of approximately 15 years from the mainstem reaches of the Latrobe River did not meet the SEPP (Waters) objectives at any WMIS site examined for any water quality indicator tested, except pH. These results reflect the largely agricultural landscapes that the reaches flow through, often with extensive catchment clearance, poor riparian cover and substantial stock access to the waterways. These impacts contribute sediments and nutrients to the stream system, resulting in elevated turbidity levels, phosphorus and nitrogen concentrations, and electrical conductivities. Similar land use impacts were reflected in the water quality results in the tributaries on the Coastal Plains (Reaches 10 and 11), although Traralgon Creek (Reach 11) had generally better water quality, most likely reflecting the fact that a substantial part of its catchment lies in the less impacted Strzelecki Ranges.

The elevated nutrient concentrations in these reaches may lead to eutrophic conditions, impacting the physical habitat via blooms of phytoplankton, filamentous algae and weeds. Eutrophic conditions are also likely to lead to oxygen-stress, particularly during warmer periods when flows are likely to be lowest, plant and algal growths high, and oxygen concentrations dangerously low for the stream biota. Flow measures to ameliorate these impacts would include stricter coordination of any water extractions from the waterways or nearby groundwater, and provision of small and large freshes.

Uplands A

Reaches 8 and 9 (Tanjil and Tyers Rivers) are both situated below substantial reservoirs (Blue Rock Lake and Moondarra Reservoir, respectively). Although both reaches may technically be placed within the Coastal Plain, the WMIS sites used in these reaches were both close to the outlets of reservoirs that drain predominantly forested, Uplands A catchments. The maintenance of forested catchments in these catchments will lead to less soil erosion and hence less inputs of sediments and nutrients to the receiving streams. Further, the reservoirs will trap a substantial proportion of sediments delivered to them, further reducing sediment and nutrient loads in the stream system downstream.

The water quality data at the WMIS sites for Reaches 8 and 9 met the SEPP (Waters) objectives for all indicators assessed. Despite the high-quality water, both reaches were assess as only being in 'Moderate' condition by the Index of Stream Condition. This is reflecting the flow stress caused by the unnatural flow regime from the reservoirs on channel morphology and aquatic life and, in the Tanjil River, the exacerbating effects of a highly agricultural catchment downstream of the Blue Rock Reservoir creating a highly modified streamside zone and further impacting aquatic life.

Wetlands

The water properties (based on evidence of change in salinity and nutrient enrichment activities) of Sale Common, Heart Morass and Dowd Morass were all rated as excellent in the 2011 Gippsland Lakes Report Card (Gippsland Lakes & Catchment Taskforce 2011). In contrast, the hydrology was generally rated as 'Very Poor'.

Using more recent data from the Waterwatch Victoria data portal (http://www.vic.waterwatch.org.au/water_data_portal.php), the *Water Measurement Information System* (WMIS) (http://data.water.vic.gov.au/monitoring.htm), and information from Hale et al (2018) to supplement the older data in the report card, allows the following descriptive summary of the three wetlands:

- Sale Common is a freshwater system, with electrical conductivity ranging from approximately 250 to 1000 µS/cm with a median around 450 µS/cm. Its pH is circum-neutral, averaging around 7 and its turbidity fluctuates spatially and temporally, with a max turbidity of 300 NTU recorded at one location (South Gippsland Highway) whereas at a nearby location (Stephenson Street Boardwalk) recorded 35 NTU on the same day).
- Dowd Morass is a brackish but variably saline wetland fringing Lake Wellington that has experienced intrusions of saline water from Lake Wellington. Water quality data from the *Water Measurement Information System* (WMIS) (http://data.water.vic.gov.au/monitoring.htm) (approximately 60 sampling events between 1996 and 2018) documents the variability in salinity, with electrical conductivity ranging from approximately 400 to over 26,000 µS/cm with a median around 2800 and a 75th percentile at 7600 µS/cm. pH at the site was also highly variable: despite a median of 7.2 and a 75th percentile of 7.5 pH units, it highest pH was 9.4 and its lowest was 3.6, with nearly 20 percent of its pH readings being below 4.0, its turbidity also fluctuates, with a minimum turbidity recorded as below detection and a maximum of 760 NTU recorded. The results are widespread, with 25th and 75th percentiles being 10 and 85 NTU, respectively.

- **Heart Morass** typically has slightly higher salinities than Dowd Morass, with a median electrical conductivity of 5570 µS/cm from approximately 60 measurements recorded between 2001 and 2018 (Waterwatch Victoria data portal, site WG_HRT514). The minimum measure during this period was 330 and the maximum was 17900 µS/cm. The site was clearly more acidic (from acid sulphate soils - Frood et al. 2015), with a 25th percentile of 3.2, a median of 3.9 and a 75th percentile of 4.5 pH units. In contrast, the turbidity of the site was low, most likely due to the acidic conditions, with a median of 12, a 75th percentile of 19 and a maximum of 150 NTU

Objectives and relevant reaches

The following objective is relevant for all study reaches:

- Avoid adverse water quality conditions and prolonged stratified condition in pools such as high nutrients, Low DO or high salinities

In addition, the following objective applies to the Latrobe River Estuary:

- Maintain surface water salinity at a level to enable growth and reproduction of emergent vegetation on banks and shoreline of estuary.
- Maintain freshwater supply to Latrobe Estuary, Dowd Morass, Sale Common, Heart Morass, and associated freshwater habitats

Lastly, the following objectives are applicable to all wetlands:

- Provide suitable physio-chemical conditions to support aquatic biota

Water requirements

Maintenance of low flows (avoidance of cease-to-flow events) and the provision of small and large freshes will be important for the provision of acceptable water quality for all reaches. this will be particularly so in summer, when high nutrient concentrations can combine with optimal growth conditions and lead to algal blooms and water weed infestations. Sufficient provision of all flow components should be allocated year-round as required to maintain freshwater supply to the wetlands of the study area and also Lake Wellington.

The relevant functions and flow components for the water quality objectives are provided in Table 28.

Table 28. Water quality objectives and functions for all reaches

Water quality objective	Relevant reaches	Function	Component	Timing
Avoid adverse water quality conditions and prolonged stratified condition in pools such as high nutrients, Low DO or high salinities	River reaches and Estuary	Maintain dissolved oxygen levels in pools above thresholds for gill-breathing organisms (fish, macroinvertebrates and zooplankton) during summer/autumn	Low flow	Summer / Autumn
		Flush pools to maintain good dissolved oxygen levels, low salinity and low nutrients in the water column to support aquatic ecosystems (e.g. fish, macroinvertebrate populations and zooplankton)	Fresh	Summer / Autumn
Maintain surface water salinity at a level to enable growth and reproduction of emergent vegetation on banks and shoreline of estuary.	Estuary	Limit surface water salinity to enable growth and reproduction of emergent vegetation and submerged aquatic macrophytes.	Bankfull	Any time

Maintain freshwater supply to Latrobe Estuary, Dowd Morass, Sale Common, Heart Morass, and associated freshwater habitats	Estuary	Provide sufficient freshwater to maintain freshwater wetland flora and fauna, including provision of habitat for foraging, reproduction and longitudinal connectivity	All	Any time
Provide suitable physio-chemical conditions to support aquatic biota	Heart Morass Dowd Morass	Export salt	Flushing flow	Spring, 1 in 2 years
		Minimise saltwater intrusion	Wetting flow – partial fill	
		Minimise acid sulfate soils risk	Wetting flow – partial fill	All year
	All wetlands	Breakdown organic matter and encourage nutrient recycling	Drawdown	

The frequency and duration for the above objectives should be based on the flow requirements of flora and fauna identified in this study.

To prevent and remove **thermal stratification** in pools, the following criteria can be adopted:

- A velocity of 0.1m/s through pools to help prevent thermal stratification (low flows)
- A velocity of 0.3m/s through pools to remove thermal stratification from pools. (Summer / Autumn fresh)

4.7 System limitations

Maintaining the ecological objectives and supporting functions in the Latrobe catchment cannot be achieved through the provision of the recommended environmental flow regime alone. Other threats and constraints can limit the achievement of objectives in parts of the Latrobe system. These limitations include:

- Deterioration of water quality and saline intrusion
- Stream bed and bank condition
- Exotic species
- Flow limiting infrastructure
- Barriers to fish movement
- Grazing pressure

Complementary management actions are recommended for these system limitations to help optimise the benefit of improvements in the flow regime.

Deterioration of water quality and saline intrusion

Declining water quality is evident through the catchment. Threats include acidification, eutrophication, pollution, litter and stormwater inputs. Water quality is an important factor for the survival of most flora and fauna. The water quality of the study area reflects ongoing significant impacts from catchment clearance, poor riparian cover and stock access to the waterway. The high nutrient concentrations are expected to lead to eutrophic conditions in the river, impacting the habitat and contributing to oxygen-stress. Maintaining water quality in the Latrobe catchment cannot be achieved through the provision of the recommended environmental flow regime alone.

Aside from these water quality threats from upstream, saline intrusion is a major consideration. Saline intrusion events into Dowds Morass are anticipated to become more frequent and last longer with climate change, the associated sea level rise and reduced flows from upstream.

Stream bed and bank condition

Geomorphic processes are strongly influenced by riparian vegetation. The root systems of trees increase the shear strength of the bank sediments, reducing the likelihood of mass failure. Ground covers 'shield' bank material from high shear stress and reduce hydraulic entrainment (removal) of sediment particles. Clearing of vegetation, including through stock grazing, can result in bank erosion and bed incision of streams, increasing sediment delivery to the river and changes in channel morphology. Much of the Latrobe system has been subjected to past clearing and stock and grazing pressures, with livestock access to waterways causing bank erosion, degraded riparian vegetation and water quality issues.

Exotic species

Invasive species are one of the biggest threats to the environment. Exotic species that require complementary management include, but are not limited to:

- exotic vegetation species
- introduced fish species such as exotic carp species, including goldfish, carp, roach, tench, eastern gambusia, redfin perch, rainbow trout and brown trout
- invasive fauna such as rabbits and foxes.

Riparian vegetation management

Riparian vegetation provides an important habitat corridor for wildlife, provides shading for aquatic biota and assists in maintaining stream stability and water quality. The environmental flow regime aims to provide the conditions to support self-sustaining diverse riparian and wetland vegetation in the Latrobe River system. This supports the ongoing health of the existing vegetation and natural regeneration processes to enable recruitment of new individuals to regenerate the plant communities. Additional significant influences on the health and condition of riparian vegetation are the adjacent land use and impacts of agriculture, livestock grazing, deer (Sambar) grazing and recreation.

Instream and riparian vegetation limit channel erosion processes and provide essential instream and riparian habitat for species targeted for environmental water. In the longer-term, riparian vegetation provides the source of essential large wood to the stream system. The current degraded riparian corridor can be attributed to past clearing and ongoing grazing pressure.

Flow limiting infrastructure

The provision of environmental flows can be constrained by the capacity of the available infrastructure to deliver water from storages (i.e. channels and gates) and flow capacity constraints in the system (e.g. weirs, levees and bridges). The inundation of private land also needs to be considered when delivering environmental flows.

Barriers to fish movement

Fish need to be able to move freely between habitats and reaches for spawning, feeding and dispersal. Waterways have been modified and barriers to fish passage, such as dams, and weirs and road culverts have been constructed. Unrestricted fish movement is a key characteristic of a healthy waterway and while environmental flows can assist in fish movement, physical barriers can limit their effectiveness. Lake Narracan, in particular, is a major fish barrier in the Latrobe River system. Other barriers include the other storages on the Latrobe River system including, Moondarra and Blue Rock together with several smaller weirs on the Tyers River including Wirilda Park weir, the constructed watercourse diversion through the Yallourn open cut pit, and Yallourn Weir.

Stock access and bank stability

While stock access is not the only factor influencing bank erosion and stability, grazing and trampling can increase bank slumping, with increased nutrient and sediment inputs to the channel impacting on the Lower Latrobe Wetlands downstream. Riparian fencing and off-stream watering points can reduce stock access and associated impacts on the riparian zone.

5 Gunaikurnai Traditional Owner cultural water objectives

This section describes the Gunaikurnai Traditional Owner cultural water values of the Latrobe system, and the flow objectives that support these values. This section has been developed based values identified in the Aboriginal Waterways Assessment for the Durt-Yowan (Latrobe River system) recently undertaken by GLaWAC. The Environmental Flows Technical Panel used this information to identify the relevant flow objectives (from Section 4) and ensure objectives and criteria suitably covered the Traditional Owner cultural water values identified by GLaWAC. Gunaikurnai words have also been provided for use in relevant sections of this report.

These Gunaikurnai Traditional Owner cultural water values and objectives are summarised in Table 29.

Heathy Country

The overarching objective to provide and maintain aboriginal cultural values is '**healthy country'.** Healthy country refers to the importance of place and the health of the entire ecosystem, with some specific elements including water quality, controlling pest species and maintaining a natural, seasonal flow regime. The concept of **healthy country** includes the practices of only taking what you need and moving seasonally.

While the health of the broader landscape and waterways is important, there is particular emphasis on the health of the Latrobe estuary and Lower Latrobe Wetlands as this is where Boran (pelican) crossed the Durt-Yowan on his way south (see Creation Story below).

A **seasonal flow regime** with wet and dry periods is an important element of healthy country. This element is captured through flow components adopted for this investigation – defining water requirements at different times of year and for different years helps to determine flow recommendations that provide a seasonal flow regime.

Quarenook (meeting place) is an important value. This includes lifestyle, family, storytelling and Mia Mia (camping) values as well as Woorngan (hunting), tool making and food / materials, and providing fish for Bunjil Tambun (the fish hunter). The wetlands are important Quarenook, including the rookery at Dowd Morass, Gidai (black swan) nesting at Sale Common and Heart Morass as well as canoe scar trees. Some of the aspects of fishing/hunting, tool making, and food / materials are discussed further below.

Maintaining the **Lower Latrobe Wetlands** as a Quarenook (meeting place) requires **seasonal variation in flows** to maintain a diversity of wetting/drying cycles to deliver a variety of vegetation and habitat outcomes. This will ensure the seasonal populations of birds and fish are available to enable the continued cultural practices. This also requires **deep enough freshwater** in the wetlands to provide appropriate habitat conditions for important plants and animals. Overbank flows also play an important role in ensuring floodplain input and ongoing productivity of these areas.

Providing **freshwater to the Lower Latrobe Wetlands** is important. Historically the Lower Latrobe Wetlands would have been fresh, and most of the values are tied to maintaining freshwater ecosystems. For example, the presence of canoe scar trees and the rookery at Dowd Morass demonstrates the importance of freshwater to that wetland. That is, canoe scar trees indicate that there was hunting plants and animals would have been present for hunting and collected; freshwater would have provided the conditions suitable for these plants and animals.

While the Lower Latrobe Wetlands were once a freshwater system, the system has been fundamentally changed since the opening of the Gippsland Lakes. This is acknowledged in the Ramsar objectives. Returning to a freshwater system is beyond the current catchment constraints and beyond the scope of this study. Nonetheless, freshwater supply to the lower Latrobe Wetlands is still an important objective of this study, but the ultimate goal is not a completely freshwater system for the lower Latrobe Wetlands.

Maintaining **water quality** is also a sign of healthy country in the river and estuary reaches. Freshwater flows can be provided to avoid adverse water quality conditions.

Objectives:
Maintain freshwater supply to Latrobe Estuary, Dowd Morass, Sale Common, Heart Morass, and associated freshwater habitats
Avoid adverse water quality conditions and prolonged stratified condition in pools such as high nutrients, Low DO or high salinities

Controlling pest species is an important part of healthy country and, where possible, returning country to its natural state. This includes controlling carp and streambank weed species (e.g. blackberries). European carp can be minimised in the wetlands by having drawdown periods and also through inclusion of carp screens on any wetland infrastructure. A flow regime that supports native fish also provides an advantage for native fish compared to European carp.

Environmental flows are generally ineffective at controlling these inundation-tolerant species (e.g. Blackberries) as they are neither sufficiently prolonged or deep to cause mortality and can instead promote their growth and dispersal. This has been observed in monitoring in the Thomson system (Arthur Rylah Institute for Environmental Research 2019). While weed reduction is not typically targeted through environmental flow, the regeneration of native species is targeted with environmental flows through vegetation objectives. The flow regime aims to provide disturbances and water availability aligned to supporting regeneration of native species.

Complementary measures such as increasing cover of riparian mid-storey and canopy species can reduce the vigour and impact of some weed species. Recent work has shown that revegetation plantings can be used a weed suppression method for Phalaris infestations in wetland and riparian situations (Sutcliffe, 2019). However, management of exotic plant species, aiming for a reduction in weed impacts, needs to be addressed as a land and catchment management activity. This could require cooperation between the land management agencies and landholders. Collaborative programs targeting priority weed species such as Blackberry can be undertaken.

Objectives:
Minimise European carp (reduce habitat)
Minimise exotic plant impact on healthy country through targeting native vegetation species

Keystone species

The Mother and Father song line within the Gunaikurnai creation story is important. If Boran (pelicans) and Tuk (musk duck) are living and breeding there, it is a sign Country is healthy. Or, if they are not present, then provide the flows to promote required habitat/ecosystem services and Boran and Tuk will return.

Creation Story
In dreaming terms, the first Gunaikurnai came down from the mountains in Victoria's northwest carrying his gree (canoe) on his head. He was Borun, the pelican. He crossed over the river at what is now Sale, and walked on alone to Tarra Warackel (Port Albert) in the west. As he walked, he heard a constant tapping sound but could not identify it. When he reached the deep water of the inlets, Borun put down his gree and, much to his surprise, there was a woman in it. She was Tuk, the musk duck.
He was very happy to see her and she became his wife and the mother of the Gunaikurnai people – they are the parents of the five Gunaikurnai clans.

Boran (pelican) require open water with good populations of fish, shrimps and yabbies species to survive. **Tuk (musk duck)** dive in deep water mainly feed on animals, including aquatic insects, crustaceans, snails, shellfish, fish, frogs and ducklings. Flow events which stimulate fish and macroinvertebrate populations to breed and build large populations are critical to both species. Habitat and food source would typically be provided from Lake Wellington. Boran breed in colonies on peninsulas and islands in lakes. Small breeding colonies are present in Lake King. Boran are flexible in requirements (time / space) as long as physical conditions and biological requirements are met. Tuk respond to seasonal cues for breeding but require open water habitat and good prey populations to thrive and have successful breeding events.

Objectives: Maintain the different waterbird functional feeding groups in the wetlands, such as duck and rails, insectivorous guilds, colonial water birds, and shorebirds

Yeerung and Djeetgun (Fairy wren) are also a totem species, although they are not considered water dependent. While environmental flows may not directly support Yeerung and Djeetgun, a diversity of flows supporting shrubs and riparian vegetation will provide habitat for fairy wren. For example, when flooding inundates wetlands, bush birds (including Yeerung and Djeetgun and other species) are known to increase in abundance and diversity (Parkinson et al. 2002; Baxter et al 2005; Ballinger and Lake 2006).

Objectives: Improve condition, extent and diversity of all riparian vegetation

Balagen (Platypus) are an important keystone species. Balagen are considered an umbrella species. The provision of freshwater allows Loombrak (water ribbons) to grow, and macro invertebrates to feed on the algae that grow on the Loombrak. These macro invertebrates are the food source of Balagen and the Loombrak contributes to Balagen's habitat. Supporting Balagen platypus is relevant to the river reaches and Upper Estuary.

Objectives: Improve extent of and maintain abundance of existing platypus (Balagen) & rakali populations

Traditional practices

Traditional practices include Bunjl Tambun (fishing) / Woorngan (hunting), food, materials, and tool making. It is important to maintain and restore freshwater habitat to support native fish populations for **Bunjl Tambun (fishing) / Woorngan (hunting)**. In particular, species of significance include Noy yang (eels), Australian Bass, River Blackfish, Estuary perch and Kine (Black Bream).

Birds can also be important for Woorngan (hunting) / food, including Nalbong (water hens – colloquially known as "bush chooks"), Gidai (black swans) and Boyangs (eggs), and Koortgan (ducks except Tuk, musk duck). Gidai (swans) require submerged and softer emergent vegetation to make nest mounds. The nest is placed either on a small island or floated in deeper water. Gidai breed in late winter to early spring following water level increases. Objectives which produce filling of the large wetlands and support the growth of Loombrak (water ribbon) and submerged aquatic plants will support Gidai (Pringle 1985). Ensuring the lower wetlands and floodplain depressions (e.g. billabongs) receive freshwater flows in Winter / Spring will provide the conditions for submerged and emergent aquatic plants to grow and provide the food and nesting materials for the water birds.

Objectives:
Maintain abundance of Noy yang (eel) populations
Maintain abundance and improve recruitment of Australian Bass populations
Improve recruitment of River Blackfish
Maintain abundance and improve breeding and recruitment of estuarine resident species including Estuary Perch, and Kine (Black Bream)
Maintain the different waterbird functional feeding groups in the wetlands, such as Koortgan (duck) and rails, insectivorous guilds, colonial water birds, and shorebirds.
Maintain or restore a self -sustaining mosaic of submerged and emergent aquatic vegetation types in wetlands and floodplain depressions.

Loombrak (Water ribbon, *Triglochin sp*) is important for food and basket weaving, as well as being a food source for animals and nesting areas for birds and habitat for fish and frogs; this is particularly relevant in the estuary and Lower Latrobe Wetlands.

Many other **reeds and grasses** are also used for basket weaving; emergent vegetation is relevant to river reaches, the estuary and the wetlands.

Yooro gree (Red-gum canoe trees) are important cultural values. They are located around the lower Latrobe Wetlands and some floodplain areas of the lower Durt-Yowan (Latrobe River). There are limited records of scar trees along the Latrobe River, particularly upstream of Rosedale.

Objectives:
Improve condition, extent and diversity of emergent macrophyte vegetation on banks and shorelines.
Improve condition and extent of submerged vegetation to provide structural habitat for macroinvertebrates and various fish species.
Maintain water quality to support health of Vallisneria sp beds in Thomson River and Sale Canal
Improve condition, extent and diversity of riparian vegetation as part of endangered EVCs.

Tools (stone blades etc) are also important but are typically made elsewhere and brought to the wetlands**. Rock grooves** near Rosedale are important, but there are no specific flow requirements. Overbank flows that inundate billabongs, would support cultural practice in the area rock grooves are found. This could reflect an increased food availability in the area supporting the practice that produced the rock grooves.

Table 29. Summary of Traditional Owner cultural water values and objectives

Objective	Traditional Owner Cultural water value	Reach	Function	Component	Timing / frequency
			AQUATIC MAMMALS		
Improve extent of platypus & rakali populations Maintain abundance of existing platypus (Balagen) & rakali populations	Keystone species	All river reaches	Provide longitudinal connectivity between reaches for local movement	Fresh	Summer / Autumn
			Provide pool habitat for refuge/permanent habitat	Baseflow	Summer
			Flow freshes to keep fine sediment from infilling gravel beds and allow large macroinvertebrate populations for food	Fresh	Winter / Spring
		Upper estuary	Provide freshwater habitat conditions in the (upper) estuary	Baseflow	All year
			FISH		
Maintain abundance of **eel (noy yang)** populations	Fishing (Bunjil Tambun) / hunting (Woorngan)	All river reaches except 8, 11 Estuary reaches	Provide water in pools and freshwater for habitat and food sources	Baseflow	All year
			Provide water over riffles / freshwater to allow fish to migrate upstream from estuary	Fresh	Nov to May
			Downstream migration of eels (noy yang) to allow for ocean breeding	Fresh	Oct to May
			Provide water over riffles to allow longitudinal connectivity and for fish to move between pools	Fresh	April to August
Maintain abundance of **Australian Bass** populations Improve recruitment of **Australian Bass** populations	Fishing (Bunjil Tambun) / hunting (Woorngan)	All river reaches except 8, 11	Provide water in pools for habitat and food sources	Baseflow	All year
			Provide water over riffles to allow fish to move between pools to feed, grow and find new habitats (allow juvenile Tupong to move upstream)	Fresh	August to Feb
			Provide connectivity to allow fish to migrate downstream to breed	Fresh	March to July
		Estuary reaches	Downstream migration of Australian Bass adults to allow for estuarine breeding	Fresh	April to July
			Allow upstream movement of juveniles into freshwater habitats	Fresh	Sept to April
			Maintain freshwater habitat	Baseflow	All year

Objective	Traditional Owner Cultural water value	Reach	Function	Component	Timing / frequency
Improve recruitment of **River Blackfish**	Fishing (Bunjil Tambun) / hunting (Woorngan)	All river reaches	Submerge and clean woody debris and hard surfaces to provide breeding substrate	Fresh	Nov to Jan
Maintain abundance and improve breeding and recruitment of estuarine resident species including **Estuary Perch**, and **Black Bream (Kine)**	Fishing (Bunjil Tambun) / hunting (Woorngan)	Reach 5 and Estuary	Provide water in pools and freshwater for habitat and food sources	Baseflow	All year
			Downstream migration of Estuary adults to allow for estuarine breeding	Fresh	July to August
			Flows which maintain estuarine salinities and high dissolved oxygen levels	Fresh	Sept to December
			Provide water over riffles and freshwater to allow longitudinal connectivity and for fish to move between habitats	Fresh	Sept to March
			BIRDS		
Maintain the different **waterbird functional feeding groups** in the wetlands, such as duck and rails, insectivorous guilds, colonial water birds, and shorebirds.	Mother and Father song line within the Gunaikurnai creation story (Boran and Tuk) Hunting (Woorngan) / food	All wetlands	Stimulation of bird breeding - Nesting for some waterbirds, including rails and waterfowl, and for birds requiring waterbodies next to reed beds. Waterbird food supply - foraging along shallow margin for insectivorous guilds with inundation	Wetting flow – partial fill	Annually
			Waterbird food supply and breeding habitat provision Waterfowl, piscivorous and herbivorous waterbird foraging while inundated Nesting habitat for colonial and other waterbirds in inundated reed bed, and for birds requiring broad waterbodies and deep water next to reed beds Provides access to fresh drinking water for waterbirds. Maintain suitable environmental conditions to continue to support White Bellied sea eagle.	Wetting flow – partial fill	Annually
			Flooding of fringing vegetation and samphire communities for waterbird and terrestrial avian species foraging habitat Provides access to fresh drinking water for waterbirds by flushing salts	Wetting flow – fill	~ three years out of five

Objective	Traditional Owner Cultural water value	Reach	Function	Component	Timing / frequency
			and nutrients. Maintain abundance of riparian zone birds (including Azure Kingfisher, Nankeen Night Heron).		
			Expose mudflats and submerged and emergent vegetation communities Increase waterbird food supply and facilitate waterbird foraging Stimulate nutrient cycling Expose wetland fringe and create shallows for a many shorebird species and other waterbird species from all guilds.	Drawdown	Three years in five
			Flooding of banks and riparian zone to create conditions for nesting	Wetting flow – fill	~ three years out of five
			VEGETATION		
Improve condition and extent of **submerged vegetation** to provide structural habitat for macroinvertebrates and various fish species	Materials, Basket-making	All	Maintain adequate depth of permanent water in channel	Baseflow	All year
			Cease to flow with seasonal drawdown in late summer/autumn to promote recruitment	Cease to flow	1 every 3-4 years
		Thomson River and Sale Canal	Maintain adequate depth of freshwater in channel	Baseflow	All year
			Maintain water quality to support health of Vallisneria sp. beds	Baseflow	All year
Improve condition, extent and diversity of **emergent macrophyte vegetation** to provide structural habitat and channel/lower bank stability to low and moderate flows.	Materials, Basket-making Keystone species habitat	All river reaches and estuary	Maintain adequate depth of permanent water in stream channel to limit terrestrial encroachment into aquatic habitats.	Baseflow	All year
			Provide disturbance in riparian zone and channel to open recruitment niches for emergent plants.	Bankfull	~2 per year or based on natural regime
			Support growth on terraces, channel edge and lower bank. (including by providing fresh water in the estuary)	Fresh	~6 per year or based on natural regime
			Provide a mosaic of spatially and temporally differentially wetted areas within stream channel, benches, lower banks and wetland margins.	Fresh	~6 per year or based on natural regime

Objective	Traditional Owner Cultural water value	Reach	Function	Component	Timing / frequency
			Provide freshwater conditions at River mouth to support phragmites reproduction	Fresh	Spring ~1 per year or based on natural regime
Maintain or restore a self-sustaining mosaic of **submerged and emergent aquatic vegetation** types	Materials, Basket-making, hunting (Woorngan) / food	Sale Common Heart Morass	Provide habitat inundation for vegetative growth and flowering with seasonal variation of depth within the wetlands.	Wetting flow – partial fill	Annual Winter / Spring (June – December)
			Increase oxygenation for germination and recruitment of aquatic vegetation	Drawdown	Annual Summer (December – March)
			Water level fluctuations to provide conditions for reproduction and expansion of Swamp Scrub and Tall Marsh	Drawdown	2-3 months Areas to dry out 1 in 2 years Summer (December – March)
			Encourage seed and propagule dispersal Reduce salinity levels to maintain species diversity	Flushing flow	1 in 2 years Winter / Spring (June – November)
Improve condition, extent and diversity of all **riparian and floodplain vegetation** especially for endangered EVCs	Tool making: Yooro gree (Red gum-canoe trees); Woorngan (hunting) / food	River reaches, Lower Latrobe, River Delta & Mouth	Support growth of riparian vegetation on terraces, channel edge and lower bank (including by providing fresh water in the estuary)	Fresh	~6 per year or based on natural regime
			Provide disturbance in riparian zone and channel to open recruitment niches for riparian plants. Especially Eucalypt species.	Fresh	~6 per year or based on natural regime
			Provide mechanism for dispersal of riparian and floodplain seeds and support growth of aquatic plants in floodplain depressions.	Overbank	August - December
			Inundate all channel vegetation and support its growth.	Bankfull	Anytime
		All wetlands	Encourage habitat inundation of vegetation E.g. Floodplain Riparian Woodland (EVC 56)	Wetting flow – fill	Minimum of 2 months
			Encourage seed and propagule dispersal	Flushing flow	Sale: 3 events in 10 years

Objective	Traditional Owner Cultural water value	Reach	Function	Component	Timing / frequency
					Heart / Dowd: 6 events in 10 years Winter / Spring (June – November)
			WATER QUALITY		
Maintain freshwater supply to Latrobe Estuary, Dowd Morass, Sale Common, Heart Morass, and associated freshwater habitats	Healthy country	All	Provide sufficient freshwater to maintain freshwater wetland flora and fauna, including provision of habitat for foraging, reproduction and longitudinal connectivity	All	Any time
		Heart Morass Dowd Morass	Export salt	Flushing flow	1 in 2 years
			Minimise saltwater intrusion	Wetting flow – partial fill	6 events in 10 years
			Minimise acid sulfate soils risk	Wetting flow – partial fill	Maintain water level
Minimise European Carp (reduce habitat)	Healthy country	All wetlands	Drawdown to reduce habitat for European Carp	Drawdown	Refer other criteria
Avoid adverse water quality conditions and prolonged stratified condition in pools such as high nutrients, Low DO or high salinities	Healthy country	All river and estuary reaches	Maintain dissolved oxygen levels in pools above thresholds for gill-breathing organisms (fish, macroinvertebrates and zooplankton) during summer/autumn	Baseflow	Summer/ autumn
			Flush pools to maintain good dissolved oxygen levels, low salinity and low nutrients in the water column to support aquatic ecosystems (e.g. fish, macroinvertebrate populations and zooplankton)	Freshes	Summer/ autumn

Part B: Environmental water requirements

Photo: Latrobe River, Reach 5 (Alluvium)

6 Environmental water requirements – river reaches

6.1 Approach to developing environmental water requirements

The process for deriving environmental flow recommendations (Figure 38) includes identifying water dependent value in the system and ecological objectives to support those values (see Section 4). The flow components and hydraulic criteria (detailed below) are derived from these objectives using conceptual models as described in Section 4 (refer to 'Water requirements' heading for each value). Based on the hydraulic criteria, relevant hydraulic models (see below) are used to determine the magnitude of the flow recommendation. An understanding of the system hydrology (see Section 2) is used in conjunction with the conceptual models and hydraulic criteria to determine the frequency, duration and timing of the flow recommendations. The determination of the number and duration of recommended flow events has then been considered in this study for four prevailing climatic conditions; drought, dry, average and wet years (see Section 2).

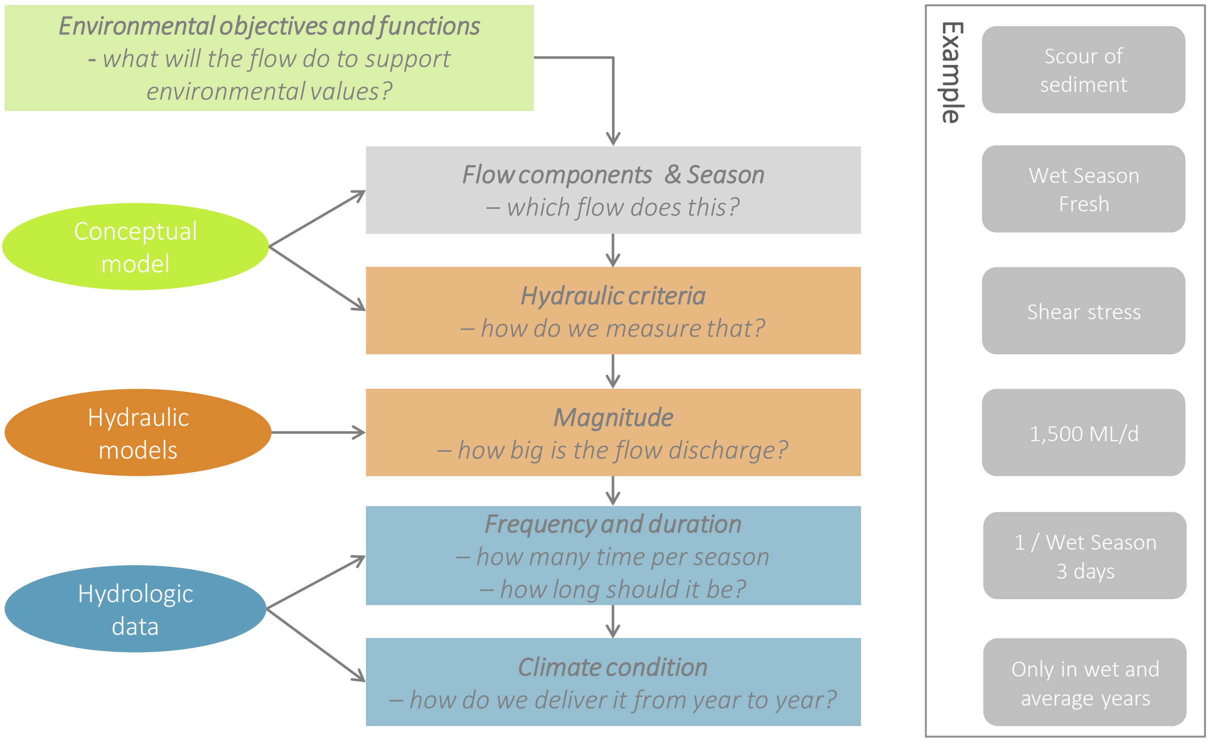


Figure 38. *Process for determining river environmental flow requirements.*

Flow components are discussed in see Section 2 and a summary is provided in the box below.

Flow components

Summer / Autumn baseflows are the natural dry period (summer/autumn) flows or 'baseflows' that maintain water flowing through the channel, keeping in-stream habitats wet and pools full.

Summer / Autumn freshes are frequent, small, and short duration flow events that last for one to several days as a result of localised rainfall during the low flow period.

Winter / Spring baseflows refer to the persistent increase in low or base flow that occurs with the onset of the wet period.

Winter / Spring freshes refer to sustained increases in flow during the high flow period as a result of sustained or heavy rainfall events.

Bankfull flows fill the channel, but do not spill onto the floodplain. **Overbank flows** are higher and less frequent than bankfull flows and spill out of the channel onto the floodplain. Bankfull and overbank flows are more common in the wet period, but also occurs in the dry period.

Application of hydraulic criteria

The hydraulic criteria required to support the values identified and achieve the flow objectives in Section 4 are detailed in Table 30. Hydraulic criteria have been determined by Environmental Flow Technical Panel members based on relevant literature, expert knowledge and using the conceptual models detailed in Section 4. These criteria have been updated from the previous FLOWS study to reflect the updated objectives and the best available science.

Table 30. Objectives and hydraulic criteria for river reaches

Value	Objective	Traditional Owner Cultural water values	Reach	Function	Component	Timing / frequency	Criteria	
FISH								
Migratory fish	Maintain abundance of grayling populations Improve recruitment of grayling populations	Fishing (Bunjil Tambun) / hunting (Woorngan)	All except 8, 11	Spawning (freshwater)	Fresh	February to May	F1	300 mm over instream benches
				Migration of larvae from freshwater to estuary and downstream juvenile habitat	Fresh	May to July	F2	500 mm over riffles
				Juveniles migrate upstream from sea	Fresh	October to January	F3	500 mm over riffles
				Maintain permanent deep pools	Baseflow	All year	F4	Pools 2 m deep
				Longitudinal connection in channel for adult grayling movement	Fresh	December to March	F5	500mm over riffles
	Maintain abundance of eel (noy yang) populations	Fishing (Bunjil Tambun) / hunting (Woorngan)	All	Provide water in pools for habitat and food sources	Baseflow	All year	F6	Maintain depth of pools preferably 1-2 m deep
				Provide water over riffles to allow fish to migrate upstream from estuary	Fresh	Nov to May	F7	500 mm over riffles
				Downstream migration of eels (noy yang) to allow for ocean breeding	Fresh	Oct to May	F8	500 mm over riffles
				Provide water over riffles to allow longitudinal connectivity and for fish to move between pools	Fresh	April to August	F9	500 mm over riffles
	Improve recruitment of small-bodied migratory fish including Tupong, Broad-finned Galaxias and Common Jollytail		All	Provide water in pools for habitat and food sources	Baseflow	All year	F10	At least 500-600 mm deep in pools
				Provide water over riffles to allow fish to move between pools to feed, grow and find new habitats (allow juvenile Tupong to move upstream)	Fresh	August to Feb	F11	300 mm over riffles
				Provide connectivity to allow fish to migrate downstream to breed	Fresh	March to July	F12	500 mm over riffles
	Maintain abundance of	Fishing (Bunjil Tambun) /		Downstream migration of Australian Bass adults to allow for estuarine breeding	Fresh	April to July	F13	500 mm over riffles

Value	Objective	Traditional Owner Cultural water values	Reach	Function	Component	Timing / frequency	Criteria	
	Australian Bass populations	hunting (Woorngan)	All except 8, 11	Allow upstream movement of juveniles into freshwater habitats	Fresh	Sept to April	F14	500 mm over riffles
	Improve recruitment of Australian Bass populations			Maintain permanent deep pool of minimum depth 2 m	Baseflow	All year	F15	Pools 2 m deep
Resident freshwater fish	Improve recruitment of small-bodied freshwater resident fish such as Dwarf Galaxias, Pygmy Perch, Australian Smelt, flathead gudgeon and dwarf flathead gudgeon		All	Provide prolonged seasonal inundation of vegetation beds and instream benches as habitat to stimulate invertebrate hatching and fish breeding	Fresh	Aug to Nov	F16	500 mm water depth over some instream benches and vegetation beds
				Provide water over riffles to allow longitudinal connectivity and for fish to move between pools	Fresh	April to August	F17	500mm over riffles
	Improve recruitment of River Blackfish	Fishing (Bunjil Tambun) / hunting (Woorngan)	All	Submerge and clean woody debris and hard surfaces to provide breeding substrate	Fresh	Nov to Jan	F18	500 mm water depth over some instream benches and vegetation beds
	Maintain abundance of resident freshwater fish, including Dwarf Galaxias, Pygmy Perch, Australian Smelt and Gudgeon		All	Provide water in pools for habitat and food sources	Baseflow	Nov to March	F19	500mm water depth in pools
Estuary Residen	Maintain abundance and improve breeding	Fishing (Bunjil Tambun) /	5	Provide water in pools for habitat and food sources	Baseflow	All year	F20	Pools 2m deep
				Downstream migration of Estuary adults to allow for estuarine breeding	Fresh	July to August	F21	500mm over riffles

Value	Objective	Traditional Owner Cultural water values	Reach	Function	Component	Timing / frequency	Criteria	
	and recruitment of estuarine resident species (Estuary Perch, River Garfish, Black Bream (Kine), eastern blue-spot goby and lagoon goby)	hunting (Woorngan)		Flows which maintain estuarine salinities and high dissolved oxygen levels	Fresh	Sept to December	F22	500 mm water depth over some instream benches and vegetation beds
				Provide water over riffles to allow longitudinal connectivity and for fish to move between pools	Fresh	Sept to March	F23	500mm over riffles
OTHER FAUNA								
Macro-invertebrates and zooplankton	Improve abundance of all macroinvertebrate and zooplankton populations		All	Create and extend aquatic habitats for macroinvertebrates and zooplankton	Fresh	Aug to Nov	M1	Increase wetted area by inundating instream benches by 300mm deep
				Sustain macroinvertebrate and zooplankton communities during summer as a food source for fish, frog and platypus (Balagen) populations	Fresh	Nov to March	M2	Inundate benches by 100mm deep
				Maintain pool habitat	Baseflow	Nov to March	M3	Maintain full pools
				Create aquatic floodplain habitats for macroinvertebrates and zooplankton (including rotifers) and stimulate production	Overbank	Winter / Spring	M4	Inundate floodplain
Frogs	Maintain refuge habitat for frog populations Improve extent of frog populations		All	Provide pool habitat	Fresh	Summer	FR1	Refer to WQ2
				Allow growth and reproduction of macroinvertebrate communities	Fresh	Spring	FR2	Refer to M1, G7
				Provide longitudinal connectivity between reaches	Fresh	Spring	FR3	300 mm water depth over riffles
Aquatic mammals	Improve extent of platypus (Balagen) & rakali populations	Keystone species	All	Provide longitudinal connectivity between reaches for local movement	Fresh	Summer / Autumn	PL1	500 mm water depth over riffles
	Maintain abundance of		All	Provide pool habitat for refuge/permanent habitat	Baseflow	Summer	PL2	Flow between pools Minimum pool depth of >1m

Value	Objective	Traditional Owner Cultural water values	Reach	Function	Component	Timing / frequency	Criteria	
	existing platypus (Balagen) & rakali populations			Flow freshes to keep fine sediment from infilling gravel beds and allow large macroinvertebrate populations for food	Fresh	Winter / Spring		Refer to M1, G2 and G3
				Support breeding opportunities by avoiding bankfull flows	Bankfull	October - March	PL3	Address in risk management
				Avoid extended high flows events to allow for foraging	Fresh /Bankfull	All year	PL4	No sediment on gravels
Birds	Maintain abundance of riparian zone birds		All	Flooding of riparian vegetation for foraging habitat	Overbank flows	July to December	B3	~ 3 out of 5 years
Turtles	Maintain abundance of Freshwater Turtle Populations		All	Provide pool habitat	Baseflow	Summer	T1	Flow between pools Minimum pool depth of >0.51m
				Allow growth and reproduction of macroinvertebrate communities as food source	Fresh	Spring/Summer	T2	300 mm water depth over instream benches
				Flooding of banks and riparian zone to create conditions for nesting	Fresh /Bankfull	Summer	T3	Annual (2-3 times for the season)
				VEGETATION				
Submerged	Improve condition and extent of **submerged vegetation** to provide structural habitat for macroinvertebrates and various fish species	Materials, Basket-weaving	All	Maintain adequate depth of permanent water in channel	Baseflow	All year	V1	400 mm water depth in pools
				Cease to flow with seasonal drawdown in late summer/autumn to promote recruitment	Cease to flow	1 every 3-4 years	V2	1-3 months

Value	Objective	Traditional Owner Cultural water values	Reach	Function	Component	Timing / frequency	Criteria	
Emergent macrophyte	Improve condition, extent and diversity of **emergent macrophyte vegetation** to provide structural habitat and channel/lower bank stability to low and moderate flows.	Basket-weaving, keystone species habitat	All	Maintain adequate depth of permanent water in stream channel to limit terrestrial encroachment into aquatic habitats.	Baseflow	All year	V4	400 mm water depth in pools
				Provide disturbance in riparian zone and channel to open recruitment niches for emergent plants.	Bankfull	~2 per year or natural regime	V5	Inundate all channel
				Support growth on terraces, channel edge and lower bank.	Fresh	~6 per year or natural regime	V6	Inundate the lower bank, channel terraces and wetland margins
				Provide a mosaic of spatially and temporally differentially wetted areas within stream channel, benches, lower banks and wetland margins.	Fresh	~6 per year or natural regime	V7	Variations in water depth of approximately 500 mm over low-flow levels or 200 mm over channel benches
Riparian	Improve condition, extent and diversity of all **riparian vegetation** especially for endangered EVCs	Tool making: Yooro gree trees (Red gum-canoe trees); Woorngan (hunting) / food	All	Support growth of riparian vegetation on terraces, channel edge and lower bank.	Fresh	~6 per year or natural regime	V8	Inundate the lower bank and channel benches up to 500 mm from low flow level
				Provide disturbance in riparian zone and channel to open recruitment niches for riparian plants. Especially Eucalypt species.	Fresh	~6 per year or natural regime	V9	Replacement of exotic grasses with native shrubs and ground cover
				Provide mechanism for dispersal of riparian and floodplain seeds.	Overbank	Spring	V10	Commence overbank flooding
				Inundate all channel vegetation and support its growth.	Bankfull	~6 per year or natural regime	V11	Inundate all channel
Floodplain	Improve condition and extent of all **floodplain vegetation** especially for endangered EVCs (e.g. Swamp Scrub EVC53)	Tool making: Yooro gree trees (Red gum-canoe trees); Woorngan (hunting) / food	All	Fill floodplain depressions and billabongs to support the growth of seasonal and emergent wetland vegetation.	Overbank	Spring/ summer	V12	Commence overbank flooding
				Inundate floodplain and provide moisture to floodplain species and promote carbon exchange.	Overbank	1 every 2-3 years	V14	Water flows to floodplain

Value	Objective	Traditional Owner Cultural water values	Reach	Function	Component	Timing / frequency	Criteria	
				SUPPORTING FUNCTIONS				
Water quality	Avoid adverse water quality conditions and prolonged stratified condition in pools such as high nutrients, Low DO or high salinities	Healthy country	All	Maintain dissolved oxygen levels in pools above thresholds for gill-breathing organisms (fish, macroinvertebrates and zooplankton) during summer/autumn	Baseflow	Summer/ autumn	WQ1	Velocity of 0.1 m/s through pools
				Flush pools to maintain good dissolved oxygen levels, low salinity and low nutrients in the water column to support aquatic ecosystems (e.g. fish, macroinvertebrate populations and zooplankton)	Freshes	Summer/ autumn	WQ2	Velocity of 0.3 m/s through pools
Geomorphology	Maintain habitat to support ecological values and processes		All	Maintain gross channel capacity through provision of the dominant channel-forming flow events (bankfull events)	Bankfull	Any time	G1	Bankfull event
				Maintain gross channel capacity through provision of events capable of mobilising bed load sediment	Baseflow	Winter / Spring	G2	Mobilise and transport bed load sediment
				Provide flows that establish and maintain high flow benches (scour and deposit sediment on high flow benches)	Fresh	Winter / Spring	G3	Inundate high benches
					Bankfull	Anytime	G4	Mobilise sediment of high benches
				Provide flows that maintain low flow benches through Summer / Autumn (scour and deposit sediment on low flow benches)	Freshes	Summer / Autumn	G5	Inundate low benches
				Provide flows that maintain pool depth and abrade algae on riffles and large wood through Summer / Autumn, by scouring fine sediment from bed of pools.	Fresh	Summer / Autumn	G6	Mobilise sediment in bed of pool (criteria adopted based on reach sediment type)
				Provide overbank inundation to enable exchange of sediment and carbon to and from the river	Overbank Anytime	Overbank	G8	Maintain occurrence of overbank events

Hydraulic modelling

The magnitudes of the flow required to achieve the flow functions were estimated using one-dimensional hydraulic models. The HEC-RAS modelling software, developed by the US Army Corp of Engineers, has been used as the hydraulic modelling platform for this part of the investigation.

Four new models were developed as part of this study based on the new sites selected (see Appendix B) for the Latrobe River reaches (reaches 3,4,5) and the Morwell River site (reach 10). For the other three river reaches (8 – Tanjil River, 9- Tyers River, and 11 – Traralgon Creek) the existing models from the 2007 FLOWS study were reviewed and adopted. Detailed of the hydraulic models are provided in Appendix F.

For a given flow rate (magnitude), the hydraulic models provide the resultant hydraulic conditions in the presentative site, this includes stream velocity, shear stress, inundation depths and inundation extents. Many flow rates are run through the model and the Environmental Flows Technical Panel and project team are then able to asses which flow rate produces the hydraulic conditions that best meet the target criteria at various locations throughout the representative site (e.g. the minimum velocity through a pool or the inundation over a specific bench).

Reach 5 is located upstream of the Latrobe estuary and is therefore influenced by the fluctuations in water level driven by Lake Wellington. Therefore, for developing the hydraulic model, this was taken into account at the downstream boundary condition. The range of water levels for different flow rates were taken from the estuary hydrodynamic model. Two rating curves (and therefore two scenarios in the hydraulic model) were developed: one based on the typical water level that occurs in the modelled results while the other was based on an upper bound of water levels identified for a given flow rate. The model with typical water levels as the rating curve was used for the lower flow recommendations (Summer Autumn Baseflow, Summer / Autumn Fresh, Winter / Spring Baseflow), while both models were used to inform the higher flow recommendations (Winter / Spring Fresh, Bankfull, Overbank). Further information is provided in Appendix F.

Note that subsequent flood modelling undertaken by West Gippsland CMA suggests that under maximum water level conditions in the estuary, the channel capacity of the lower part of Reach 5 is exceeded at lower flow rates. Under these conditions (high water levels in the estuary), may lead to floodplain inundation in the lower part of reach 5 at lower discharges, which may prove to be a constraint to the delivery of some flow recommendations. Further work is required to better understand this constraint and the conditions under which it is most relevant to management decisions.

Hydrologic modelling and analysis

There are several stream flow gauges available for the Latrobe system to characterise the hydrology of the system and assess compliance with the environmental flow recommendations. These gauges are identified in Section 2.

The water resource modelling undertaken for this study is discussed in Section 2. **Unimpacted conditions** represent flows in the river in the absence of diversions from the river and flow regulating structures, but under historical land cover. **Current conditions** represent regulated flows at current entitlement volumes, the 2017 level of demand and water use behaviour, and historical land cover.

'or natural'

Natural flow variability is an important aspect of an environmental flow regime. While all baseflow recommendations are expressed as 'continuous', an 'or natural' clause has been added to these flow recommendations. This clause is designed to allow reduced flows and seasonal drawdown to occur, if it would have done so naturally.

The inclusion of the 'or natural' clause, is based on an understanding that 'natural' (or unimpacted) flows should support the environmental values and objectives. Australian native species have adapted to the natural variability in ways that we don't fully understand. This adaption has provided Australian native species with a competitive advantage over many introduced species. Inclusion of a 'or natural' clause provides for variability that will assist with the long-term success of Australian native species.

Determining the natural flow variability in these circumstances will need to be addressed as part of the implementation of the environmental flow recommendations, through a statistical analysis of the modelled flow data. Noting that the 'or natural' clause refers to the unimpacted flow under the historic climate, and not an unimpacted regime under climate change conditions.

While the Latrobe is a modified system, it is assumed here that other threats (outside the direct scope of environmental water management), will be adequately managed such that it can be considered a natural system. The 'or natural' clause assumes that complementary measures have been undertaken to create a waterway environment that reflects key elements of a natural system; these elements include the presence of large wood and riparian vegetation.

Timing definition

The flow recommendations (specifically baseflows and freshes) have been developed and expressed as either 'Summer / Autumn' or 'Winter / Spring'. The 'Summer / Autumn' recommendations cover the s period from December to May and the 'Winter / Spring' period covers June to November. Flow frequencies expressed as '/period' denote the number of events in the 'Summer / Autumn' or 'Winter / Spring' (i.e. a six-month period). For example, a summer fresh with a frequency of 6/period would occur a total of six times across the December – May period.

The variation in seasonal definitions is recognised and exact timing of flows should be coordinated to take into consideration:

- The unimpacted or 'natural' flow regime
- Cultural seasons
- Weather events
- Ecological life cycles

The delivery of the recommended flow regime can be developed further in an environmental water management plan.

Spells analysis

Flow duration curves are provided for each reach and each period (Summer / Autumn or Winter / Spring) in Section 2 (Figure 7 - Figure 10). In addition, a spells analysis has been undertaken for each recommended flow magnitude. A 'high spells' analysis using eWater's RAP software identified the mean frequency of a given flow (or greater) occurring and the mean duration of those flow events, for the period of interest (Summer / Autumn or Winter / Spring). This analysis was performed for all years of modelled data and also for each different climate condition (Drought, Dry, Average, Wet year), and combined with an understanding of ecological requirements, was used to develop the recommended frequency and duration for each recommendation. For overbank and bankfull recommendations, a maximum duration between events is also recommended, based on the maximum duration between events for the natural time series, and or ecological requirements.

Rates of rise and fall

The rate of rise and fall relates to the rate of change in flow from day to day, with a focus on the rate of increase up to a target flow and a rate of decrease from this target flow. These fluctuations in the flow rate serve important ecological and geomorphic functions in a river system. Excessive rates of water-level fall can result in fish being stranded by falling waters or bank slumping. It is therefore important that this rate is not significantly altered from the natural (unimpacted) rates of rise and fall in stream flow.

Within the context of flow management, recommended rates of rise and fall are useful to ensure that the delivery of *managed* flows is such that ecological harm is minimised. The recommended rates of rise and fall were determined from the modelled unimpacted daily flow data. Rates of rise and fall are reported as the maximum rate of permissible rise/fall from one day to the next. For example, if the flow is at 100 ML/d and the recommended rate of fall is 0.7, the flow on the following day should not be below 70 ML/d. Similarly, if the flow rate was 100 ML/d and the recommended rate of rise is 1.8, the flow on the following day should not exceed 180 ML/d.

The recommended maximum rate of rise and fall have been defined for modelled unimpacted flows as 90th percentile of rise and 10th percentile of fall for dry and Winter / Spring freshes and around 80th percentile of rise and 10th percentile of fall for all flows above bankfull magnitude (Table 31).

Table 31. Rates of rise and fall for the Latrobe system river reaches.

Reach		Flow component	Rise	Fall
3	Latrobe River (Lake Narracan to Scarnes)	Summer / Autumn freshes	1.6	0.8
		Winter / Spring freshes	1.8	0.8
		Bankfull/overbank	3.4	0.6
4	Latrobe River (Scarnes Bridge to Kilmany South)	Summer / Autumn freshes	2.0	0.8
		Winter / Spring freshes	2.0	0.8
		Bankfull/overbank	3.5	0.6
5	Latrobe River (Kilmany South to Thomson confluence)	Summer / Autumn freshes	2.0	0.8
		Winter / Spring freshes	2.0	0.8
		Bankfull/overbank	3.0	0.6
8	Tanjil River	Summer / Autumn freshes	1.8	0.8
		Winter / Spring freshes	1.7	0.8
		Bankfull/overbank	7.3	0.4
9	Tyers River	Summer / Autumn freshes	2.7	0.5
		Winter / Spring freshes	2.4	0.6
		Bankfull/overbank	6.8	0.3
10	Morwell River	Summer / Autumn freshes	1.6	0.7
		Winter / Spring freshes	1.8	0.8
		Bankfull/overbank	2.8	0.6
11	Traralgon Creek	Summer / Autumn freshes	2.5	0.6
		Winter / Spring freshes	2.5	0.6
		Bankfull/overbank	7.0	0.3

6.2 Environmental flow recommendations

Environmental flow recommendations have been determined for the seven river reaches of the Latrobe River system within the scope of this study. . The tables below include a summary of the environmental values and functions supported by each flow component to help to achieve the environmental objectives.

Each recommendation is comprised of a flow component, discharge (magnitude), timing (period), frequency (generally number of times per period) and duration (generally in days), as well as the inclusion of climate condition (Figure 39). In this section, the recommendations are described for each reach and for each flow component. Flows components for river reaches are described in Section 2 and include Summer / Autumn low flow, Summer / Autumn fresh, Winter / Spring low flow, Winter / Spring Fresh, Bankfull and Overbank.

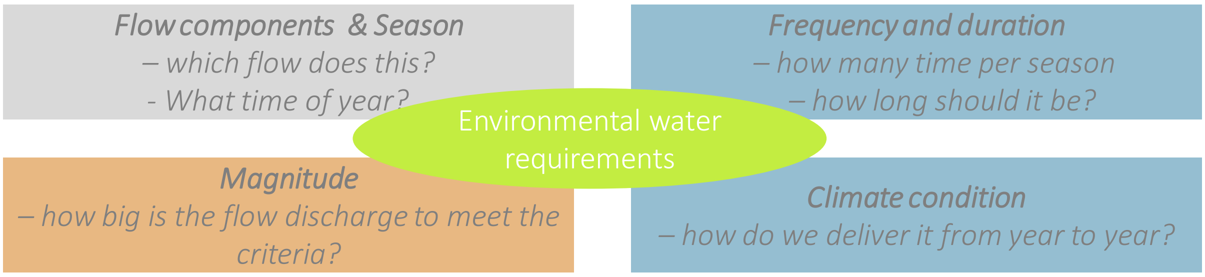


Figure 39. *Components of a flow recommendation*

Flow recommendations are presented below for each of the seven river reaches.

Note: Recommendations for different climate conditions are provided to allow for a seasonally adaptive approach to environmental water delivery. The climate conditions are based on the historic climate record, where Dry or Drought years occurred less than 25% of the time (see Section 2.4). The Average (or Wet) recommendations should be provided at least 75% of the time In order to have confidence that the objectives can be met. The provision of average or wet conditions in 75% of years will be required under a continuation of the current climate or under a drying climate with an increasing number of Dry and Drought years.

Flow magnitudes were determined to contribute to the achievement of environmental objectives. Where possible, flow recommendations were developed to meet the greatest number of criteria, while optimising to feasibly meet the intent of the flow functions for each flow component. Criteria marked with an asterisk (*) are deemed 'partially achieved' by the listed flow magnitude. These include situations where criteria could not fully be met by other constraints such as channel capacity, channel morphology, flow availability, criteria of other values or additional constraints. Hydraulic criteria codes are available in Table 30.

The updated flow recommendations arising from this investigation (provided below) differ from those developed from previous studies. Some of the reasons for differences include:

- refined and updated environmental objectives
- updated ecological and system knowledge
- improved hydrologic and hydraulic modelling.

Latrobe Reach 3

Flow component	Magnitude (ML/day)	Frequency (No/period)	Duration (days)	Hydraulic criteria met	Values and functions supported
Summer / Autumn Baseflow	440 ML/day or natural	DROUGHT / DRY / AVG / WET: Cont	DROUGHT / DRY / AVG / WET: Cont	F4, F6, F10, F15, F19, PL2, M3 V1,V4, WQ1	Supporting healthy country, fishing (Bunjil Tambun) / hunting (Woorngan) and platypus (Balagen), providing pool habitat (adequate depth) to support migratory and resident freshwater fish, macroinvertebrates, aquatic mammals, turtles, and submerged vegetation. Limit terrestrial vegetation encroachment to support emergent macrophyte vegetation. Maintain dissolved oxygen levels in pools (water quality).
Summer / Autumn Fresh - Water quality	980 ML/day	DROUGHT: 4 DRY: 5 AVG: 6 WET: 6	DROUGHT: 1 day DRY: 1 day AVG: 1 day WET: 1 day	G6*, WQ2,	Supporting healthy country by flushing sediment (sands) from pools and velocity for pool turnover (water quality and geomorphic processes). This also supports pool habitat for frogs.
Summer / Autumn Fresh - Fish and Vegetation	980 ML/day	DROUGHT: 1 DRY: 2 AVG: 3 WET: 3	DROUGHT: 4 days DRY: 3 days AVG: 4 days WET: 5 days	F1, F2, F3, F5, F7, F8, F9, F11, F12, F13, F17, F18, M2, FR1, PL1, V6, G5	Supporting healthy country, fishing (Bunjil Tambun) / hunting (Woorngan) and platypus (Balagen). Inundating benches to maintain habitat (geomorphic processes), support growth of emergent macrophyte vegetation and sustain macroinvertebrate and zooplankton communities, and breeding substrate for Blackfish. Longitudinal connectivity for aquatic mammals, migratory fish and estuary residents; including depth over benches for Grayling.
Winter / Spring Baseflow	1,500 ML/day or natural	DROUGHT / DRY / AVG / WET: Cont	DROUGHT / DRY / AVG / WET: Cont	G2	Supporting healthy country by providing Summer / Autumn low flow functions plus flushing of sediment (sands) from pools.
Winter / Spring Fresh	6,000 ML/day	DROUGHT: - DRY: 1 AVG: 3 WET: 4	DROUGHT: - DRY: 2 days AVG: 2 days WET: 2 days	F2, F3, F9, F11, F14, F16, F17, F18, M1, FR3, T2, V7, V8, V9, G3	Supporting healthy country, fishing (Bunjil Tambun) / hunting (Woorngan) and platypus (Balagen). Inundation over benches (at greater depth) activating ecological processes to provide habitat for macroinvertebrates and zooplankton, providing a food source, habitat and connectivity for resident and estuary resident fish, turtles and frogs. Provide a mosaic of wetted areas for emergent macrophyte vegetation. Inundation of higher benches (geomorphic processes) to improve bench habitat and support growth of riparian vegetation.
Bankfull	10,000 ML/day	DROUGHT / DRY: - AVG: 1/year WET: 1/year Overall: Max duration between events: 2 years	DROUGHT / DRY: - AVG: 2 days WET: 2 days	G1, V5, V11, T3	Supporting healthy country, canoe trees (Yooro gree). Inundation of riparian vegetation and disturbance of emergent vegetation. This is turn provides habitat for riparian zone birds. Flooding of banks and riparian zone to create nesting conditions for turtles. Maintain channel capacity and bench habitat (geomorphic processes)
Overbank	> 15,000 ML/day	DROUGHT / DRY: - AVG / WET: 1/ 2yrs Overall: Max duration between events: 4 years	DROUGHT / DRY: - AVG / WET: 1 day	V10, V12, V14, G8, B3, M4	Supporting healthy country, Fairy wren (Yeerung and Djeetgun), canoe trees (Yooro gree). Inundation of floodplain and riparian vegetation and disturbance of emergent vegetation. This is turn provides habitat for riparian zone birds. Stimulate macroinvertebrate and zooplankton production. Exchange of sediment (and nutrients), and carbon between waterway and floodplain to increase productivity.

Latrobe Reach 4

Flow component	Magnitude (ML/day)	Frequency (No/period)		Duration (days)		Hydraulic criteria met	Environmental values and functions supported
Summer / Autumn Baseflow	380 or natural	DROUGHT	Cont	DROUGHT	Cont	F4, F6, F10, F15, F19, PL2, M3 V1,V4, WQ1	Supporting healthy country, fishing (Bunjil Tambun) / hunting (Woorngan) and platypus (Balagen), providing pool habitat (adequate depth) to support migratory and resident freshwater fish, macroinvertebrates, aquatic mammals, turtles, and submerged vegetation. Limit terrestrial vegetation encroachment to support emergent macrophyte vegetation. Maintain dissolved oxygen levels in pools (water quality).
		DRY		DRY			
		AVG		AVG			
		WET		WET			
Summer / Autumn Fresh - Water quality	1,400 ML/day	DROUGHT	4	DROUGHT	1 day	G6*, WQ2,	Supporting healthy country by flushing sediment (sands) from pools and velocity for pool turnover (water quality and geomorphic processes). This also supports pool habitat for frogs.
		DRY	5	DRY	1 day		
		AVG	6	AVG	1 day		
		WET	6	WET	1 day		
Summer / Autumn Fresh - Fish and Vegetation	1,400 ML/day	DROUGHT	1	DROUGHT	4 days	F1, F2, F3, F5, F7, F8, F9, F11, F12, F13, F17, F18, M2, FR1, PL1, V6, G5,	Supporting healthy country, fishing (Bunjil Tambun) / hunting (Woorngan) and platypus (Balagen). Inundating benches to maintain habitat (geomorphic processes), support growth of emergent macrophyte vegetation and sustain macroinvertebrate and zooplankton communities, and breeding substrate for Blackfish. Longitudinal connectivity for aquatic mammals, migratory fish and estuary residents; including depth over benches for Grayling.
		DRY	2	DRY	3 days		
		AVG	3	AVG	4 days		
		WET	3	WET	5 days		
Winter / Spring Baseflow	1,800 or natural	DROUGHT	Cont	DROUGHT	Cont	G2	Supporting healthy country by providing Summer / Autumn low flow functions plus flushing of sediment (sands) from pools.
		DRY		DRY			
		AVG		AVG			
		WET		WET			
Winter / Spring Fresh	3,000 ML/day	DROUGHT	1	DROUGHT	2 days	F2, F3, F9, F11, F14, F16, F17, F18, M1, FR3, T2, V7, V8, V9, G3	Supporting healthy country, fishing (Bunjil Tambun) / hunting (Woorngan) and platypus (Balagen). Inundation over benches (at greater depth) activating ecological processes to provide habitat for macroinvertebrates and zooplankton, providing a food source, habitat and connectivity for resident and estuary resident fish, turtles and frogs. Provide a mosaic of wetted areas for emergent macrophyte vegetation. Inundation of higher benches (geomorphic processes) to improve bench habitat and support growth of riparian vegetation.
		DRY	1	DRY	2 days		
		AVG	3	AVG	2 days		
		WET	4	WET	2 days		
Bankfull	8,000 ML/day	DRT / DRY	-	DRT / DRY	-	G1, V5, V11, T3	Supporting healthy country, canoe trees (Yooro gree). Inundation of riparian vegetation and disturbance of emergent vegetation. Flooding of banks and riparian zone to create nesting conditions for turtles. Maintain channel capacity and bench habitat (geomorphic processes)
		AVG	1/year	AVG	2 days		
		WET		WET			
		Overall: Max duration between events: 2 years					
Overbank	> 10,000 ML/day	DRT / DRY	-	DRT / DRY	-	V10, V12, V14, G8, M4, B3	Supporting healthy country, Fairy wren (Yeerung and Djeetgun), canoe trees (Yooro gree). Inundation of floodplain and riparian vegetation and disturbance of emergent vegetation. This is turn provides habitat for riparian zone birds. Stimulate macroinvertebrate and zooplankton production. Exchange of sediment (and nutrients), and carbon between waterway and floodplain to increase productivity.
		AVG / WET	1/ 2 years	AVG / WET	2 days		
		Overall: Max duration between events: 2 years					

Latrobe Reach 5

Flow component	Magnitude (ML/day)	Frequency (No/period)		Duration (days)		Hydraulic criteria met	Environmental values and functions supported
Summer / Autumn Baseflow	250 ML/day or natural	DROUGHT DRY AVG WET	Cont	DROUGHT DRY AVG WET	Cont	F4, F6, F10, F15, F19, F20, PL2, M3 V1,V4, WQ1	Supporting healthy country, fishing (Bunjil Tambun) / hunting (Woorngan) and platypus (Balagen), providing pool habitat (adequate depth) to support migratory and resident freshwater fish, macroinvertebrates, aquatic mammals, turtles, and submerged vegetation. Limit terrestrial vegetation encroachment to support emergent macrophyte vegetation. Maintain dissolved oxygen levels in pools (water quality).
Summer / Autumn Fresh - Water quality	920 ML/day	DROUGHT	4	DROUGHT	1 day	G6, WQ2,	Supporting healthy country by flushing sediment (sands) from pools and velocity for pool turnover (water quality and geomorphic processes). This also supports pool habitat for frogs.
		DRY	5	DRY	1 day		
		AVG	6	AVG	1 day		
		WET	6	WET	1 day		
Summer / Autumn Fresh - Fish and Vegetation	920 ML/day	DROUGHT	1	DROUGHT	4 days	F1, F2, F3, F5, F7, F8, F9, F11, F12, F13, F17, F18, F21, F23, M2, FR1, PL1, V6, G5	Supporting healthy country, fishing (Bunjil Tambun) / hunting (Woorngan) and platypus (Balagen). Inundating benches to maintain habitat (geomorphic processes), support growth of emergent macrophyte vegetation and sustain macroinvertebrate and zooplankton communities, and breeding substrate for Blackfish. Longitudinal connectivity for aquatic mammals, migratory fish and estuary residents; including depth over benches for Grayling.
		DRY	2	DRY	3 days		
		AVG	3	AVG	4 days		
		WET	3	WET	5 days		
Winter / Spring Baseflow	620 ML/day or natural	DROUGHT DRY AVG WET	Cont	DROUGHT DRY AVG WET	Cont	G2	Supporting healthy country by providing Summer / Autumn low flow functions plus flushing of sediment (sands) from pools.
Winter / Spring Fresh	2,200 ML/day*	DROUGHT	1	DROUGHT	2 days	F2, F3, F9, F11, F14, F16, F17, F18, M1, FR3, T2, V7, V8, V9, G3	Supporting healthy country, fishing (Bunjil Tambun) / hunting (Woorngan) and platypus (Balagen). Inundation of benches activating ecological processes to provide habitat for macroinvertebrates and zooplankton, providing a food source, habitat and connectivity for resident and estuary resident fish, turtles and frogs. Provide a mosaic of wetted areas for emergent macrophyte vegetation. Inundation of higher benches at greater depth (geomorphic processes) to improve bench habitat and support growth of riparian vegetation *Under typical water level conditions:* Benches just inundated. *Under upper bound of water level conditions:* Greater depth of inundation over benches to fully meet criteria.
		DRY	1	DRY	2 days		
		AVG	3	AVG	2 days		
		WET	4	WET	2 days		

Flow component	Magnitude (ML/day)	Frequency (No/period)		Duration (days)		Hydraulic criteria met	Environmental values and functions supported
Bankfull	3,500 ML/day*	DROUGHT	1	DROUGHT	2 days	G1, V5, V11, T3	Supporting healthy country, canoe trees (Yooro gree). Inundation of riparian vegetation and disturbance of emergent vegetation. This is turn provides habitat for riparian zone birds. Flooding of banks and riparian zone to create nesting conditions for turtles. Maintain channel capacity and bench habitat (geomorphic processes) *Under typical water level conditions:* Below bankfull but still perform channel maintenance function. *Under upper bound of water level conditions:* Bankfull conditions to fully meet criteria.
		DRY	1	DRY	3 days		
		AVG	2	AVG	3 days		
		WET	2	WET	3 days		
		Overall: Max duration between events: 2 years					
Overbank	> 5,000 ML/day*	DRT / DRY	1	DRT / DRY	2 days	V10, V12, V14, G8, B3, M4	Supporting healthy country, Fairy wren (Yeerung and Djeetgun), canoe trees (Yooro gree). Inundation of floodplain and riparian vegetation and disturbance of emergent vegetation. This is turn provides habitat for riparian zone birds. Stimulate macroinvertebrate and zooplankton production. Exchange of sediment (and nutrients), and carbon between waterway and floodplain to increase productivity. *Some overbank inundation should occur for all downstream water level conditions, with greater inundation with increased water levels.*
		AVG / WET	1	AVG WET	2 days		
		Overall: Max duration between events: 2 years					

*Flow recommendations have been developed based on two scenarios in the hydraulic model: one representing typical water level conditions as the downstream boundary condition, one representing the upper bound of water level conditions (refer to Appendix F for further information).

Note that subsequent flood modelling undertaken by West Gippsland CMA suggests that under maximum water level conditions in the estuary, the channel capacity of the lower part of Reach 5 is exceeded at lower flow rates (i.e. at flows lower than the bankfull recommendation of 3,500 ML/day). Under these conditions (high water levels in the estuary), may lead to floodplain inundation in the lower part of reach 5 at lower discharges, which may prove to be a constraint to the delivery of some flow recommendations. Further work is required to better understand this constraint and the conditions under which it is most relevant to management decisions.

Morwell Reach 10

Flow component	Magnitude (ML/day)	Frequency (No/period)		Duration (days)		Hydraulic criteria met	Environmental values and functions supported
Summer / Autumn Baseflow	90 ML/day or natural	DROUGHT	Cont	DROUGHT	Cont	F4*, F6, F10, F15*, F19, PL2, M3 V1,V4, WQ1	Supporting healthy country, fishing (Bunjil Tambun) / hunting (Woorngan) and platypus (Balagen), providing pool habitat (adequate depth) to support migratory and resident freshwater fish, macroinvertebrates, aquatic mammals, turtles, and submerged vegetation. Limit terrestrial vegetation encroachment to support emergent macrophyte vegetation. Maintain dissolved oxygen levels in pools (water quality).
		DRY		DRY			
		AVG		AVG			
		WET		WET			
Summer / Autumn Fresh	320 ML/day	DROUGHT	2	DROUGHT	3 days	F1, F2, F3, F5, F7, F8, F9, F11, F12, F13, F17, F18, M2, FR1, PL1, V6, G5, G6, WQ2*	Supporting healthy country, fishing (Bunjil Tambun) / hunting (Woorngan) and platypus (Balagen). Inundating benches to maintain habitat (geomorphic processes), support growth of emergent macrophyte vegetation and sustain macroinvertebrate and zooplankton communities, and breeding substrate for Blackfish. Supporting healthy country by flushing sediment (sands) from pools and velocity for pool turnover (water quality and geomorphic processes). This also supports pool habitat for frogs. Longitudinal connectivity for aquatic mammals, migratory fish and resident freshwater fish.
		DRY	2	DRY	3 days		
		AVG	2	AVG	4 days		
		WET	3	WET	4 days		
Winter / Spring Base flow	210 ML/day or natural	DROUGHT	Cont	DROUGHT	Cont	G2	Supporting healthy country by providing Summer / Autumn low flow functions plus flushing of sediment (sands) from pools.
		DRY		DRY			
		AVG		AVG			
		WET		WET			
Winter / Spring Fresh	680 ML/day	DROUGHT	1	DROUGHT	4 days	F2, F3, F9, F11, F14, F16, F17, F18, M1, FR3, T2, V7, V8, V9, G3	Supporting healthy country, fishing (Bunjil Tambun) / hunting (Woorngan) and platypus (Balagen). Inundation over benches (at greater depth) activating ecological processes to provide habitat for macroinvertebrates and zooplankton, providing a food source, habitat and connectivity for resident and estuary resident fish, turtles and frogs. Provide a mosaic of wetted areas for emergent macrophyte vegetation. Inundation of higher benches (geomorphic processes) to improve bench habitat and support growth of riparian vegetation.
		DRY	3	DRY	3 days		
		AVG	3	AVG	4 days		
		WET	4	WET	4 days		
Bankfull	1,800 ML/day	DRT / DRY	-	DRT / DRY	-	G1, V5, V11, T3	Supporting healthy country, canoe trees (Yooro gree). Inundation of riparian vegetation and disturbance of emergent vegetation. This is turn provides habitat for riparian zone birds. Flooding of banks and riparian zone to create nesting conditions for turtles. Maintain channel capacity and bench habitat (geomorphic processes)
		AVG	1/year	AVG	2 days		
		WET		WET			
		Overall: Max duration between events: 2 years					
Overbank	> 2,200 ML/day	DRT / DRY	-	DRT / DRY	-	V10, V12, V14, G8, B3, M4	Supporting healthy country, Fairy wren (Yeerung and Djeetgun), canoe trees (Yooro gree). Inundation of floodplain and riparian vegetation and disturbance of emergent vegetation. This is turn provides habitat for riparian zone birds. Stimulate macroinvertebrate and zooplankton production. Exchange of sediment (and nutrients), and carbon between waterway and floodplain to increase productivity.
		AVG / WET	1/year	AVG / WET	2 days		
		Overall: Max duration between events: 4 years					

Tanjil Reach 8

Flow component	Magnitude	Frequency (No/period)		Duration (days)		Hydraulic criteria met	Environmental values and functions supported
Summer / Autumn Baseflow	90 ML/day or natural	DROUGHT	Cont	DROUGHT	Cont	F6, F10, F19, , PL2, M3 V1,V4, WQ1	Supporting healthy country, fishing (Bunjil Tambun) / hunting (Woorngan) and platypus (Balagen), providing pool habitat (adequate depth) to support migratory and resident freshwater fish, macroinvertebrates, aquatic mammals, turtles, and submerged vegetation. Limit terrestrial vegetation encroachment to support emergent macrophyte vegetation. Maintain dissolved oxygen levels in pools (water quality).
		DRY		DRY			
		AVG		AVG			
		WET		WET			
Summer / Autumn Fresh	360 ML/day	DROUGHT	1	DROUGHT	3 days	F9*, F11, F12*, F17*, F18*, M2, FR1, PL1, V6, G5, G6, WQ2*	Supporting healthy country, fishing (Bunjil Tambun) / hunting (Woorngan) and platypus (Balagen). Inundating benches to maintain habitat (geomorphic processes), support growth of emergent macrophyte vegetation and sustain macroinvertebrate and zooplankton communities, and breeding substrate for Blackfish. Supporting healthy country by flushing sediment (sands) from pools and velocity for pool turnover (water quality and geomorphic processes). This also supports pool habitat for frogs. Longitudinal connectivity for aquatic mammals, migratory fish and resident freshwater fish.
		DRY	1	DRY	3 days		
		AVG	2	AVG	3 days		
		WET	3	WET	4 days		
Winter / Spring Baseflow	240 ML/day or natural	DROUGHT	Cont	DROUGHT	Cont	G2	Supporting healthy country by providing Summer / Autumn low flow functions plus flushing of sediment (sands) from pools.
		DRY		DRY			
		AVG		AVG			
		WET		WET			
Winter / Spring Fresh	1,100 ML/day	DROUGHT	-	DROUGHT	-	F2, F3, F9, F11, F14, F16, F17, F18, M1, FR3, T2, V7, V8, V9, G3	Supporting healthy country, fishing (Bunjil Tambun) / hunting (Woorngan) and platypus (Balagen). Inundation over benches (at greater depth) activating ecological processes to provide habitat for macroinvertebrates and zooplankton, providing a food source, habitat and connectivity for resident and estuary resident fish, turtles and frogs. Provide a mosaic of wetted areas for emergent macrophyte vegetation. Inundation of higher benches (geomorphic processes) to improve bench habitat and support growth of riparian vegetation.
		DRY	1	DRY	2 days		
		AVG	2	AVG	2 days		
		WET	3	WET	2 days		
Bankfull	4,000 ML/day	DRT / DRY	-	DRT / DRY	-	G1, V5, V11, T3	Supporting healthy country, canoe trees (Yooro gree). Inundation of riparian vegetation and disturbance of emergent vegetation. This is turn provides habitat for riparian zone birds. Flooding of banks and riparian zone to create nesting conditions for turtles. Maintain channel capacity and bench habitat (geomorphic processes)
		AVG	1/ 5 years	AVG	1 day		
		WET	1/2 years	WET	1 day		
		Overall: Max duration between events: 4 years					
Overbank	> 5,000 ML/day	DRT / DRY / AVG	-	DRT / DRY / AVG	-	V10, V12, V14, G8, B3, M4	Supporting healthy country, Fairy wren (Yeerung and Djeetgun), canoe trees (Yooro gree). Inundation of floodplain and riparian vegetation and disturbance of emergent vegetation. This is turn provides habitat for riparian zone birds. Stimulate macroinvertebrate and zooplankton production. Exchange of sediment (and nutrients), and carbon between waterway and floodplain to increase productivity.
		WET	1/2 years	WET	1.5 days		
		Overall: Max duration between events: 4 years					

Tyers Reach 9

Flow component	Magnitude (ML/day)	Frequency (No/period)		Duration (days)		Hydraulic criteria met	Environmental values and functions supported
Summer / Autumn Baseflow	100 ML/day or natural	DROUGHT	Cont	DROUGHT	Cont	F4*, F6, F10, F15*, F19, PL2, M3, V1,V4, WQ1	Supporting healthy country, fishing (Bunjil Tambun) / hunting (Woorngan) and platypus (Balagen), providing pool habitat (adequate depth) to support migratory and resident freshwater fish, macroinvertebrates, aquatic mammals, turtles, and submerged vegetation. Limit terrestrial vegetation encroachment to support emergent macrophyte vegetation. Maintain dissolved oxygen levels in pools (water quality).
		DRY		DRY			
		AVG		AVG			
		WET		WET			
Summer / Autumn Fresh	440 ML/day**	DROUGHT	1	DROUGHT	3 days	F2, F3, F5, F7, F8, F9, F11, F12, F13, F17, F18, M2, FR1, PL1, V6, G5, G6*, WQ2	Supporting healthy country, fishing (Bunjil Tambun) / hunting (Woorngan) and platypus (Balagen). Inundating benches to maintain habitat (geomorphic processes), support growth of emergent macrophyte vegetation and sustain macroinvertebrate and zooplankton communities, and breeding substrate for Blackfish. Flushing sediment (fine gravels) from pools and velocity for pool turnover (water quality and geomorphic processes). This also supports pool habitat for frogs. Longitudinal connectivity for aquatic mammals, migratory fish and resident freshwater fish.
		DRY	1	DRY	3 days		
		AVG	2	AVG	2 days		
		WET	3	WET	3 days		
Winter / Spring Baseflow	200 ML/day or natural	DROUGHT	Cont	DROUGHT	Cont	G2	Supporting healthy country by providing Summer / Autumn low flow functions plus flushing of sediment (sands) from pools.
		DRY		DRY			
		AVG		AVG			
		WET		WET			
Winter / Spring Fresh	860 ML/day	DROUGHT	1	DROUGHT	2 days	F2, F3, F9, F11, F14, F16, F17, F18, M1, FR3, T2, V7, V8, V9, G3	Supporting healthy country, fishing (Bunjil Tambun) / hunting (Woorngan) and platypus (Balagen). Inundation over benches (at greater depth) activating ecological processes to provide habitat for macroinvertebrates and zooplankton, providing a food source, habitat and connectivity for resident and estuary resident fish, turtles and frogs. Provide a mosaic of wetted areas for emergent macrophyte vegetation. Inundation of higher benches (geomorphic processes) to improve bench habitat and support growth of riparian vegetation.
		DRY	1	DRY	2 days		
		AVG	2	AVG	2 days		
		WET	3	WET	2 days		
Bankfull	2,000 ML/day	DRT / DRY	-	DRT / DRY	-	G1, V5, V11, T3	Supporting healthy country, canoe trees (Yooro gree trees). Inundation of riparian vegetation and disturbance of emergent vegetation. This is turn provides habitat for riparian zone birds. Flooding of banks and riparian zone to create nesting conditions for turtles. Maintain channel capacity by inundating high terraces (geomorphic processes)
		AVG	1/ year	AVG	1.5 days		
		WET		WET			
		Overall: Max duration between events: 2 years					
Overbank	> 2,500 ML/day	DRT / DRY	-	DRT / DRY	-	V10, V12, V14, G8, B3, M4	Supporting healthy country, Fairy wren (Yeerung and Djeetgun), canoe trees (Yooro gree). Inundation of floodplain and riparian vegetation and disturbance of emergent vegetation. This is turn provides habitat for riparian zone birds. Stimulate macroinvertebrate and zooplankton production. Exchange of sediment (and nutrients), and carbon between waterway and floodplain to increase productivity.
		AVG / WET	1/2 years	AVG / WET	1.5 days		
		Overall: Max duration between events: 4 years					

** Note, for the provision of longitudinal connectivity, the flow recommendations here is based on flow magnitudes required to provide appropriate depths over riffles in the representative site. In the determination of the flow recommendations, it was assumed that major fish barriers from the reach will be removed.

Traralgon Reach 11

Flow component	Magnitude	Frequency (No/period)		Duration (days)		Hydraulic criteria met	Environmental values and functions supported
Summer / Autumn Baseflow	40 ML/day or natural	DROUGHT DRY AVG WET	Cont	DROUGHT DRY AVG WET	Cont	F6, F10, F19, PL2, M3 V1,V4, WQ1	Supporting healthy country, fishing (Bunjil Tambun) / hunting (Woorngan) and platypus (Balagen), providing pool habitat (adequate depth) to support migratory and resident freshwater fish, macroinvertebrates, aquatic mammals, turtles, and submerged vegetation. Limit terrestrial vegetation encroachment to support emergent macrophyte vegetation. Maintain dissolved oxygen levels in pools (water quality).
Summer / Autumn Fresh	160 ML/day	DROUGHT	1	DROUGHT	2 days	F2*, F3*, F5*, F7*, F8*, F9*, F11, F12*, F13*, F17*, M2, FR1, PL1, V6, G5, G6*, WQ2	Supporting healthy country, fishing (Bunjil Tambun) / hunting (Woorngan) and platypus (Balagen). Inundating benches to maintain habitat (geomorphic processes), support growth of emergent macrophyte vegetation and sustain macroinvertebrate and zooplankton communities, and breeding substrate for Blackfish. Flushing sediment (fine sands) from pools and velocity for pool turnover (water quality and geomorphic processes). This also supports pool habitat for frogs. Longitudinal connectivity for aquatic mammals, migratory fish and resident freshwater fish.
		DRY	1	DRY	2 days		
		AVG	2	AVG	2 days		
		WET	3	WET	2 days		
Winter / Spring Baseflow	100 ML/day or natural	DROUGHT DRY AVG WET	Cont	DROUGHT DRY AVG WET	Cont	G2*	Supporting healthy country by providing Summer / Autumn low flow functions plus flushing of sediment (sands) from pools.
Winter / Spring Fresh	500 ML/day	DROUGHT	-	DROUGHT	-	F2, F3, F9, F11, F14, F16, F17, F18, M1, FR3, T2, V7, V8, V9, G3	Supporting healthy country, fishing (Bunjil Tambun) / hunting (Woorngan) and platypus (Balagen). Inundation over benches (at greater depth) activating ecological processes to provide habitat for macroinvertebrates and zooplankton, providing a food source, habitat and connectivity for resident and estuary resident fish, turtles and frogs. Provide a mosaic of wetted areas for emergent macrophyte vegetation. Inundation of higher benches (geomorphic processes) to improve bench habitat and support growth of riparian vegetation.
		DRY	1	DRY	1 days		
		AVG	2	AVG	2 days		
		WET	3	WET	2 days		
Bankfull	1,400 ML/day	DRT/DRY	-	DRT/DRY	-	G1, V5, V11, T3	Supporting healthy country, canoe trees (Yooro gree trees). Inundation of riparian vegetation and disturbance of emergent vegetation. This is turn provides habitat for riparian zone birds. Flooding of banks and riparian zone to create nesting conditions for turtles. Maintain channel capacity by inundating higher terraces (geomorphic processes)
		AVG WET	1/year	AVG WET	1 day		
		Overall: Max duration between events: 4 years					
Overbank	> 4,000 ML/day	DRT/DRY	-	DRT/DRY	-	V10, V12, V14, G8, B3, M4	Supporting healthy country, Fairy wren (Yeerung and Djeetgun), canoe trees (Yooro gree). Inundation of floodplain and riparian vegetation and disturbance of emergent vegetation. This is turn provides habitat for riparian zone birds. Stimulate macroinvertebrate and zooplankton production. Exchange of sediment (and nutrients), and carbon between waterway and floodplain to increase productivity.
		AVG	1/ 5 years	AVG	1 day		
		WET	1/ 2 years	WET	1 day		
		Overall: Max duration between events: 4 years					

7 Environmental water requirements – Latrobe estuary

7.1 Approach to developing environmental water requirements

The process for deriving environmental flow recommendations (Figure 40) includes identifying water dependent value in the system and ecological objectives to support those values (see Section 4). The flow components and criteria (detailed below) are derived from these objectives using conceptual models as described in Section 4 (refer to 'Water requirements' heading for each value). Based on these criteria, relevant hydrodynamic models (see below) are used to determine the magnitude of the flow recommendation. An understanding of the system hydrology (see Section 2is used in conjunction with the conceptual models and criteria to determine the frequency, duration and timing of the flow recommendations. The determination of the number and duration of recommended flow events has then been considered in this study for four prevailing climatic conditions; drought, dry, average and wet years (see Section 2).

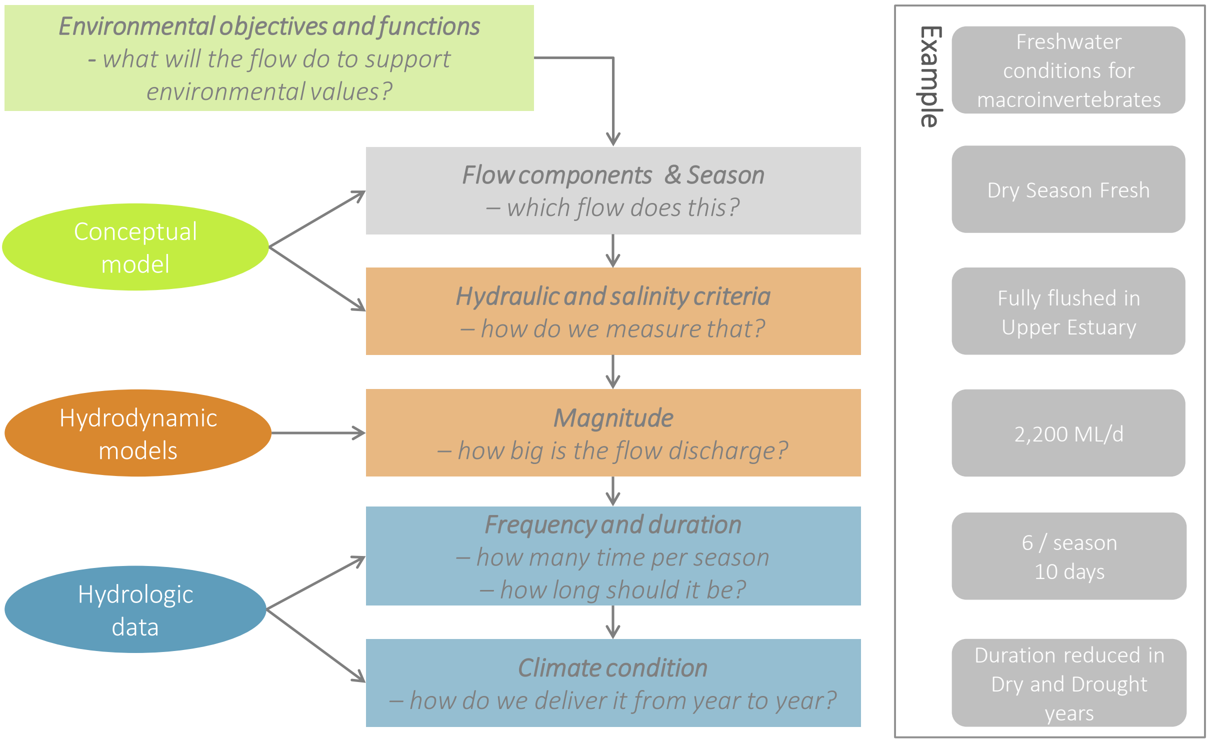


Figure 40. *Process for determining estuary environmental flow requirements.*

Flow components are discussed in see Section 2 and a summary is provided in the box below.

Flow components

Summer / Autumn baseflows are the natural dry period (summer/autumn) flows or 'baseflows' that maintain water flowing through the channel, keeping in-stream habitats wet and pools full.

Summer / Autumn freshes are frequent, small, and short duration flow events that last for one to several days as a result of localised rainfall during the low flow period.

Winter / Spring baseflows refer to the persistent increase in low or base flow that occurs with the onset of the wet period.

Winter / Spring freshes refer to sustained increases in flow during the high flow period as a result of sustained or heavy rainfall events.

Bankfull flows fill the channel, but do not spill onto the floodplain. **Overbank flows** are higher and less frequent than bankfull flows and spill out of the channel onto the floodplain. Bankfull and overbank flows are more common in the wet period, but also occurs in the dry period.

Application of hydraulic and salinity criteria

The hydraulic and salinity criteria required to support the values identified and achieve the flow objectives in Section 4 are detailed in Table 30. Hydraulic criteria have been determined by Environmental Flow Technical Panel members based on relevant literature, expert knowledge and using the conceptual models detailed in Section 4. These criteria have been updated from the previous estuary FLOWS study to reflect the updated objectives and the best available science.

As described in see Section 2, the Latrobe estuary is considered in three parts as follows (refer to Figure 12 in Section 2):

- Lower estuary: Lake Wellington to ~ 0.5km west of the western water control structure "Big Drain" in Dowd Morass.
- Mid estuary: From the Latrobe-Thomson confluence at the Swing Bridge, downstream to about to about 0.5km west of the western water control structure "Big Drain" in Dowd Morass.
- Upper estuary: The Latrobe and Thomson Rivers above the confluence and Sale Canal.

Where there are references to freshwater, this is defined as < 1 g/L (equivalent to levels below 1500-1800 EC, depending on the water source).

Table 32. Objectives and hydraulic criteria for Latrobe estuary

Value	Objective	Traditional Owner Cultural water values	Sub-reach	Function	Component	Timing / frequency	Criteria	
FISH								
Migratory fish	Maintain abundance of grayling populations Improve recruitment of grayling populations	Fishing (Bunjil Tambun) / hunting (Woorngan)	All	Juveniles migrate upstream from sea	Fresh	October to January	F3	Freshwater outflows to create salinity gradient from Latrobe River into Lake Wellington (freshwater lens over salt wedge is sufficient to provide signal)
				Maintain permanent freshwater habitat	Baseflow	All year	F4	Allow sufficient depth and flow to support grayling populations (freshwater levels of >2m over the salt wedge)
				Longitudinal connection in channel for adult grayling movement	Fresh	December to March	F5	Freshwater flows creating salinity gradient and passage to allow grayling to reach the Lakes or entrance
	Maintain abundance of eel (noy yang) populations	Fishing (Bunjil Tambun) / hunting (Woorngan)	All	Provide freshwater for habitat and food sources	Baseflow	All year	F6	Maintain depth of freshwater available, preferably 1-2 m deep
				Provide freshwater to allow fish to migrate upstream from estuary	Fresh	Nov to May	F7	Freshwater flows to provide a signal to eels to migrate upstream by creating a salinity gradient and sufficient depth
				Downstream migration of eels (noy yang) to allow for ocean breeding	Fresh	Oct to May	F8	Freshwater flows creating salinity gradient and passage to allow eels to reach Lakes Entrance
	Improve recruitment of small-bodied migratory fish including Tupong, Broad-finned Galaxias and Common Jollytail		All	Provide freshwater for habitat and food sources	Baseflow	All year	F10	Allow sufficient depth of freshwater, at least 500-600 mm, above the salt-wedge
				Provide freshwater to allow fish to move between pools to feed, grow and find new habitats (allow juvenile Tupong to move upstream)	Fresh	August to Feb	F11	Freshwater flows to provide a signal to small-bodied fish to migrate locally or upstream by creating a salinity gradient and sufficient depth
				Provide connectivity to allow fish to migrate downstream to breed	Fresh	March to July	F12	Freshwater flows to provide a signal to small-bodied fish to migrate downstream by creating a salinity gradient and sufficient depth
	Maintain abundance of Australian Bass populations	Fishing (Bunjil Tambun) /	All	Downstream migration of Australian Bass adults to allow for estuarine breeding	Fresh	April to July	F13	Freshwater flows creating salinity gradient and passage to allow Bass to reach the Lakes or the entrance

Value	Objective	Traditional Owner Cultural water values	Sub-reach	Function	Component	Timing / frequency	Criteria	
	Improve recruitment of Australian Bass populations	hunting (Woorngan)		Allow upstream movement of juveniles into freshwater habitats	Fresh	Sept to April	F14	Freshwater flows to provide a signal for juvenile Bass to migrate upstream by creating a salinity gradient and sufficient depth
				Maintain freshwater habitat	Baseflow	All year	F15	Allow sufficient depth and flow to support Australian Bass populations (freshwater levels of >2m over the salt wedge)
Resident freshwater fish	Improve recruitment of small-bodied freshwater resident fish such as Pygmy Perch, Australian Smelt and Flat-headed Gudgeon		All	Provide prolonged seasonal inundation of vegetation beds and instream benches as habitat to stimulate invertebrate hatching and fish breeding	Fresh	Aug to Nov	F16	500 mm water depth over some instream benches and vegetation beds
	Maintain abundance of resident freshwater fish, including Pygmy Perch, Australian Smelt and Flat-headed Gudgeon			Provide freshwater for habitat and food sources	Baseflow	Nov to March	F19	Allow sufficient depth of freshwater, at least 500 mm, above the salt-wedge
Estuary Resident Fish	Maintain abundance and improve breeding and recruitment of estuarine resident species (Estuary Perch, River Garfish, Black (Kine) Bream eastern blue-spot goby and lagoon goby)	Fishing (Bunjil Tambun) / hunting (Woorngan)	All	Provide freshwater for habitat and food sources	Baseflow	All year	F20	Maintain depth of freshwater available, preferably 1-2 m deep
				Downstream migration of Estuary Perch adults to allow for estuarine breeding	Low Fresh	July to August	F21	Freshwater flows to provide a signal for Estuary Perch to migrate downstream by creating a salinity gradient and sufficient depth (500mm)
				Flows which maintain estuarine salinities to enable estuarine resident fish to breed and grow	Fresh	Sept to December	F22	Flows which maintain estuarine salinities between 15-20 ppt and high dissolved oxygen levels
				Provide freshwater to allow longitudinal connectivity and for fish to move between habitats	Fresh	Sept to March	F23	Freshwater flows to provide a signal for fish to migrate locally or upstream by creating a salinity gradient and sufficient depth over salt wedge

Value	Objective	Traditional Owner Cultural water values	Sub-reach	Function	Component	Timing / frequency	Criteria	
OTHER FAUNA								
Macro-invertebrates and zooplankton	Improve abundance of macroinvertebrate and zooplankton populations		Upper estuary	Create and extend aquatic habitats for macroinvertebrates and zooplankton	Fresh	Aug to Nov	M1	Increase wetted area by inundating instream benches by 300mm deep and provide freshwater
				Sustain macroinvertebrate and zooplankton communities during summer as a food source for fish, frog and platypus (Balagen) populations	Fresh	Nov to March	M2	Inundate benches and provide freshwater
				Create aquatic floodplain habitats for macroinvertebrates and zooplankton (including rotifers) and stimulate production	Overbank	Winter / Spring	M4	Inundate floodplain
Frog Populations	Maintain abundance of frog populations Improve extent of frog populations		Mid and upper estuary	Provide habitat with appropriate water quality	Fresh	Summer	FR1	Refer to WQ2
				Allow growth and reproduction of macroinvertebrate communities	Fresh	Spring	FR2	Refer to M1
				Provide habitat links between wetlands and estuary	Fresh	Spring	FR3	300 mm freshwater water depth
Aquatic mammals	Improve extent of platypus (Balagen) and rakali populations	Keystone species	Upper estuary	Provide freshwater habitat conditions in the (upper) estuary	Baseflow	All year	PL1	Provide year-round freshwater conditions
Waterbirds	Maintain or enhance waterbird and threatened fauna breeding, recruitment, foraging and sheltering opportunities Maintain the different waterbird functional feeding groups in the wetlands, such as duck	Mother and Father song line within the Gunaikurnai creation story (Boran and Tuk) Hunting (Woorngan) /food	All	Provide access to fresh drinking water	Fresh	All year	B1	Freshwater in mid-estuary

Value	Objective	Traditional Owner Cultural water values	Sub-reach	Function	Component	Timing / frequency	Criteria	
	and rails, insectivorous guilds, colonial water birds, and shorebirds.							
	Maintain abundance of riparian zone birds		All	Flooding of riparian vegetation for foraging habitat	Overbank	July to December	B2	~ 3 out of 5 years
VEGETATION								
Submerged	Improve condition and extent of **submerged vegetation**	Materials, Basket-making	Thomson River and Sale Canal	Maintain adequate depth of freshwater in channel	Baseflow	All year	V1	400 mm water depth in pools
				Maintain water quality to support health of Vallisneria sp beds	Baseflow	All year	V3	Maintain water salinity < 4 g/L
Emergent macrophyte	Improve condition, extent and diversity of **emergent macrophyte vegetation** on banks and shorelines to provide structural habitat	Materials, Basket-weaving, keystone species habitat Hunting (Woorngan) / food	All	Maintain adequate depth of permanent fresh water in stream channel to limit terrestrial encroachment into aquatic habitats.	Baseflow	All year	V4	400 mm water depth in pools Salinity < 10 g/L
				Provide disturbance in riparian zone and channel to open recruitment niches for emergent plants.	Bankfull	~2 per year or natural regime	V5	Inundate all channel
				Support growth on terraces, channel edge and lower bank by providing fresh water.	Fresh	Summer/ Autumn ~6 per year or natural regime	V6	Inundate the lower bank, channel terraces and wetland margins Salinity < 10 g/L
				Provide a mosaic of spatially and temporally differentially wetted areas within stream channel, lower banks and wetland margins.	Fresh	Winter / Spring ~6 per year or natural regime	V7	Variations in water depth of approximately 500 mm over low-flow levels
				Provide freshwater conditions at River mouth to support phragmites reproduction	Fresh	Spring ~1 per year or natural regime	V8	Salt wedge displaced from estuary. Ideal duration of freshwater conditions ~ 1 month .
Riparia n	Improve condition, extent and diversity of all **riparian vegetation**	Tool making: Yooro gree trees (Red gum-canoe	Lower Latrobe,	Support growth of riparian vegetation on terraces, channel edge and lower bank.	Fresh	Winter / Spring ~6 per year or natural regime	V8	Inundate the lower bank and channel benches up to 500 mm from low flow level

Value	Objective	Traditional Owner Cultural water values	Sub-reach	Function	Component	Timing / frequency	Criteria	
	especially for endangered EVCs	trees); Woorngan (hunting) / food	River Delta & Mouth	Provide disturbance in riparian zone and channel to open recruitment niches for riparian plants. Especially Eucalypt species.	Fresh	Winter / Spring ~6 per year or natural regime	V9	Replacement of exotic grasses with native shrubs and ground cover
				Provide mechanism for dispersal of riparian and floodplain seeds.	Overbank	August - December	V10	Freshwater, minimum depth 5 cm over top of soil
				Inundate all channel vegetation and support its growth.	Bankfull	Anytime	V11	Inundate all channel
Floodplain	Improve condition and extent of all **floodplain vegetation** especially for endangered EVCs (e.g. Swamp Scrub EVC53)		Lower Latrobe, Upper Latrobe and Thomson	Fill floodplain depressions and billabongs to support the growth of seasonal and emergent wetland vegetation.	Overbank	Spring/ summer	V12	Commence overbank flooding
				Inundate floodplain and provide moisture to floodplain species and promote carbon exchange.	Overbank	1 every 2-3 years	V14	Water flows to floodplain Periodic flooding, min depth 5 cm over top of soil, any time of year Salinity of groundwater / soil water <15 ppt (20,000 EC)
SUPPORTING FUNCTIONS								
Water quality	Avoid adverse water quality conditions such as prolonged stratified conditions in pools, Low DO levels, high salinities and high nutrient levels	Healthy country	All	Maintain dissolved oxygen levels above thresholds for gill-breathing organisms (fish, macroinvertebrates and zooplankton) during summer/autumn	Baseflow	Summer / Autumn	WQ1	Velocity of 0.1 m/s through pools Halocline > 1.5 m deep
				Maintain adequate flows to reduce potential of prolonged stratified conditions in pools and promote adequate levels of water quality to allow fish, macroinvertebrate and zooplankton populations to persist	Fresh	Summer / Autumn	WQ2	Velocity of 0.3 m/s through pools Flushing of entire water column
	Maintain surface water salinity at a level to enable growth and reproduction of emergent vegetation on banks and shoreline of estuary.		All	Limit surface water salinity to enable growth and reproduction of emergent vegetation and submerged aquatic macrophytes.	Bankfull	Any time	WQ3	Displace salt wedge into Lake Wellington

Value	Objective	Traditional Owner Cultural water values	Sub-reach	Function	Component	Timing / frequency	Criteria	
	Maintain freshwater supply to Latrobe Estuary, Dowd Morass, Sale Common, Heart Morass, and associated freshwater habitats	Healthy country	All	Provide sufficient freshwater to maintain freshwater wetland flora and fauna, including provision of habitat for foraging, reproduction and longitudinal connectivity	All	Any time	WQ4	River levels to supply wetlands with freshwater (especially winter and spring) and to maintain at least a permanently high water table
Geomorphology	Maintain habitat to support ecological values and processes		All	Maintain gross channel capacity through provision of the dominant channel-forming flow events (bankfull events)	Bankfull	Any time	G1	Bankfull event
				Maintain gross channel capacity through provision of events capable of mobilising bed load sediment	Fresh	Winter / Spring	G2	Mobilise and transport bed load sediment (0.1 N/m^2 shear stress through mid/ lower estuary and 1.1 N/m^2 in upper estuary)
				Provide flows that establish and maintain high flow benches (scour and deposit sediment on high flow benches)	Freshes	Winter / Spring	G3	Inundate high benches
					Bankfull	Anytime	G4	Mobilise sediment of high benches
				Provide overbank inundation to enable exchange of sediment and carbon to and from the river	Overbank	Anytime	G5	Maintain occurrence of overbank events
	Maintain the silt jetties and the bar at the mouth of the Latrobe River		River Mouth & Delta	Maintain sediment export from the Latrobe River	Fresh	Anytime	G9	Salt wedge displaced into Lake Wellington to allow sediment transport
					Baseflow	All year	G10	Flow velocities sufficiently high to transport silt through estuary and maintain in water column (0.01 m/s)

Hydrodynamic modelling and analysis

The magnitudes of the flow required to achieve the flow functions were estimated using two hydrodynamic models: a one-dimensional hydrodynamic model using Mike 11 software and a three-dimensional hydrodynamic model using Mike 3.

The one-dimensional model provides water levels and flow rates in the estuary based on inflows from the Latrobe River Reach 5, the lower Thomson River, Lake Wellington levels, and water that is transferred to the wetlands. This model was developed by Water Technology as part of the 2013 estuary flow study, and the time series has been extended and the model rerun as part of this project. The time series modelled now included 1957 – 2017. This model has been used to estimate the flow rates necessary at any given site to achieve nominated target criteria such as stream velocity, shear stress, inundation depths and inundation extents.

The three-dimensional model represents salinity patterns throughout the estuary, based on inflow rates from the upstream reaches and Lake Wellington conditions. This model was developed by Water Technology as part of the 2013 estuary flow study, and results have been used directly as input to this project (see Appendix F for further information).

Updated hydrodynamic modelling was undertaken to understand the sensitivity of the flow recommendations to sea level rise. The recommended flow magnitudes (and minimum durations) were tested in the three-dimensional hydrodynamic model, with modified water level boundary conditions in Lake Wellington (see Appendix G for further information). We tested the proposed environmental flow recommendations using the hydrodynamic models for two sea level rise scenarios: 0.1 m and 0.27 m, representing 2050 predictions based on substantial reductions and small reduction in global CO_2 emissions respectively. We found the 0.1m sea level rise scenario did not impact on the attainment of the environmental flow objectives. However, we found the 0.27 m sea level rise scenario impacted on the attainment of objectives associated with the Summer / Autumn Fresh 1 and Winter / Spring Fresh 2. The sea level rise sensitivity analysis has revealed that the flow recommendations provide some resilience to sea level rise without being overly conservative for current conditions.

In addition, environmental flow response monitoring was undertaken from 2014 – 2016 (Water Technology 2017). This monitoring included salinity monitoring at multiple locations throughout the estuary and within the water column at each location. This monitoring work has provided additional information about the flows required to create freshwater conditions at selected locations through the estuary and also the response time for the salt wedge to return after a flow event (see Appendix F for further information).

Hydrologic modelling and analysis

'or natural'

Natural flow variability is an important aspect of an environmental flow regime. While all low flow recommendations are expressed as 'continuous', an 'or natural' clause has been added to these flows. This clause is designed to allow reduced flows and seasonal draw down to occur, if it would have done so naturally. Determining the natural flow variability in these circumstances will need to be addressed as part of the implementation of the environmental flow recommendations.

Season definition

The flow recommendations (specifically baseflows and freshes) have been developed and expressed as either 'Summer / Autumn' or 'Winter / Spring'. The 'Summer / Autumn' recommendations cover the summer and autumn period from December to May and the 'Winter / Spring' period covers winter and spring from June to November. Flow frequencies expressed as '/period' denote the number of events in the 'Summer / Autumn' or 'Winter / Spring' (i.e. a six-month period). For example, a summer fresh with a frequency of 6/period would occur a total of six times across the December – May period.

The variation in seasonal definitions is recognised and exact timing of flows within the defined period should be coordinated to take into consideration:

- The unimpacted or 'natural' flow regime
- Cultural seasons

- Weather events
- Ecological life cycles

The delivery of the recommended flow regime can be developed further in an environmental water management plan.

Spells analysis
Flow duration curves are provided for each reach and each period (Summer / Autumn or Winter / Spring) in Section 2 (Figure 14, Figure 15). In addition, a spells analysis has been undertaken for each recommended flow magnitude. A 'high spells' analysis using eWater's RAP software identified the mean frequency of a given flow (or greater) occurring and the mean duration of those flow events, for the period of interest (Summer / Autumn or Winter / Spring). This analysis was performed for all years of modelled data and also for each different climate condition (Drought, Dry, Average, Wet year), and combined with an understanding of ecological requirements, was used to develop the recommended frequency and duration for each recommendation. For overbank and bankfull recommendations, a maximum duration between events is also recommended, based on the maximum duration between events for the natural time series, and or ecological requirements.

Rates of rise and fall
The rate of rise and fall relates to the rate of change in flow from day to day, with a focus on the rate of increase up to a target flow and a rate of decrease from this target flow. These fluctuations in the flow rate serve important ecological and geomorphic functions in a river system. Excessive rates of water-level fall can result in fish being stranded by falling waters or bank slumping. It is therefore important that this rate is not significantly altered from the natural (unimpacted) rates of rise and fall in stream flow.

Within the context of flow management, recommended rates of rise and fall are useful to ensure that the delivery of *managed* flows is such that ecological harm is minimised. The recommended rates of rise and fall were determined from the modelled unimpacted daily flow data. Rates of rise and fall are reported as the maximum rate of permissible rise/fall from one day to the next. For example, if the flow is at 100 ML/d and the recommended rate of fall is 0.7, the flow on the following day should not be below 70 ML/d. Similarly, if the flow rate was 100 ML/d and the recommended rate of rise is 1.8, the flow on the following day should not exceed 180 ML/d.

The recommended maximum rate of rise and fall have been defined for modelled unimpacted flows as 90th percentile of rise and 10th percentile of fall for dry and Winter / Spring freshes and around 80th percentile of rise and 10th percentile of fall for all flows above bankfull magnitude (Table 33).

Table 33. Rates of rise and fall for the Latrobe estuary .

Reach	Period	Rise	Fall
Latrobe estuary (upper, middle, lower)	Summer / Autumn freshes	1.7	0.7
	Winter / Spring freshes	1.5	0.9
	Bankfull/overbank	1.5	0.9
Upper estuary (Thomson estuary)	Summer / Autumn freshes	1.8	0.7
	Winter / Spring freshes	1.8	0.8
	Bankfull/overbank	NA	NA

7.2 Environmental flow recommendations

Environmental flow recommendations have been determined for the seven river reaches of the Latrobe River system within the scope of this study. The tables below include a summary of the environmental values and functions supported by each flow component to help to achieve the environmental objectives.

Each recommendation is comprised of a flow component, discharge (magnitude), timing (period), frequency (generally number of times per period) and duration (generally in days), as well as the inclusion of climate condition (Figure 41). Flows components for the estuary are described in Section 2 and include Summer / Autumn low flow, Summer / Autumn fresh, Winter / Spring low flow, Winter / Spring Fresh, Bankfull and Overbank.

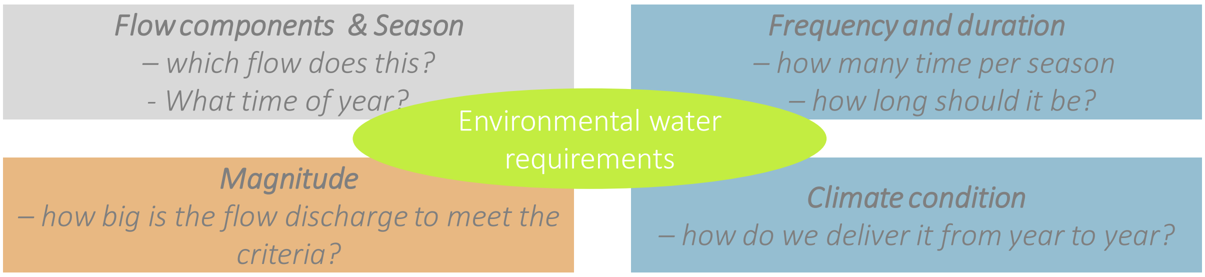


Figure 41. *Components of a flow recommendation*

In this section, flow recommendations are provided for each flow component, for the Latrobe River estuary at Swing Bridge (representing the Mid and Lower Estuary) and the Thomson River Estuary (part of the Upper Estuary). The Latrobe River at Swing Bridge is the compliance point used for the Latrobe estuary as this is where a gauge is located, and model data is available.

The updated flow recommendations arising from this investigation (provided below) differ from those developed from previous studies. Some of the reasons for differences include:

- refined and updated environmental objectives
- updated ecological and system knowledge
- improved hydrologic and hydraulic modelling.

Note: Recommendations for different climate conditions are provided to allow for a seasonally adaptive approach to environmental water delivery. The climate conditions are based on the historic climate record, where Dry or Drought years occurred less than 25% of the time (see Section 2.4). The Average (or Wet) recommendations should be provided at least 75% of the time in order to have confidence that the objectives can be met. The provision of average or wet conditions in 75% of years will be required under a continuation of the current climate or under a drying climate with an increasing number of Dry and Drought years.

The flow recommendations provided for the Thomson are focused on the reach that is influenced by salt wedge movement, downstream of Sale. The recommendations do not apply to the full river reach (up to the Macalister River confluence); the recommendations for the Thomson River upstream of Sale should be updated as part of a full review of the Thomson River flow recommendations.

Recommendations for the Latrobe River part of the Upper Estuary (Reach 5) are provided in Section 6.2. The salt wedge does not extend into the Latrobe River upstream of the confluence and there is no existing salinity modelling available for this reach.

Notes

1. Specific estuary reach representative sites were not inspected by the environmental flows technical panel, as the hydrodynamic model was already developed for the full estuary as part of the previous study.
2. The environmental flow recommendations consider watering of the Lower Latrobe Wetlands by providing flows that create freshwater conditions in the estuary suitable for watering of the adjoining wetlands. However, the recommendations have not considered the specific flow rates required in the estuary to enable watering of the wetlands via the existing (or any proposed) infrastructure.

Latrobe Estuary

Flow component	Magnitude at Swing Bridge	Frequency (No/period)		Duration (days)		Values and functions supported (Upper portion of water column refers to 2-3 m below surface) [Criteria met in brackets] *Mid Estuary*	*Lower estuary*
Summer / Autumn Baseflow	1,100 ML/day or natural (Typical water level range: 0-0.3 m AHD)	DROUGHT DRY AVG WET	Cont	DROUGHT DRY AVG WET	Cont	*Partially flushed in upper portion of water column* Supporting healthy country Provide freshwater above halocline for fish [F4,F6, F10, F15, F19, F20] Salinity low enough to support emergent macrophyte vegetation [V4]	*Not flushed* Velocities to ensure fine sediment remains suspended and transported out of estuary. [G10]
Summer / Autumn Fresh 1	2,200 ML/day (Typical water level range: 0.1-0.4 m AHD)	DROUGHT DRY AVG WET	2 2 3 3	DROUGHT DRY AVG WET	7 days 10 days 10 days 10 days	*Upper portion fully flushed* Supporting healthy country, fishing (Bunjil Tambun) / hunting (Woorngan), freshwater for wetlands Provide freshwater above halocline for fish [F4,F5,F6, F7, F8 F10,F11,F12,F13,F14,F15,F19, F20,F21,F23] Provide freshwater conditions for birds [B1] Flushing of water column for water quality [WQ2, FR1] Support growth of emergent macrophytes [V6] Suitable conditions for wetland watering of Sale Common and Heart Morass [WQ4]	*Upper portion partially flushed*
Summer / Autumn Fresh 2	3,200 ML/day (Typical water level range: 0.15-0.4 m AHD)	DROUGHT DRY AVG WET	1 1 1 2	DROUGHT DRY AVG WET	4 days 7 days 10 days 10 days	*Fully flushed* Supporting healthy country, freshwater for wetlands Freshwater in mid estuary area for wetland watering (Sale Common, western and central Heart Morass structures, western Dowd Morass) [WQ4]	Upper portion of water column fully flushed
Winter / Spring Baseflow	1,100 ML/day or natural (Typical water level range: 0-0.3 m AHD)	DROUGHT DRY AVG WET	Cont	DROUGHT DRY AVG WET	Cont	*Partially flushed in upper portion of water column* Supporting healthy country, fishing (Bunjil Tambun) / hunting (Woorngan) Provide freshwater above halocline for fish [F4,F6, F10, F15, F19, F20] Salinity low enough to support emergent macrophyte vegetation [V4]	*Not flushed* Velocities to ensure fine sediment remains suspended and transported out of estuary. [G10]

Flow component	Magnitude at Swing Bridge	Frequency (No/period)		Duration (days)		Values and functions supported (Upper portion of water column refers to 2-3 m below surface) [Criteria met in brackets]	
						Mid Estuary	*Lower estuary*
Winter / Spring Fresh 1	3,200 ML/day (Typical water level range: 0.15-0.4 m AHD)	DROUGHT	2	DROUGHT	5 days	*Fully flushed* Supporting healthy country, canoe trees (Yooro gree), freshwater for wetlands Provide freshwater above halocline for fish [F4,F5,F6, F7, F8 F10,F11,F12,F13,F14,F15,F19, F20,F21,F23] Provide freshwater conditions for frogs and birds [FR3, B1] Freshwater in mid estuary area for wetland watering (Sale Common, western and central Heart Morass structures, western Dowd morass) [WQ4] Flushing silts [G2] Mosaic of wetted areas for emergent and riparian vegetation. [V7, V8, V9]	*Upper portion of water column fully flushed* Supporting healthy country, canoe tress, freshwater for wetlands Freshwater in lower estuary area for wetland watering (eastern Heart Morass, central and eastern Dowd Morass) [WQ4] Flushing silts [G2] Salinities for Black Bream Spawning [F22]
		DRY	2	DRY	10 days		
		AVG	3	AVG	15 days		
		WET	3	WET	20 days		
Winter / Spring Fresh 2	4,500 ML/day (Typical water level range: 0.3-0.5 m AHD)	DROUGHT	1	DROUGHT	10 days	*Fully flushed*	*Fully flushed* Displace salt wedge for sediment export [G9] Support growth of Phragmites in lower Estuary during Spring [V8] Salinity gradient for Grayling [F3]
		DRY	1	DRY	15 days		
		AVG	2	AVG	20 days		
		WET	2	WET	30 days		
Bankfull	9,500 (to 12,000 ML/day) (Typical water level range: 1.1-1.3 m AHD)	DROUGHT	-	DROUGHT	-	Supporting healthy country, canoe tress (Yooro gree) Inundation of riparian vegetation and disturbance to support emergent vegetation [V11, V5] Maintain channel capacity (geomorphic process) [G1]	
		DRY	1	DRY	4 days		
		AVG	2	AVG	5 days		
		WET	2	WET	8 days		
		Overall: Max duration between events: 2 years					
Overbank	14,000 (to 17,000 ML/day) (Typical water level range: ~1.4 m AHD)	DROUGHT	-	DROUGHT	-	Supporting healthy country. Inundation and seed dispersal for floodplain and riparian vegetation [V12, V14, V10] Riparian vegetation then provides habitat for riparian zone birds [B2] Stimulate macroinvertebrate and zooplankton production [M4] Exchange of sediment (and nutrients), and carbon between waterway and floodplain to increase productivity. [G5]	
		DRY	-	DRY	-		
		AVG	1/ 2 years	AVG	3 days		
		WET	1	WET	5 days		
		Overall: Max duration between events: 5 years					

Upper Estuary: Thomson Estuary

Flow component	Magnitude	Frequency (No/period)		Duration (days)		Environmental values and functions supported [Criteria met in brackets]
Summer / Autumn Baseflow	340 ML/day or natural (Typical water level range: 0-0.3 m AHD)	DROUGHT	Cont	DROUGHT	Cont	*Fully flushed in upper portion of water column (lower layer is 2m below surface).* Supporting healthy country. Maintain freshwater conditions for aquatic mammals, fish, and submerged vegetation [PL1, V1, V3; F4, F6, F10, F15, F19, F20] Maintain dissolved oxygen levels [WQ1]
		DRY		DRY		
		AVG		AVG		
		WET		WET		
Summer / Autumn Fresh 1	930 ML/day (Typical water level range: 0-0.6 m AHD)	DROUGHT	3	DROUGHT	2 days	*Fully flushed* Supporting healthy country, fishing (Bunjil Tambun) / hunting (Woorngan), freshwater for wetlands Flushing sediment (sands and silts) from upper estuary [G2] Provide freshwater to sustain macroinvertebrate and zooplankton communities. [M1] Future opportunity: Freshwater in upper estuary area for wetland watering (Sale Common) [WQ4]
		DRY	3	DRY	2 days	
		AVG	3	AVG	3 days	
		WET	4	WET	4 days	
Winter / Spring Baseflow	490 ML/day or natural (Typical water level range: 0-0.3 m AHD)	DROUGHT	Cont	DROUGHT	Cont	*Fully flushed* Supporting healthy country, fishing (Bunjil Tambun) / hunting (Woorngan) Maintain freshwater conditions for aquatic mammals, fish, and submerged vegetation [PL1, V1, V3; F4, F6, F10, F15, F19, F20] Maintain dissolved oxygen levels [WQ1] Flushing of sediment (sands) [G2]
		DRY		DRY		
		AVG		AVG		
		WET		WET		
Winter / Spring Fresh 1	930 ML/day (Typical water level range: 0-0.6 m AHD)	DROUGHT	2	DROUGHT	5 days	*Fully flushed* Supporting healthy country, canoe trees (Yooro gree), freshwater for wetlands Provide flushing of salt wedge for wetland watering and displacing salt wedge [WQ4, G9, V8] Future opportunity: Freshwater in upper estuary area for wetland watering (Sale Common) [WQ4]
		DRY	2	DRY	10 days	
		AVG	3	AVG	15 days	
		WET	3	WET	20 days	

Flow component	Magnitude	Frequency (No/period)		Duration (days)		Environmental values and functions supported [Criteria met in brackets]
Winter / Spring Fresh 2	3,000 ML/day (Typical water level range: 0.4 – 1.4 m AHD)	DROUGHT	2	DROUGHT	3 days	Inundate benches and provide freshwater to sustain macroinvertebrate and zooplankton communities. [M2, FR2, F16, G3] Mosaic of wetted areas for emergent and riparian vegetation. [V7, V8, V9]
		DRY	2	DRY	4 days	
		AVG	3	AVG	5 days	
		WET	4	WET	5 days	
Bankfull	13,000 ML/day (Typical water level range: 1.5-2.0 m AHD)	DROUGHT	-	DROUGHT	-	Supporting healthy country, canoe tress (Yooro gree trees) Inundation of riparian vegetation and disturbance to support emergent vegetation [V5, V11] Maintain channel capacity (geomorphic process) [G1]
		DRY	-	DRY	-	
		AVG	1	AVG	2 days	
		WET	1	WET	2 days	
		Overall: Max duration between events: 2 years				
Overbank	17,000 ML/day (Typical water level range: ~2.4 m AHD)	DROUGHT	-	DROUGHT	-	Supporting healthy country. Inundation and seed dispersal for floodplain and riparian vegetation [V12, V14] Riparian vegetation then provides habitat for riparian zone birds [B2] Stimulate macroinvertebrate and zooplankton production [M4] Exchange of sediment (and nutrients), and carbon between waterway and floodplain to increase productivity [G5]
		DRY	-	DRY	-	
		AVG	1	AVG	2 days	
		WET	1	WET	2 days	
		Overall: Max duration between events: 3 years				

8 Environmental water requirements – Lower Latrobe wetlands

8.1 Approach to developing environmental water requirements

The process for deriving environmental flow recommendations (Figure 42) includes identifying water dependent value in the system and ecological objectives to support those values (see Section 4). The watering components, reference water levels, timing, duration and frequency (detailed below) are derived from these objectives using conceptual models as described in Section 4 (refer to 'Water requirements' heading for each value). Ecological vegetation classes (EVCs) are used to define the reference water levels, and based on the mapping of these EVCs, an elevation (m AHD) for watering can be identified. Using hydraulic models and the reference elevation a volume to fill the wetland to the nominated water level can be calculated.

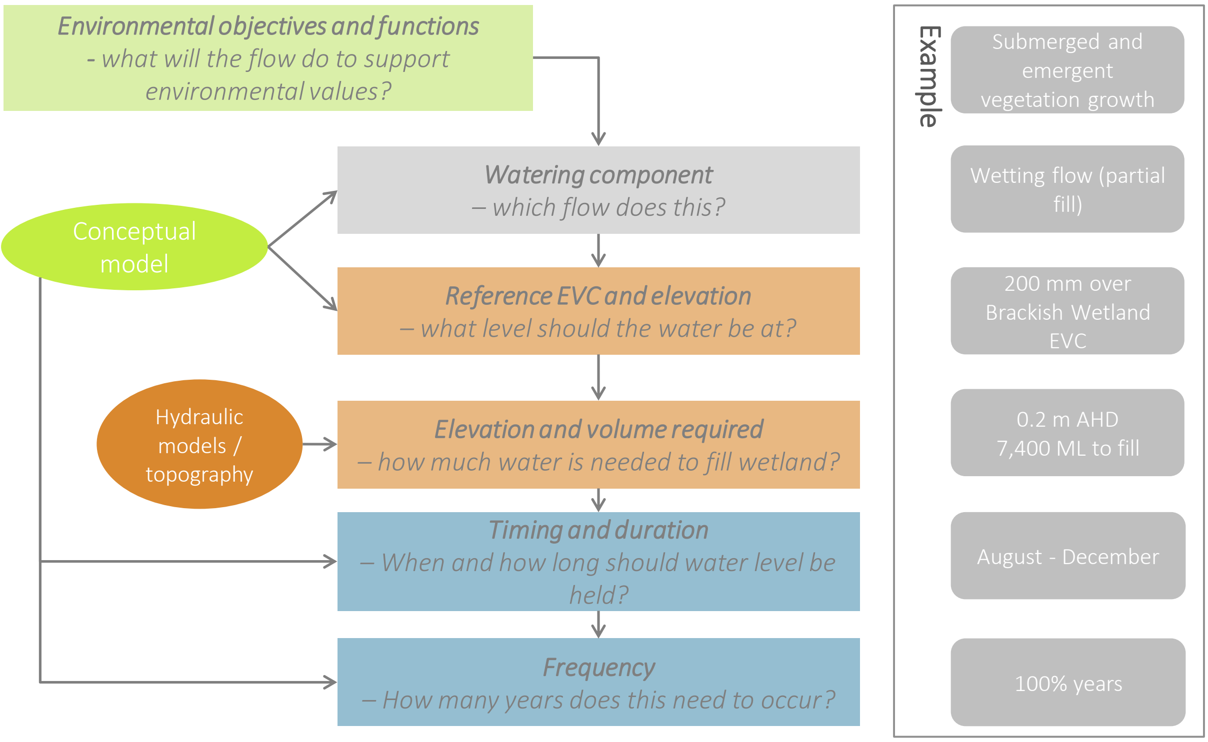


Figure 42. *Process for determining wetland environmental flow requirements.*

Watering components are discussed in Section 2 and a summary is provided in the box below.

Watering components

A **wetting flow** is an inundation event or events sufficient to fill or partially fill the wetland.

A **flushing flow** includes inflow sufficient to push water into and out of the wetland and fill it.

A **drawdown** is a period of receding water levels resulting in large areas of the wetland surface drying out.

Application of watering criteria

The criteria required to support the values identified and achieve the environmental objectives and functions in Section 4 are detailed in Table 30. These criteria have been determined by Environmental Flow Technical Panel members based on relevant literature, expert knowledge and using the conceptual models detailed in Section 4. These criteria have been updated from the previous studies to reflect the updated objectives and the best available science.

Table 34. Objectives and hydraulic criteria for Lower Latrobe wetlands

Environmental objective	Traditional Owner Cultural water value	Wetlands	Flow function	Watering component	Duration, frequency	Timing	Reference criteria
			VEGETATION				
Maintain or restore a self -sustaining mosaic of **submerged and emergent aquatic vegetation** types	Materials, Basket-making	All wetlands	Provide habitat inundation for vegetative growth and flowering with seasonal variation of depth within the wetlands.	Wetting flow – partial fill	Annual	Winter / Spring (June – December)	V1
			Increase oxygenation for germination and recruitment of aquatic vegetation	Drawdown	Annual	Summer (December – March)	V2
			Water level fluctuations to provide conditions for reproduction and expansion of Swamp Scrub and Tall Marsh	Drawdown	2-3 months Areas to dry out 1 in 2 years	Summer (December – March)	V3
			Encourage seed and propagule dispersal Reduce salinity levels to maintain species diversity	Flushing flow	1 in 2 years	Winter / Spring (June – November)	V4
Maintain or restore the diversity, condition and/or extent of native **riparian vegetation fringing wetlands**	Tool making: Yooro gree trees (Red gum-canoe trees); Woorngan (hunting) / food	All wetlands	Encourage habitat inundation of vegetation - E.g. Floodplain Riparian Woodland (EVC 56)	Wetting flow – fill	Minimum of 2 months	Winter to early Summer (June – December)	V6
			Encourage seed and propagule dispersal	Flushing flow	Sale: 3 events in 10 years Heart / Dowd: 6 events in 10 years	Winter / Spring (June – November)	V7
Discourage the introduction and spread, or reduce the extent and density, of **undesirable/invasive plant species**		Sale common	Prolong habitat inundation (reactive management action)	Wetting flow – fill	In response to extensive germination of undesirable dominate species (e.g. Juncus ingens) Minimum of 6 weeks	Summer (December – January)	V8
			Prolong drying of Aquatic Herbfields to reduce cover of Exotic grasses (e.g. *Paspalum distichum*) and aquatic herbs (e.g. *Myriophyllum aquaticum*)	Drawdown	Minimum 3-4 months, every 1 in 3 years	Summer / Autumn (December – April)	V9

Environmental objective	Traditional Owner Cultural water value	Wetlands	Flow function	Watering component	Duration, frequency	Timing	Reference criteria
			FAUNA				
Maintain or enhance **waterbird and threatened fauna** breeding, recruitment, foraging and sheltering opportunities Maintain the different **waterbird functional feeding groups** in the wetlands, such as duck and rails, insectivorous guilds, colonial water birds, and shorebirds.	Mother and Father song line within the Gunaikurnai creation story (Boran and Tuk) Hunting (Woorngan)/food	All wetlands	Stimulation of bird breeding - Nesting for some waterbirds, including rails and waterfowl, and for birds requiring waterbodies next to reed beds. Waterbird food supply - foraging along shallow margin for insectivorous guilds with inundation	Wetting flow – partial fill	Annually	Winter / Spring (July to November)	B1
			Waterbird food supply and breeding habitat provision Waterfowl, piscivorous and herbivorous waterbird foraging while inundated Nesting habitat for colonial and other waterbirds in inundated reed bed, and for birds requiring broad waterbodies and deep water next to reed beds Provides access to fresh drinking water for waterbirds. Maintain suitable environmental conditions to continue to support White Bellied sea eagle.	Wetting flow – partial fill	Annually	Spring (September to October)	B2
			Flooding of fringing vegetation and samphire communities for waterbird and terrestrial avian species foraging habitat Provides access to fresh drinking water for waterbirds by flushing salts and nutrients. Maintain abundance of Riparian zone birds (including Azure Kingfisher, Nankeen Night Heron).	Wetting flow – fill	~ three years out of five	Winter/ Spring (July to December)	B3
			Expose mudflats and submerged and emergent vegetation communities Increase waterbird food supply and facilitate waterbird foraging Stimulate nutrient cycling Expose wetland fringe and create shallows for a many shorebird species and other waterbird species from all guilds.	Drawdown	Three years in five	Summer / Autumn (November to May)	B4
Maintain abundance of Freshwater Turtle Populations		All wetlands	Provide appropriate littoral habitat	Wetting flow - partial fill	Annual	Spring/Summer (September – March)	T1

Environmental objective	Traditional Owner Cultural water value	Wetlands	Flow function	Watering component	Duration, frequency	Timing	Reference criteria
			Allow growth and reproduction of macroinvertebrate communities	Wetting flow – fill	~ three years out of five	Spring/Summer (September – March)	T2
			Flooding of banks and riparian zone to create conditions for nesting	Wetting flow –fill	~ three years out of five	Spring/Summer (September – March)	T3
Maintain abundance of Frog Populations		All wetlands	Provide appropriate littoral habitat	Wetting flow – partial fill	Annual	Spring/Summer (September – March)	FR1
			Allow growth and reproduction of macroinvertebrate communities	Wetting flow – fill	Freshwater (< 1 g/L)	Spring (September to November)	FR2
			Provide connectivity between river and wetlands and between wetlands	Wetting flow – fill	~ three years out of five	Spring (September to November)	FR3
			WATER QUALITY				
Provide suitable **physio-chemical conditions** to support aquatic biota	Healthy country	Heart Morass Dowd Morass	Export salt	Flushing flow	1 in 2 years	Spring (September to November)	WQ1
			Minimise saltwater intrusion	Wetting flow – partial fill	6 events in 10 years	Winter / Spring (August – November)	WQ2
			Minimise acid sulfate soils risk	Wetting flow – partial fill	Maintain water level	All year	WQ3
		All	Breakdown organic matter and encourage nutrient recycling	Drawdown	Annual	Summer (December – March)	WQ4

Modelling and analysis
For the wetland environmental water requirements, Ecological vegetation classes (EVCs) are used to define the reference water levels. Detailed mapping of EVCs was completed for the Lower Latrobe Wetlands by Frood et al (2015). These EVCs were grouped and overlaid on the digital elevation model (DEM) to assess the average elevation of each reference EVC. The resultant reference elevations adopted are provided below (Table 35).

Table 35. Reference EVC and average elevations for Lower Latrobe Wetlands

EVC	Sale Common reference level	Heart Morass reference level	Dowd Morass reference level
Seasonal mudflats (EVC 990/810	-0.1 m AHD	-0.3 m AHD	0.1 m AHD
Brackish Wetland (EVC 656)	N/a	0 m AHD (central & western) 0.1-0.2 m AHD (eastern)	0.1 m AHD
Tall Marsh (EVC 821)/ Open Water	0.2 m AHD	-0.4 m AHD	0.1 m AHD
Swamp Scrub (EVC 53)	0.3 - 0.4 m AHD	0 m AHD	0.1 m AHD
Estuarine Scrub	N/a	N/a	0.5 m AHD
Brackish Grassland (EVC 934)	N/a	0.4 m AHD	0.5 m AHD
Riparian Woodland (EVC 56)	N/a	0.4-0.6 m AHD	0.5 m AHD

Based on the objectives and functions detailed above, a reference EVC was selected for each watering component and each wetland to guide the inundation extent and water level. These reference EVCs and watering requirements are provided in Appendix F.

Hydraulic modelling of each wetland has been undertaken as part of previous investigations of the Lower Latrobe Wetlands (Water Technology 2011, 2014). These investigations included water level (m AHD), volume (ML), and average depth relationships. Combined with assessment of the Digital elevation model (DEM), this information was used to determine the volume to fill for each watering component. Details of these calculations are provided in Appendix F.

The three-dimensional hydrodynamic modelling of the estuary was rerun to understand the sensitivity of the existing and proposed infrastructure to sea level rise. The supply of freshwater to the wetland infrastructure under sea level rise scenarios was reviewed as a component of the estuary flow assessment and recommendations (see Section 7.1). The ability of wetland infrastructure to drawdown the wetlands under rising sea levels has been assessed here. Average water levels will increase at the outlet infrastructure locations as a result of sea level rise (Appendix G). The increases in water level will make the drawdown of wetlands, using the existing (and proposed) outlet structures, increasingly challenging. The outlet gates will only be useful to some extent and some periods of time (e.g. lower water levels due to tide / wind conditions), with the remaining drawdown to be achieved via evaporation. The flushing of wetlands using the outlet gates will be achievable to some extent under 0.1 m sea level rise scenarios but will be difficult to achieve under 0.27 m sea level rise, particularly at Heart Morass.

8.2 Environmental water requirements

Environmental flow recommendations have been determined for the three Lower Latrobe Wetlands. The tables below include a summary of the environmental values and functions supported by each watering component to help to achieve the environmental objectives.

Each recommendation is comprised of a watering component, water level (elevation), volume required, timing and duration, and frequency (how many years the watering component needs to occur) (Figure 43). In this section, the recommendations are described for each wetland and for each watering component. Flows components for wetlands are described in Section 2 and include Wetting flows (partial fills or fills), flushing flows, and drawdowns. For frequency, this included the recommended number of events per 10 years and also the recommended maximum duration between events.

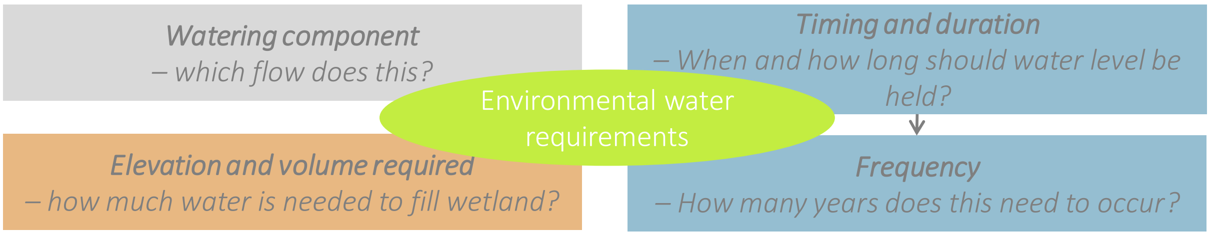


Figure 43. *Components of a wetland environmental water requirement*

Note that the watering components below may occur at the same time. For example, when a flushing flow occurs, it will also meet the requirements of a partial fill.

The updated flow recommendations arising from this investigation (provided below) differ from those developed from previous studies. Some of the reasons for differences include:

- refined and updated environmental objectives
- updated ecological and system knowledge
- improved hydrologic and hydraulic modelling.

Sale Common

Component	Level (m AHD)	Volume to fill (above drawdown level of -0.3m AHD)	Timing	Frequency	Criteria met	Environmental values and functions supported
Wetting flow – Partial fill	0.3	880 ML	July - December	10 events in 10 years	V1, T1, FR1, B1	Supporting healthy country, pelican (Boran), musk duck (Tuk), vegetation for basket weaving. Hunting (Woorngan)/food Submerged and emergent vegetation (growth and flowering) Frogs and turtles (habitat) Water bird and threatened fauna (breeding, food source, foraging, nesting) *Additional functions supported: Macroinvertebrate populations expand, and Fish grow*
Wetting flow – Fill 1	0.4	1,100 ML	August – November Minimum of 2 months	10 events in 10 years	V1, V6, B2, FR2, T2, T3, B3	Supporting healthy country, pelican (Boran), musk duck (Tuk), vegetation for basket weaving. Hunting (Woorngan)/food Submerged and emergent vegetation (growth and flowering), Fringing wetland vegetation (inundation) Frogs (food source, connectivity), Turtles (food source, nesting) Water bird and threatened fauna (breeding, food source) Water birds and terrestrial avian species (fringing vegetation inundation for foraging) *Additional functions supported: Macroinvertebrate populations expand, and Fish grow and stimulated to breed*
Wetting flow – fill 2	0.5	1,130 ML	December-January Minimum of 6 weeks	In response to management requirements - typically 2 events in 10 years.	V8	Discourage undesirable / invasive plant species (prolong inundation)
Flushing flow	0.5	3,400 ML (based on 3 times fill volume)	Winter - Spring	3 events in 10 years Maximum duration between events: 3 years	V4, V7, FR3	Supporting healthy country, productivity of important meeting place (Quarenook) Submerged, emergent and fringing vegetation (seed and propagule dispersal, reduce salinity levels) Fringing wetland vegetation (inundation) *Additional functions supported: Fish migrate into and between wetlands and into river*
Drawdown 1	-0.2	-	December - March	10 events in 10 years	V2, V3, WQ4	Supporting healthy country – reducing exotic species, vegetation for basket weaving. Aquatic vegetation (oxygenation for germination and recruitment) Emergent vegetation (water level fluctuations for reproduction and expansion of Swamp Scrub and Tall Marsh) Water quality (breakdown organic matter; nutrient cycling) *Additional function supported: Minimise European Carp (reduce habitat)*
Drawdown 2	-0.3	-	December - April 3-4 months	5 events in 10 years Maximum duration between events: 2 years	V9, B4	Supporting healthy country – reducing exotic species, vegetation for basket weaving. Discourage undesirable / invasive plant species (prolong drying) Birds (expose mudflats, vegetation, wetland fringe; food source and foraging)). *Additional function supported: Minimise European Carp (reduce habitat)*

Heart Morass

Component	Level (m AHD)	Volume to fill (above drawdown level)	Timing and duration	Frequency	Criteria met	Environmental values and functions supported
Wetting flow - Partial fill 1	-0.3 m AHD	1,390 ML to fill, plus up to 3,349 ML/ year to maintain water level**	Permanent	10 events in 10 years	WQ3	Supporting healthy country Water quality (minimise acid sulphate soil risk)
Wetting flow - Partial fill 2	0.2 (central, western) 0.3 (eastern)	7,400 ML	August - December	10 events in 10 years	V1, B1, T1, FR1	Supporting healthy country, pelican (Boran), musk duck (Tuk), vegetation for basket weaving. Submerged and emergent vegetation (growth and flowering) Frogs and turtles (habitat) Water bird and threatened fauna (breeding, food source) *Additional functions supported: Macroinvertebrate populations expand, and Fish grow*
Wetting flow - Fill	0.5	12,150 ML	August – November episodic	6 events in 10 years Maximum duration between events: 3 years	WQ2, V6, T2, T3, FR2, FR3, B2, B3	Supporting healthy country, pelican (Boran), musk duck (Tuk), vegetation for basket weaving. Water birds and terrestrial avian species (fringing vegetation inundation for foraging) Frogs and turtles (food source, connectivity) Turtles (nesting) Fringing wetland vegetation (inundation) E.g. Floodplain Riparian Woodland (EVC 56) Water quality (minimise saltwater intrusion) *Additional functions supported: Macroinvertebrate populations expand, and Fish grow and stimulated to breed*
Flushing flow	0.6	28 GL (14 GL to fill to 0.6m)	Winter - Spring	3 events in 10 years Maximum duration between events: 5 years	WQ1, V4, V7	Supporting healthy country, productivity of important meeting place (Quarenook). Water quality (export salt) Submerged and emergent vegetation (reduce salinity to maintain species diversity) Submerged, emergent and fringing vegetation (seed and propagule dispersal) *Additional functions supported Fish migrate into and between wetlands and into river*

Component	Level (m AHD)	Volume to fill (above drawdown level)	Timing and duration	Frequency	Criteria met	Environmental values and functions supported
Drawdown*	-0.3	-	Summer, 2-3 months	5 events in 10 years# Maximum duration between events: 3 years	V2, V3, WQ4,B4	Supporting healthy country – reducing exotic species, vegetation for basket weaving. Aquatic vegetation (oxygenation for germination and recruitment). Emergent vegetation (water level fluctuations for reproduction and expansion of Swamp Scrub and Tall Marsh) Water quality (breakdown organic matter; nutrient cycling) Birds (expose mudflats, vegetation, wetland fringe; food source and foraging). *Additional function supported: Minimise European Carp (reduce habitat)*

*Note that only one Drawdown level is recommended for Heart Morass. Further (lower) drawdown is not recommended due to the risk of Acid Sulphate Soils. The recommended level for Drawdown aligns with the level for Partial fill 1, which is provided to minimise acid sulphate soil risk.

**Note retention of water level required to minimise acid sulphate soil risk

Note that this is more frequently than previous recommendations. 5 events in 10 years is recommended to support aquatic and emergent vegetation.

Dowd Morass

Component	Level (m AHD)	Volume to fill (above drawdown level)	Timing	Frequency	Criteria met	Environmental values and functions supported
Wetting flow - Partial fill	0.3	2,990 ML	April - December	10 events in 10 years	WQ1, WQ2, V1, T1/FR1, B1, B2	Supporting healthy country, pelican (Boran), musk duck (Tuk), vegetation for basket weaving. Water quality (minimise acid sulphate soil risk and saltwater iintrusion) Submerged and emergent vegetation (growth and flowering) Frogs and turtles (habitat, food source, connectivity, nesting) Water bird and threatened fauna (breeding, food source) *Additional functions supported: Macroinvertebrate populations expand, and Fish grow*
Wetting flow - fill	0.6	5,360 ML	August – November 4 months	6 events in 10 years Maximum duration between events: 3 years	V6, T2, T3, FR2, FR3, B2, B3	Supporting healthy country, pelican (Boran), musk duck (Tuk), vegetation for basket weaving. Fringing wetland vegetation (inundation) Water bird and threatened fauna (breeding, food source, foraging, nesting) Water birds and terrestrial avian species (fringing vegetation inundation for foraging) Frogs (food source, connectivity) Turtles (food source, nesting) *Additional functions supported: Macroinvertebrate populations expand, and Fish grow and stimulated to breed*
Flushing flow	1.0	15 – 20 GL	Winter - Spring	3 per 10 years Maximum duration between events: 5 years	WQ1, V4, V7	Supporting healthy country, productivity of important meeting place. Water quality (export salt) Submerged, emergent and fringing vegetation (seed and propagule dispersal) *Additional functions supported Fish migrate into and between wetlands and into river*
Drawdown 1	0	-	January - March	5 events in 10 years Maximum duration between events: 3 years	V2, V3, WQ4	Supporting healthy country – reducing exotic species, vegetation for basket weaving. Aquatic vegetation (oxygenation for germination and recruitment) Emergent vegetation (water level fluctuations for reproduction and expansion of Swamp Scrub and Tall Marsh) Water quality (breakdown organic matter; nutrient cycling) *Additional function supported: Minimise European Carp (reduce habitat)*
Drawdown 2	-0.1	-	January to March	2 events in 10 years Maximum duration between events: 5 years	B4	Birds (expose mudflats, vegetation, wetland fringe; food source and foraging) *Additional function supported: Minimise European Carp (reduce habitat)*

Part C: Environmental water management

Photo: Dowd Morass from above after October – November 2019 flood (Supplied by WGCMA)

9 Delivery and management

9.1 Activities to address constraints to the delivery of environmental water

There are some constraints to the delivery of environmental water in the Latrobe system. They are discussed in Section 2.1 and include outlets at Moondarra Blue Rock Reservoir, the channel capacity of the Tanjil River and lower Latrobe River, and the ability to provide water into the Lower Latrobe Wetlands. The following recommendations are included to help reduce some of these constraints and enable environmental water delivery in order to achieve the environmental objectives.

Wetland infrastructure upgrades

The water regime in all three of the Lower Latrobe wetlands is now to some extent managed by regulators connected to the Latrobe River. However, greater environmental benefits from environmental water could be achieved with upgrades to inlets and outlets. Upgrades would mean a lower hydraulic head (and therefore volume of water) required to achieve environmental objectives in the wetlands, more frequent access to freshwater (as infrastructure is further upstream) and more efficient transfer of water in the face of drier conditions and climate change.

Overbank inundation and landholder agreements

Delivery of the flow recommendations set out in this report have the potential to have some adverse impacts on adjoining land use. In the Latrobe system, inundation of private land can occur in the lower reaches (Latrobe River reach 5), if environmental flows in the upstream reaches (Reach 3 and 4) are targeted, or when there are high water levels in the estuary. Further work is required to better understand the occurrence of floodplain inundation in Reach 5 under different flow scenarios and estuary water levels to better understand this constraint.

Flow releases should be carefully managed based on an understand of the system capacities, monitoring of water levels at key locations and consideration of potential catchment run-off from forecast rainfall. In addition, options to mitigate impacts can be investigated such as the communication of environmental flow releases and establishment of Landholders' agreements.

9.2 Complementary recommendations

This study has identified the water requirements to achieve a set of adopted environmental objectives for the Latrobe River system. However, the provision of environmental water alone will not result in the attainment of the adopted objectives. This study has identified threats that require management intervention beyond the provision of water, in order to attain the adopted objectives. Complementary management actions that will be necessary in order to realise the benefits of the recommended environmental water regime are discussed in this section. Table 36 identifies the high priority complementary measures for each study reach.

Table 36. Summary of priority complementary measures by reach

Complementary measures	Tanjil River	Tyers River	Morwell River	Traralgon Creek	Latrobe Reach 3	Latrobe reach 4	Latrobe reach 5	Thomson and Latrobe estuary	Sale Common	Heart and Dowd morass
Riparian vegetation management	✓		✓	✓	✓	✓	✓			
Improving fish passage		✓	✓							
Bed and bank stability	✓		✓	✓	✓	✓	✓			
Water quality management	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Management of saline intrusion								✓	✓	✓

Riparian vegetation management

Riparian vegetation provides an important habitat corridor for wildlife, provides shading for aquatic biota and assists in maintaining stream stability and water quality. The environmental flow regime aims to provide the conditions to support self-sustaining diverse riparian and wetland vegetation in the Latrobe River system. This supports the ongoing health of the existing vegetation and natural regeneration processes to enable recruitment of new individuals to regenerate the plant communities. Additional significant influences on the health and condition of riparian vegetation are the adjacent land use and impacts of agriculture, livestock grazing, deer (Sambar) grazing and recreation.

Instream and riparian vegetation limit channel erosion processes and provide essential instream and riparian habitat for species targeted for environmental water. In the longer-term, riparian vegetation provides the source of essential large wood to the stream system. The current degraded riparian corridor can be attributed to past clearing and river management programs, and ongoing grazing pressure.

The provision of environmental water to the system should be accompanied by a program of catchment-scale riparian vegetation management. Failure to provide such riparian vegetation management will limit the attainment of the objectives sought through the provision of environmental water. Actions for riparian vegetation management, including landholder agreements, establishing vegetation, constructing fencing to exclude stock, supplementary planting for past works, and weed control is included in the *West Gippsland Waterway Strategy 2014-2022.* The following waterways are included in the strategy for threat reduction priorities: Thomson and Latrobe estuary, Lower Latrobe Wetlands, Latrobe River reaches 3-5, Tanjil River, and Traralgon Creek. The Tyers River is listed as a priority for maintaining values / past works. These actions should be supported and continued.

There is also limited riparian vegetation through the Morwell River diversion at Yallourn. This limits the shading of the river and has the potential to limit fish passage through this reach.

Improving fish movement across the system

The existing storages on the Latrobe River system including lake Narracan, Moondarra reservoir and Blue Rock reservoir together with several smaller weirs including Wirilda Park weir on the Tyers River are significant barriers to fish passage. Based on the size and role of the larger storages in the system (Moondarra and Blue Rock), it would be challenging to provide fish passage passed these structures.

Lake Narracan significantly impacts on fish movement to the upper reaches of the Latrobe River. As water users in the Latrobe system change with the closure of power stations, the role and purpose of Lake Narracan as a regulating structure may also change. Options for the provision of fish passage at Lake Narracan should be considered as part of the Latrobe Valley Regional Rehabilitation Strategy.

The Tyers River (downstream of Moondarra) has smaller structures that are barriers to fish passage and good instream habitat condition above the structures; therefore, the Tyers River should be a priority for improving fish movement. A scoping study was undertaken for improving fish passage in the Tyers River (Kingfisher Research 2016), with recommendations of removal of a redundant weir and a fishway for the Pumping Station Weir, which are supported by this study.

As mentioned above, the limited riparian vegetation through the Morwell River diversion at Yallourn has the potential to limit fish passage through this reach. There is no potential to improve the riparian vegetation within the current diversion arrangement, and therefore can only be addressed as part of the rehabilitation arrangements at Yallourn. Improving fish passage through the Morwell River should be resolved within the Latrobe Valley Regional Rehabilitation Strategy and or closure planning for Yallourn power station.

Bed and bank stability

In addition to the recommendations around riparian vegetation management above that will assist with waterway stability, targeted works to reduce active bank erosion are also recommended. The priority reaches for targeted waterway stability works are Latrobe River Reaches 3 and 4, Traralgon Creek, and Morwell River. The Tanjil River should also be considered for targeted works, but as a lower priority as some sediment will be captured by Lake Narracan. An action of the *West Gippsland Waterway Strategy 2014-2022* is to investigate the fluvial geomorphology of the Latrobe River and its tributaries – this will be an important step in targeting reaches and locations that are most vulnerable to erosion. The Waterway Strategy also includes specific actions to reduce active bank erosion in Traralgon Creek and the Latrobe River Reaches 3 and 4. This study supports those actions as priority reaches for erosion management to support achievement of environmental water objectives and recommends the inclusion actions for the Morwell River. The riparian vegetation management may assist with this bed and bank stability.

Water quality management

Declining water quality is evident through the catchment (refer to Appendix E). Some threats include stormwater, bank erosion, sewer overflows, catchment runoff and point source pollution. This can lead to eutrophication, algal blooms, and high turbidity. Improving stream condition and water quality can help to reduce eutrophic conditions in the river and increase survival of most flora and fauna. Water quality improvements can be achieved through:

- Improved riparian vegetation along the riverbanks, providing shade, and woody debris for instream biota, while also providing bank stability and trapping sediment being delivered from the catchment during storm events.
- Removal of stock access to the river, thereby reducing bank erosion and slumping, as well as reducing direct inputs of nutrients to the channel.
- Stricter management of point sources of pollution contributing to poor water quality.

Sources of pollutants are not restricted to the streamside zone. Management of industrial, agricultural, horticultural and forestry activities across the catchment will influence the inputs of pollutants ranging from nutrients and sediments to agricultural biocides.

A study was undertaken in 2017 titled '*Dealing with Dirty Rivers: Where to invest to cost-effectively reduce sediment loads to the Gippsland Lakes from waterway erosion'* (Alluvium 2017b). The mid Latrobe River basin, including the Latrobe River, Morwell River and other tributaries, as well as the lower Latrobe and Thomson rivers were identified as priority areas: they were assessed as having a high likelihood of sediment liberation and delivery to the Lake Wellington, with a high consequence for water quality in the Lakes and for important fringing wetlands. This study supports the priorities and recommendations provided in the *Dealing with Dirty Rivers* report, and the implementation of on-ground water quality management to support achievement of the environmental water objectives.

Similarly, increases in dryer and warmer conditions are expected to lead to increased bushfire frequency. Activities to reduce intensities (such as fuel reduction burns) and post-fire sediment and debris flow management interventions may help reduce inputs of sediment and nutrients from post-fire storm events.

Management of saline intrusion

Saline intrusion events into Dowds Morass are anticipated to become more frequent and last longer with climate change, the associated sea level rise and reduced flows from upstream (Hale 2019). Similar risks of increasing salinity in Sale Common and Heart Morass has also been documented in Hale (2019).

Water levels need to be carefully managed to minimise the risk of saltwater intrusion in face of climate change. The report by Hale (2019) investigating the impacts of climate change on salinity risks in Dowd Morass compared a selection of potential management options ranging from interim to long term scale. The report recommended that recreating sediment microtopography to provide micro-niches with appropriate hydrologic and salinity regimes is more feasible - at least in the short- to medium- term, to reduce salinity risks in the future as opposed to whole-of-wetland scale hard engineering interventions (e.g. constructing new inlet structure, re-instatement of Heywood's Levee, pumping freshwater into Dowd Morass).

An option recommended in Hale (2019) includes interventions within Dowd Morass aimed at recreating sediment microtopography rather than attempting to modify hydrological and salinity regimes at a whole-of-wetland scale with one-off engineering interventions such as the construction of new regulators or the re-instatement of internal levees. Re-creating sediment microtopography using hummock and hollow topography, sedimentation, litter accumulation or tree falls has been proven to provide ecological benefits of creating small-scale hydrologic variations within a wetland and can facilitate wetting and drying regimes that increase plant species richness and survivorship of seedlings (Hale 2019). A trial of this kind was previously completed in Dowd Morass, that showed swamp paperbark seedlings establish themselves quickly. It is therefore recommended that trials are continued at a small scale in other parts of the wetland to improve understanding of climate change impacts of salinity intrusion in Dowd Morass and its neighbouring wetlands.

Groundwater extraction

Many of the waterways within the Latrobe Basin are fed by groundwater and support Groundwater Dependent Ecosystems (GDEs). Mine dewatering has led to lowering of the water table in the shallow (upper) aquifer and depressurisation of the Morwell Formation Aquifer System. In general, groundwater levels within the major middle and lower aquifers underlying the Latrobe Valley have slightly declined since the late 1980s. Investigation of groundwater issues associated with the operation and closure of power stations and mines in the Latrobe Valley will provide information that can assist prevention of adverse impacts on waterway values.

9.3 Alternative approaches to achieving the environmental objectives

The environmental water requirements in this report are based on the current waterway condition. There are some alternative activities that can be considered to achieve the environmental objectives with less environmental water.

Meander reinstatements

It has been estimated that almost 77 meander cut-offs were constructed on the Latrobe River; these cut-offs have adversely impacted floodplain wetlands and instream habitat (Alluvium, 2009). The West Gippsland CMA has reinstated selected meanders of the Latrobe River. The meander reinstatements lengthen the waterway, slow down flow and lead to more frequent inundation of instream and overbank features. Further meander reinstatements in the Latrobe River would reduce the environmental flow requirements (flow magnitudes and therefore overall flow volumes) to achieve the same environmental objectives.

Additional meander reinstatements for the Latrobe River Reach 5 are included as an action for the *West Gippsland Waterway Strategy 2014-202*. We suggest that this should be supported and extended to the Latrobe River Reach 4 as an alternative approach to achieving the environmental objectives.

9.4 Environmental delivery risks

Providing and managing environmental water encompasses consideration of balancing unintended consequences of delivering environmental water. The following delivery risks to environmental outcomes should be considered when delivering environmental water:

- During Summer and Autumn, Platypus juveniles need slower flows and shallow channel depth to move within and across the reaches to source for food (between 0.3 m/s to 0.5 m/s, up to a maximum of 1 m/s for short periods, and up to 3m channel depth). This requirement is not critical during the winter/spring season as there are less juveniles present in this season. Providing freshes to the reaches as part of the recommended environmental flow regime may reduce low velocity areas in channels for platypus. This potentially decreases the environmental benefits for the platypus which may lead to less reproductive success. Bankfull flows during the breeding season (October to March) should also be avoided. Bankfull flows during this period can potentially inundate maternal burrows, drowning or displacing nestling platypuses.

- Delivery risks may occur for vegetation that is sensitive to prolonged inundation, especially during the germination stage. Young germinates are vulnerable to fresh event inundation longer than 2 – 3 weeks when they first germinate, as it can kill them off if the plants are not tall enough. This risk may be reduced once the plants past the juvenile stage, but to ensure high likelihood of succession, prolonged inundation should not occur every year.

- Fish could be affected by unexpected drawn downs after spawning and dewatering killing eggs or young of year larvae.

These risks can be further explored in an Environmental Water Management Plan.

9.5 Monitoring

Overview

This study has been undertaken based on the best available science for the Latrobe River system. The science underpinning environmental water management will continue to evolve with more monitoring, research, and management experience. The provision of environmental water to the system should be accompanied by a monitoring and evaluation program that contributes to the understanding of the system and the delivery and outcomes from the provision of environmental water.

Monitoring is required to measure progress towards achieving objectives. Monitoring is critical to:

- ensure **accountability** by enabling environmental water managers to report on the use of environmental water
- ensure **transparency** by investigating (and communicating) the ecological benefits of environmental watering
- improve **efficiency** by facilitating learning and improved management.

The information gained from each type of monitoring is shared between organisations and communities to build a comprehensive picture of the ecological benefits of environmental watering.

Monitoring that has been undertaken since the previous flows studies have informed the updated environmental water requirements in this report. In particular, the vegetation survey of the Lower Latrobe Wetlands guided the wetland watering requirements and the monitoring of salinity response to flow events in the Latrobe estuary assisted the revised estuary flow recommendations.

There are three different types of monitoring that operate over different temporal scales: operational, intervention and condition.

- Operational monitoring reports on the delivery of environmental water and whether **hydrologic objectives** are achieved.
- Intervention monitoring looks at the achievement of **ecological objectives** in the medium term, and
- condition monitoring looks at the overall health of the river, and the achievement of the long-term management goal.

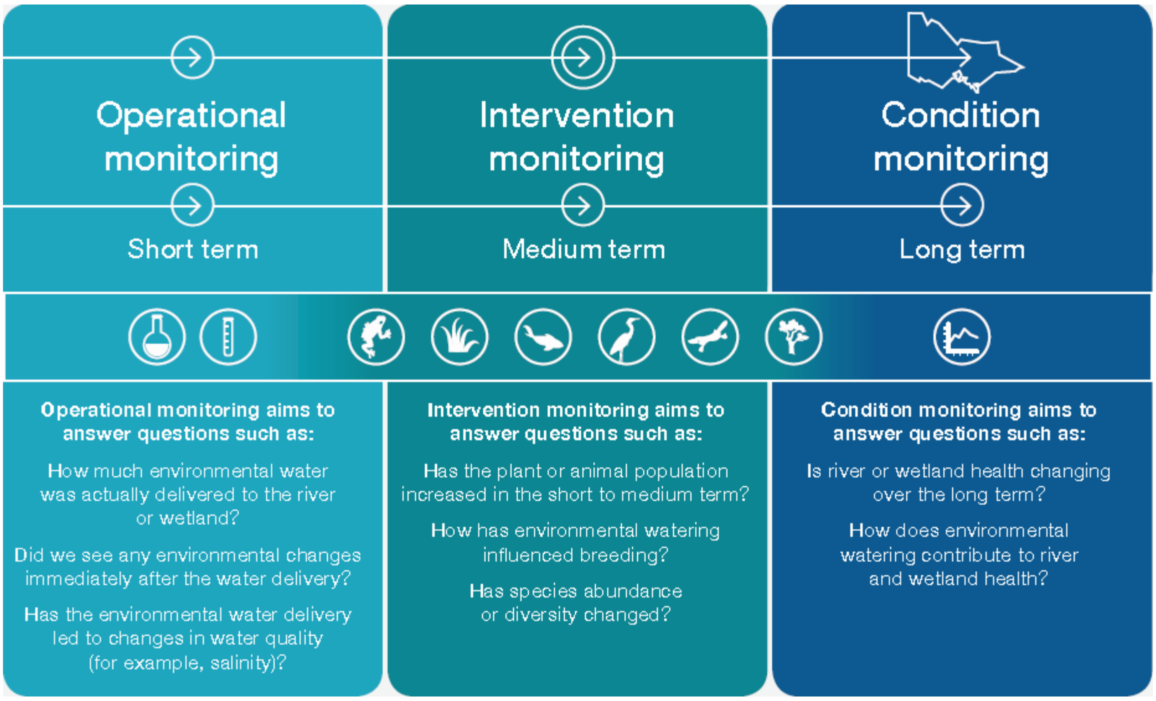


Figure 44. *Types of monitoring (VEWH 2015)*

We recommended that a monitoring and evaluation program be designed and documented as part of an Environmental Water Management Plan for the Latrobe system, with a focus on intervention and operational monitoring. This section outlines some of the key monitoring requirements for environmental water management in the Latrobe system based on the development of environmental water requirements in this study.

Operational monitoring

Operational monitoring or 'compliance monitoring' should be undertaken to measure and report on the achievement of the flow recommendations. This includes events that are delivered with environmental water, and events that occur due to the operation of Blue Rock Reservoir, Lake Narracan and Moondarra Reservoir and supply of consumptive water. This should be done at the compliance point gauges being assessed in this project (Table 3, p21).

Intervention monitoring

Specific monitoring activities will depend on the monitoring and evaluation plan to be developed. This section includes some specific items for consideration that have been identified through the course of this investigation.

Hydrological and salinity response of estuary to flows

In recent years, there has been significant advances in the understanding of the hydrological and salinity response of estuary to flows, with the 2013 Estuary flows study and also the 2017 Environmental flow response monitoring which has informed the recommendations in this report. Still, enhanced understanding of the system response is required to inform future management of the estuary and lower Latrobe wetlands. This includes understanding of how flows from the Thomson and Latrobe rivers lead to outcomes in the estuary. Further monitoring of specific events is required to further improve knowledge and understanding of responses to flow events in the estuary.

Lake Wellington salinity

One of the major threats to the system (and therefore knowledge gaps) is the influx of more seawater into the system, which may cause critical impacts on system habitats and ecosystem function in the long term. In particular this may pose a significant problem to the survival of estuarine dependent fish species as they either need to use Lake Wellington or pass through it to find suitable habitat to complete their life cycle. If it becomes a hostile environment due to lack of aquatic vegetation, high salinity or poor DO levels (or other hostile water quality conditions) then it may form a barrier to estuarine or migratory species which need to get to the sea - including listed species and ecologically very important species. While Lake Wellington is not directly part of the study scope of this assessment, it could lead to whole of system impacts – research is required to ensure there are actions available to counter such impacts.

Fauna

Fish surveys are required to understand abundance, life stage, distribution and movement of fish species. To understand movement of fish for spawning and recruitment, telemetry (tagging) techniques are required in combination with analysis of hydrologic and hydraulic aspects of flow. In the Latrobe River Reach 5 and the Latrobe River estuary, a survey of fish diversity, abundance and distribution and monitoring of response of Black Bream to flow variability over a one-year period was undertaken in 2016 (Amtstaetter et al. 2016). These fish surveys should be continued and extended.

In reach 5, evaluation of the impact of complementary works on birds and fauna has been undertaken in recent years (e.g. Ecology Australia 2015; Wildlife Unlimited 2010). These surveys should be continued.

The understanding of the presence of platypuses and Rakali in the system is limited and should be improved by a targeted population study or building on online databases with more current sightings. Monitoring efforts should focus on the instances where significant threats occur, specifically:

- Bankfull flows during breeding season
- Extended periods of high flow
- Poor water quality
- Areas with poor riparian vegetation

Monitoring requirements for macroinvertebrates are well established. Targeting the abundance and response of key species (as opposed to family level ID) which are more likely to response to flow events is also necessary to ensure the objectives for aquatic macroinvertebrates are being met by the various flow components delivered.

Vegetation
There are five areas for intervention monitoring of vegetation in the Latrobe system. Monitoring should be undertaken to determine:

- if the diverse wetland plant communities in the Lower Latrobe River wetlands are retained.
- whether submerged and emergent aquatic vegetation re-establishes in the main channel of the river.
- whether the extent of riparian vegetation is retained.
- if recruitment of native vegetation occurs in the riparian zone.
- the extent and cover of undesirable/invasive exotic species

The effectiveness of complementary works including fencing, control of stock access, and weed control needs to be understood in comparison to the outcomes from the environmental flows. Monitoring vegetation responses in areas along the river that have complementary works implemented should be compared with areas that do not; e.g. fringing vegetation in riparian areas with free stock access versus that in areas that have been fenced or where stock access is otherwise controlled. This program would allow the beneficial effects of an improved flow regime to be compared with the beneficial effects of the proposed complementary works.

Items to monitor to assess if these areas are being delivered include:

- vegetation assessment including EVCs present, total vegetation cover, native vegetation cover, exotic vegetation cover, life forms present and species richness
- evidence of plant recruitment and presence of multiple ages classes of vegetation on the waterway.
- wetland plant community survey in the Lower Latrobe wetlands.

Historic vegetation surveys such as the lower Latrobe wetland assessments should be continued on a 5-yearly basis at a minimum.

Information is required to enable assumptions on the likely causal factors (e.g. flow regime vs stock exclusion) for observations made (e.g. plant recruitment). Data required to support the monitoring activities includes:

- waterway fencing activity
- grazing in the riparian zone
- weed control activities (temporally and spatially).

Water quality
A knowledge gap for water quality is the source of high phosphorus concentrations (refer Appendix E), mostly in the Latrobe River. Monitoring to address this gap would include identifying and manage the major sources (diffuse and point-sources) and assessing the impacts of high nutrients on dissolved oxygen.

Physical form
A key knowledge gaps for the geomorphology of the Latrobe River is understanding whether the diversity of physical channel form is returning to the river (through management actions of environmental flows and meander reinstatements). This requires an investigation of the fluvial geomorphology of the Latrobe system and its tributaries, to understand sediment supply, transport, and deposition throughout the system. This is identified as an action in the *West Gippsland Waterway Strategy 2014-2022*.

Condition monitoring
The WGCMA can use river health monitoring and other long-term ecological surveys to understand the overall condition of the Latrobe system, including the Index of Stream Condition (ISC). While long-term condition monitoring is an important part of the monitoring framework, the limited resources available for environmental water and outcomes monitoring for the West Gippsland CMA should be focused on intervention and operational monitoring.

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Appendix A: Project Advisory Group (PAG) Meetings

PAG Meeting 1 - December 2018: Summary notes

Attendees

Brett Davis (DELWP) , Caitlin Pilkington (WGCMA), Chris Holmes (Parks Victoria) , Chris Lamin (Native Fish Australia), Tim Paton (GLaWAC), Lloyd Hood (GLaWAC), David Stickney (Latrobe Field Naturalists), Eleisha Keogh (WGCMA), Fiona Pfeil (GW), Gary Howard (Field and Game), Geoff Gooch (landholder), Jolyon Taylor (GW), Kathryn Staniswalski (Parks Victoria), Lucas Snow (SRW), Mark Toomey (VEWH), Natasha Sertori (DELWP), Sean Phillipson (EGCMA), Stewart Lovejoy (DELWP), Wendy West (DELWP), Phil Rayment (Latrobe Valley Field Naturalists), Chris Holmes (Parks Victoria) Rob Caune (VR Fish)

Project Team: Amanda Shipp (Alluvium), Michelle Dickson (Blue Sense), Adrian Clements (WGCMA)

Apologies

Dan Cook* (WGCMA), Adam Dunn (WGCMA), Ian Birch# (landholder), Matt Gleeson* (landholder), Alan Lewis# (Port of Sale Heritage Cruises).

**Interviewed as follow up to workshop and feedback included in this summary.*
Further interviews are still to be arranged and feedback will be incorporated at a later date.

Introduction

Members of the Project Advisory Group (PAG) and Steering Committee for the Latrobe Environmental Water Requirements Investigation came together on the 4th December at the West Gippsland CMA office in Traralgon.

The aims of the meeting were:

1. Confirm the purpose and role of the PAG
2. Introduce the study approach and methods
3. Seek input to the development of flow objectives.

The project team reported on the findings from the field inspections and input was sought from the PAG on ecological and social values as well as issues and opportunities associated with water for the environment.
A summary of the input from the meeting is provided below.

Feedback to the Environmental Flows Technical Panel on their observations

The PAG considered the Environmental Flows Technical Panel observations from the field inspections regarding riparian vegetation, fish barriers, floodplain objectives and provided the following responses:

Riparian vegetation – should this be a focus for environmental watering?
- Riparian vegetation provides an important corridor for wildlife and landscape connectivity. - Watering alone may not be sufficient – there are other drivers: adjacent land use is a major influence on the condition of riparian vegetation and in some areas recreational use is impacting on vegetation. - The impacts of deer (Sambar) are noticeable in some areas. - Regeneration of Red Gums on the floodplain at the lower end of the Latrobe appears to be variable – and linked to wetland regime rather than environmental watering.

Fish and fish barriers – should objectives be based around existing species distribution or also consider if fish barriers could be removed?
- It is important to identify if and where any natural fish barriers exist. - Development of objectives could consider 'with artificial fish barriers' and 'without artificial fish barriers' scenarios. - Consider complementary measures for species not prevalent, are there opportunities to re-establish populations through restocking? - Review available evidence of what species were historically in the system and understand the causes for their loss – there may be limiting factors other than fish passage / water regime.
Floodplains and their associated values – what are the issues and opportunities?
- Timeliness of watering the floodplain needs to be considered – floodplain at the lower end of the Latrobe often already wet from May – October. Landholders need access to the floodplain between Nov – May for management activities and would be concerned if watering was proposed in this season. - Grazing regime has a significant influence on the values and condition of the floodplain. - Stability, management and long-term maintenance of banks is an associated issue – carp impacts, stock impacts and willows
Estuary and wetlands
- Managing the salinity regime needs to consider issues of timescale. How to balance short-term objectives (10 years) with longer term changes in the system. - There is an obligation to preserve some values (freshwater / variable saline wetlands and associated flora and fauna), whilst transitioning to a more saline environment.

Advice from the PAG to the Environmental Flows Technical Panel

The PAG identified a set of principles for the Environmental Flows Technical Panel to consider when developing the flow recommendations:

How – We need to understand how the system works

Why – Identify why the system and its values are the way they are

What – Look at different options and scenarios and consider what is practical and feasible

When – Consider timescale when developing objectives and future changes in the system (climate change, mine rehabilitation, salinity regime)

Exploring the Study Area (workshop session)

The PAG provided input to inform the development of flow objectives and recommendations by considering and responding to three questions around system changes, values, and issues and opportunities through a workshop session. A summary of the input is provided below.

How have things changed in the 13 years since the first study?

Water storages	Catchment and land use	Waterways and water regime	People
Changes to storages and management of storages i.e. Blue Rock and Narracan Less transfer or water between Tyers and Tanjil 2010 Lower Latrobe Wetlands Environmental Entitlement established 2013 Environmental Entitlement created in Blue Rock and used to deliver flows to the Latrobe River. Lake Narracan was being used more by power stations to cycle flows more frequently Recent changes to provide greater water-skiing opportunities in Lake Narracan. Boolarra township now supplied with water from Moondarra.	Increased timber harvesting in forested upper catchments, not all has been replanted with timber. Irrigation expansion – from MID into Latrobe floodplain. Shift in land use away from dairy in places to beef. Increase in dairy farm size and less operators. Emerging contaminants and impacts on land use and ecology Gippsland Water Factory – more reuse and less discharge to local waterways. Declining groundwater levels and increased groundwater extraction. Upgrade of the South Gippsland Highway at Sale – potential impacts on floodplain /wetland hydrology Changes to timber harvesting (less overall in Victoria) Tighter irrigation controls and improved industrial water use efficiency resulting in reduced losses More efficient practices resulting in reduced losses of nutrient and water to the environment. Core 4 program (incentives and extension) has improved dairy effluent management and improved water quality. Septic tanks removed / improved management in upper Morwell catchment.	Decline in the condition of riverbanks in some places (erosion, carp, stock). Death of Eucalypts on floodplain following mine flood. Low inflows and increase extent / magnitude of salt wedge. Lower Latrobe infilling and widening, with trees (particularly wattle regrowth) falling in and creating habitat. Improved native riparian and in-stream vegetation. Improvement to riparian vegetation and water quality in tributaries (Traralgon Creek, Middle Creek). Reduced water quality in places (turbidity and salinity). 2010 mine disaster – impact on fish populations in the Latrobe and Gippsland Lakes. Stocking of Australian Bass in the Latrobe and Blue Rock. Waterway works – fencing and willow control particularly in the Lower Latrobe. Recovery of flows / run off post drought. Positive response to delivery of environmental flows (re-establishment and growth of paperbark) Management of Macalister and Thomson entitlements – opportunities to piggy-back flows Meander reinstatement has resulted in river flow slowing down. Australian Grayling reconfirmed in the Latrobe River Deeper dredging at Lakes Entrance.	Less camping and fishing access for Traditional Owners Lower interest in recreational fishing around the Latrobe (formerly prized for its fish populations) Gunaikurnai have a constant connection to land and water over generations - source of food and water. Increased recreation – Tyers, Narracan, Sale Common and Dowd Morass Increased community engagement in waterway management activities Population changes – increases in some parts of the catchment, decline in others. More interest in recreation associated with the Gippsland Lakes. Changes in land ownership with new landholders more engaged and willing to participate in waterway projects. Increased interest and uptake of technology and data driven decision making. Increased community expectations on industry and agriculture to improve amenity / environmental values.

What are the important features and values?

Latrobe River features and values identified by PAG members

Lower Latrobe Wetlands (Sale Common, Dowd Morass, Heart Morass)

- Ramsar wetland
- Habitat for waterbirds and migratory species
- Drought refuge
- Freshwater and saline vegetation communities
- Recreational uses

Upper Catchment and tributaries

- Recreation
- Amenity
- Iconic species (crayfish, platypus)
- Agricultural land use

Water Quality

- Whole system (needs to have good water quality i.e. environmental needs)
- Drinking water and human health associated with water supply
- Salinity regime and relationship with flow (in Lower Latrobe)

Water Resource

- Water supply for industry, agricultural and drinking water

Platypus and Rakali and other icon species

- Platypus and Rakali are good indicator species; reliant on macroinvertebrates, good vegetation and habitat for burrows.
- Koala and Greater Glider (noted that these are not water dependent but associated with Riparian forests, Strzelecki Gum and use riparian vegetation for movement).

Fish

- Small bodied native fish
- Australian Bass and Estuary Perch
- Australian Grayling
- Black Bream

Vegetation

- Floodplain and wetland vegetation (Freshwater, saline and brackish – see also Lower Latrobe Wetlands)
- Riparian vegetation.
- Vegetation is critical to support recreational uses (i.e. hunting).
- Ensures important habitats are conserved.
- Unclear if submerged vegetation in the Latrobe has declined.

What are the issues and opportunities for managing water?

Issues and opportunities for managing water in the Latrobe River identified by PAG members

Water Resources and production

- Potential issue with lots of sleeper licenses and unused entitlements. What happens when/if there is full uptake?
- Possibility to look at water usage rules (for on farm storage) and options to use high/flood flows as well as utilisation of other unused entitlements.
- Continued increase in water use efficiency (increased irrigation and high value agriculture)
- Opportunity to consider hydropower on the Morwell River.
- Opportunity to consider an upstream storage to mitigate flood impacts.

Water quality - salinity

- Opportunity to manage the salt wedge through the delivery of flow.
- Potential turbidity risks associated with environmental releases.

Erosion and sediment

- Moe drain is a major source of sediment to the Latrobe compared with other sources in catchment.
- Bank erosion is exacerbated by carp mumbling.

Floodplain and private land impacts

- Consider how many landholders may be affected by watering the floodplain and what could be done to reduce impacts (timing of flows, works and measures etc).
- Flooding an issue for private landholders (productivity).
- Opportunity to improve river height monitoring

Issues of scale and prioritisation

- There are likely to be challenges when trying to consider the environmental water needs of the whole system versus individual reaches. Unclear how to resolve this.
- Similarly, there may be issues if the needs of the upper catchment are vastly different to those of the lower reaches – what principles will be used to prioritise?

Opportunities to maximise benefits

- It may be possible to deliver flows that have a benefit for recreational uses (i.e. bird breeding, bird habitat, fishing etc,).
- Consider how cultural values can be incorporated (i.e. may be traditional bush tucker plants or culturally significant fauna).
- Wetland watering has shared benefits for fish outcomes. Importance of plankton densities for recruitment success of species such as Australian Bass.
- Transfer environmental water to Moondarra reservoir and release from there.

Optimisation

- Possibility to hold environmental water in the pit lakes.
- Potential to use environmental water for emergency response – algal blooms and fish kills
- Timing of flow delivery should be optimised to provide benefits for wide range of values i.e. fish recruitment, vegetation and water quality.

Complementary works

- Consider infrastructure options to better manage available flow (some options identified for Lower Latrobe wetlands).
- Can't separate the management of flow from the other works and measures (banks, riparian vegetation, land use impacts, fish passage) – complementary measures need to be identified too.
- Potential to partially reinstate meanders (open bottom end) to facilitate settling of sediment in backwaters.
- Consider options to manage the water regime of floodplain wetlands to facilitate improved water quality.
- Take a more structured approach to weed management, is currently ad-hoc.

External factors

- How might hydropower at Blue Rock Lake influence the flow regime?
- How might mine rehabilitation influence the flow regime and availability of water?

Next Steps

The following tasks will be completed between now and February:

- Environmental Flows Technical Panel to **develop objectives** using input from PAG. This will be part of the Issues Paper, which will include information on values, objectives and water requirements (flow components, timing, criteria) to meet these objectives.
- A **project update** will be provided to the PAG in January, which will include the objectives.
- Environmental Flows Technical Panel to develop **draft environmental flow recommendations** using objectives, water requirements and hydraulic and hydrologic models.
- **Next PAG meeting to be in February** to review the draft environmental flow recommendations

PAG Meeting 2 – March 2019: Summary notes

Attendees	Brett Davis (DELWP), Chris Lamin (Native Fish Australia), Tim Paton (GLaWAC), Geoff Gooch (landholder), Jolyon Taylor (GW), Lucas Snow (SRW), Natasha Sertori (DELWP), Sean Phillipson (EGCMA), Stewart Lovejoy (DELWP), Phil Rayment (Latrobe Valley Field Naturalists), Rob Caune (VR Fish), Kathryn Walker (VEWH), Jem Milkins (WGCMA). *Project Team*: Amanda Shipp (Alluvium), Michelle Dickson (Blue Sense), Lance Lloyd (Lloyd Environmental), Ross Hardie (Alluvium), David Carew (Alluvium)
Apologies	Adrian Clements (WGCMA), Dan Cook (WGCMA), Adam Dunn (WGCMA), Ian Birch (landholder), Matt Gleeson (landholder), Alan Lewi (Port of Sale Heritage Cruises), Caitlin Pilkington (WGCMA), Chris Holmes (Parks Victoria), Kathryn Staniswalski (Parks Victoria), Eleisha Keogh (WGCMA), Fiona Pfeil (GW), Wendy West (DELWP), Mark Toomey (VEWH), Gary Howard (Field and Game), Lloyd Hood (GLaWAC), David Stickney (Latrobe Field Naturalists).

Introduction

Members of the Project Advisory Group (PAG) and Steering Committee for the Latrobe Environmental Water Requirements Investigation came together on the 12th March at the West Gippsland CMA office in Traralgon. The project team provided an update on progress since the last meeting and the WGCMA Project Manager Adrian Clements discussed the feedback on the Issues Paper. The project team including the Environmental Flows Technical Panel reported on the approach to develop flow objectives and the flow recommendations.

The meeting was an opportunity for the PAG and Steering Group to question the Environmental Flows Technical Panel about the methods and recommendations and provide observations and feedback directly to the Environmental Flows Technical Panel through a workshop process. A summary of the input from the meeting is provided below. *(N.B the presentations from the day are provided as an attachment)*

Feedback on Issues Paper

Adrian thanked members of the PAG for their feedback on the Issues Paper.
The main areas of feedback from all sources were:

- Measurability of objectives.
- Changes to the objectives from the original flows study.
- Consideration of current condition and trajectory in setting objectives.
- Importance of the detail of reach-based objectives even though this study is looking across the system.
- Consideration overarching goals and targets from existing plans and strategies (i.e. Gippsland Lakes Ramsar Site)
- Importance of microplankton (particularly zooplankton) in driving food webs and processes.
- Importance of turtle, platypus, rakali, but need to clarify where in the system
- Sediment and nutrient loads and the role of environmental flows in addressing these threats

Feedback has been addressed through the updates to the issues paper, except where feedback related to a management decision (i.e. outside the scope of this study). Any further questions relating to the feedback on the issues paper should be directed to Adrian.

Approach to Flow recommendations

The project team provided an overview of the approach taken to setting flows objectives. PAG members made comments and asked questions throughout the session. A summary is provided below.

Question/comments in response to the presentations

Representative sites: Q. Does it matter if there is a feature in a reach that is different from the rest (and isn't picked up by the representative site)?

A. *Yes, it matters as that feature may be of particular importance to the requirements for value. More sites = more costs, and this is beyond the typical budgets for FLOWS studies. However, it is more important to have a site that is representative than to have more sites in a reach.*

Hydrograph/modelling inputs:

Q: Concerned about the relevance of the use of the flow record for the period 1950s – 70s, this period was much wetter than recent time, what will be the implications for climate change scenarios.

A: For climate, scenarios will only be using the hydrograph from 1975 onwards as per other water resource assessments.

Decision making:

PAG comments:

- Will be important to consider what is optimum versus what is achievable. If trying to deliver a large flow to the wetlands, will the channel further upstream be able to contain the flow – potential for impacts on adjacent private floodplain landholders.
- In terms of critical listed species i.e. Dwarf Galaxias at what point is it no longer viable to try and support a population – how will this decision be made?
- Interested in the whole of system requirements versus individual reach requirements – how will trade-offs be made?

Other benefits / social outcomes:

PAG comments:

- Concerned that Aboriginal cultural values haven't been identified. *(note that WGCMA are working with GLaWAC to progress this work).*
- Important to identify the linked social and economic benefits of environmental water (i.e. fishing, recreation, amenity, liveability, tourism)

Fish and macroinvertebrates:

PAG comment: Pleased to see Zooplankton included in the objectives, concerned about the potential for recruitment failure due to lack of food sources.

Latrobe estuary:

PAG Comment: Water levels and water quality in the Latrobe estuary is influenced by conditions in Lake Wellington, inflows from the Thomson – Macalister systems as well as flows coming down the Latrobe.

Wetlands: Q. Do the recommendations consider the wetland vegetation needs for draw-down and refilling?

A. Yes but noting that wetland vegetation is a mosaic and different vegetation communities will exist under different conditions (wet versus dry).

Birds: Q. Have colonial nesting birds been considered in the objectives?

A. Yes, birds have been considered for wetlands.

PAG Comment: For birds there will be a range of other factors that influence the range of different species.

Vegetation: Q. Why is submerged vegetation missing from the mid-Latrobe?

A. There is a relationship with geomorphology mid-Latrobe was straightened and has deepened and widened over time. As a result, in-stream features such as benches have been lost and submerged vegetation has been lost through the mid-Latrobe. Need to re-establish the features to support submerged vegetation through complementary works (such as meander reinstatement) as well as providing flows.

Q. Are there functional objectives for vegetation at the reach level i.e. for germination?

A. Yes, that detail is in the report.

Floodplain wetlands: Q. Have off-stream wetlands been considered; how much water would be required?

A. Throughout the river reaches, off-stream wetlands do not have specific recommendations but are considered as part of the overbank flow recommendations.

Flow Recommendations Workshop

A workshop session was held to present and review the flow recommendations in a rotating round table exercise hosted by members of the project team.

The system was broken into four sections and two sessions were held. The sections were:

- Mid Latrobe (Lake Narracan to Estuary)
- Latrobe estuary
- Latrobe tributaries (Traralgon Creek, Morwell River, Tanjil River and Tyers River)
- Lower Latrobe wetlands (Sale Common, Dowd Morass, Heart Morass)

At the end of the second session, there was a whole of group discussion about the questions and issues arising from the workshop. These are summarised below:

Mid Latrobe (Lake Narracan to Estuary)

Reach 3

- Baseflow recommendations are the same as historic. 440ML/day meets the majority of minimum requirements for invertebrates and vegetation.
- Inundating benches benefits the zooplankton cycle with benefits for fish recruitment.
- Black Bream – Summer / Autumn flush requiring larger flows to induce migration upstream.

Reach 4

- More flow is required for Summer / Autumn fresh in comparison to reach 5.

Reach 5

- Reconnected meanders have changed the flow-geomorphology relationship, this new information has resulted in a difference in the flow recommendations.

PAG Questions

- *Do the recommended flows allow for fish passage through the whole River system at the levels or are there barriers to fish migration?*
- *Are there long-term assumptions for drought included in the flow recommendations i.e. 5 years of drought?*

Latrobe estuary

- Clarification made that flow recommendations have not yet considered infrastructure is adequate to get the recommended flows into wetlands.
- Concern that out of season flooding of private land will occur to get water to wetland.
- Complementary works could consider underwater barrier within the lower estuary to stop salt wedge intrusion.
- Phragmites still growing on benches in estuary and upstream reaches.
- Consider increasing Winter / Spring base flows to near natural as this could allow fresh water into wetlands.

Latrobe tributaries (Traralgon Creek, Morwell River, Tanjil River and Tyers River)

Tyers (Reach 9)

- Drought / dry base flow recommendations seems too high in both seasons
- Overbank flows – is this relevant in this reach, maybe only in the bottom 2km of the reach.

Tanjil (Reach 8)

- Under current scenarios Summer / Autumn base flow is equivalent to the bulk entitlement minimum flow while the fresh is generally provided through orders for water.
- Winter / Spring, the flow recommendations seem reasonable compared with the unimpacted flow.

Lower Latrobe wetlands (Sale Common, Dowd Morass, Heart Morass)

- Freshwater wetlands upstream of confluence are significant but are not captured in the scope of this study.
- Lidar was used to map contours of vegetation communities, used for wetting models.
- Drawdown priority is to maintain cover above known acid sulphate soils, based on risk of exposure plus a buffer.
- Hydraulic pressure from Lake Wellington into Dowd Morass (May King tides) – the April fresh is timed to push the salt wedge.
- Low points in the riverbank may influenced the ability to hold the fresh.
- Dowd Morass – interaction between water regime and salinity levels and effects of this on plant recruitment and ability to maintain a mosaic of plant communities. This needs to be considered.
- There are benefits for the wetlands by having brackish and freshwater wetlands adjacent to each other.

PAG Questions

- *What is the link between the objectives and the revised Limits of Acceptable Change for the Ramsar site?*

Benefits, costs and shortfalls assessment

Amanda gave an overview of the next stage of the project which will include an assessment of the 'shortfalls' that is a comparison of the flow recommendations against the hydrograph, this will include some scenarios. A second part of this stage will be an assessment of benefits, costs and risks associated with environmental watering.

PAG members provided feedback on considerations for this stage of work as summarised below.

Feedback on scenarios, risks and benefits

Scenarios should consider:

- 100% uptake of licensed volumes as well as current/historic levels of use.
- 'no return' of water to the river system from mines
- Seasonal changes to rainfall patterns as well as annual reduction in rainfall
- Implications of MID 2030 modernisation

Risks

- Impacts of system optimisation to meet objectives for lower Latrobe on achievement of objectives for the tributaries.
- Ability to meet obligations for Ramsar and EPBC Act.
- Private land impacts (i.e. flooding of private land out of season / more frequently than historic)

Benefits

- Potable water
- Wellbeing / liveability

- Connection to Country / Cultural values
- Recreational fishing
- Hunting
- Tourism
- Access for safe swimming

Next steps

The following tasks will be completed between now and May:

- The **flow recommendations report** will be circulated to the PAG and Steering Group for comment.
- A **project update** will be provided to the PAG in April, which will outline any changes to the flow recommendations that have resulted from the stakeholder feedback.
- **Next PAG meeting to be in May** to review the scenarios and benefit-cost analysis results.

Appendix B: Reach and site selection

A site inspection was undertaken on 16 and 17 November 2018. Attendees included Environmental Flows Technical Panel members (Ross Hardie, Lance Lloyd, and David Carew), Alluvium project manager (Amanda Shipp), WGCMA project manager (Adrian Clements) and DELWP Steering Committee members (Natasha Sertori, Brett Davis).

Based on a review of the available information, one change to reach extents was adopted, part of Reach 5 has been combined with Reach 4.

The downstream part of reach 5 (downstream of Kilmany South) was identified during the site visit as having more frequent engagement with the floodplain a more vegetated floodplain, partly due to recent meander reinstatement works. The lower part of reach 5 is also more influenced by Lake Wellington and the Latrobe Estuary backwater. Therefore, the Environmental Flows Technical Panel recommended that this section warranted its own reach and environmental water recommendations. The upstream part of the existing Reach 5 (between Rosedale and Kilmany South) was assessed as relatively similar to Reach 4 in terms of land use, channel morphology and connectedness to the floodplain.

The following adopted reach extents for this study are:

- Reach 4: Latrobe River from Scarnes Bridge to Kilmany South (immediately downstream of Crooks Lane Bridge)
- Reach 5: Latrobe River from Kilmany South (immediately downstream of Crooks Lane) to Thomson River confluence

No other changes to reach delineation were required.

Note that Reaches 1 and 2 (Latrobe River upstream of Lake Narracan) and Reach 7 (Lake Wellington) were included in the 2007 flows study but are not within the scope of this study.

The following features were considered in the selection of representative sites for this study:

- Representativeness of the site in terms of the wider features of the reach (channel morphology, habitat features, connectivity with floodplain)
- Ability to develop a suitable hydraulic model that is representative of the reach
- Proximity to stream gauges (useful for calibrating hydraulic models and for compliance)
- Availability of data on environmental assets of the site
- Ease of site access, noting that impacts from constructed features like bridges and weirs should be avoided.

Based on the information identified in the Scoping Study, some sites from the previous studies have been adopted for this study while others have been changed (Table 39).

New sites have been selected on for the three reaches of the Latrobe River. This reflects the challenges in the previous flows study regarding these sites – the lack of channel features in the sites made setting flow recommendations difficult in the Latrobe River in the 2007 study. A new site was also selected for reach 5 to reflect the new reach delineation (between Reach 4 and 5).

In addition, a new site has been selected in the Morwell River as the waterway diversion around Hazelwood mine has been constructed since the last study and the previous site is no longer available.

The site locations and descriptions based on the background review and field inspection are provided below (Table 37, Table 39) along with representative site photos (Table 38, Table 40).

Table 37. Reach extents and site selection – Lower Latrobe Estuary and wetlands

Reach	Site description
Lower Latrobe wetlands – Sale Common	Sale Common is a predominantly freshwater wetland located along the left bank of the Latrobe River near Sale. It is the westernmost feature of the Gippsland Lakes Ramsar site.
Lower Latrobe wetlands – Heart Morass	Heart Morass is a fringing brackish wetland of Lake Wellington; it is located along the left bank of the Latrobe River estuary. Some of the wetlands is part of the Gippsland Lakes Ramsar site.
Lower Latrobe wetlands – Dowd Morass	Dowd Morass is a fringing brackish wetland of Lake Wellington; it is located along the right bank of the Latrobe River estuary. Some of the wetlands is part of the Gippsland Lakes Ramsar site.
Latrobe River Estuary	The estuary can be considered in three parts, with different salinity, flow and water level interactions: ▪ Lower: Lake Wellington to about 0.5km west of the western water control structure "Big Drain" in Dowd Morass. ▪ Mid estuary: Latrobe Thomson confluence at the Swing Bridge, downstream to about to about 0.5km west of the western water control structure ("Big Drain") in Dowd Morass ▪ Upper estuary: Latrobe and Thomson Rivers above the confluence and Sale Canal.

Table 38. Site photos – Lower Latrobe Wetlands and estuary

Sale Common

Heart Morass

Dowd Morass

Latrobe River Estuary (at confluence between Latrobe River and Thomson River, looking upstream)

Lower Thomson River, looking downstream)

Table 39. Reach extents and site selection – freshwater reaches

Reach	Site location	Site description
Reach 3 – Latrobe River from Lake Narracan to Scarnes Bridge	**New site selected.** Approximately 100 m upstream of Tanjil East Road at the first meander bend at Red's Beach Camping Ground (GPS location: -38.167745, 146.410025)	Meandering waterway with sandy deposits on the inside of beds. Willows extensive along cleared banks. Riparian zone cleared of native vegetation. Sand – clay pool substrate.
Reach 4 – Latrobe River from Scarnes Bridge to Kilmany South	**New site selected.** Bridge at Willow park, approximately 100 m upstream of Princes Highway (GPS location: -38.142468, 146.790821)	Present of large wood. Limited channel features observed. Weeds (e.g. willows and blackberries) are present. Sand – clay pool substrate.
Reach 5 – Latrobe River from Kilmany South to Thomson River confluence	**New site selected.** Private access track to meander reinstatement works, south of Pearsondale. (GPS location: -38.150146, 147.021053)	Meandering riverine waterway through floodplain woodland. Meander reinstatement part of site. Stable streambanks, some undercutting of outside bank consistent with a healthy lowland river. Fine sediment (silt) on inside of bends.
Reach 8 – Tanjil River	Site from 2007 study adopted. Immediately upstream Moe-Walhalla Road (GPS location: -38.139056, 146.266971)	Meandering river channel through generally cleared grazing land. Poor bank condition - some bank slumping. Sand in streambed with some large wood. Some pools present. Instream submerged vegetation observed.
Reach 9 – Tyers River	Site from 2007 study adopted. Immediately downstream of pipe bridge crossing (McMillans Bridge) (GPS location: -38.124331, 146.428187)	Straight gorge (confined) reach with bedrock bars and cobble riffles. Some bench formation but channel generally abuts hillslope. Intact riparian vegetation. Large pool at site.
Reach 10 – Morwell River	**New site selected.** Morwell River between Strzelecki Highway and Princes Freeway (adjacent to Morwell River Wetlands). (GPS location: -38.232960, 146.362962)	Site is immediately downstream of constructed waterway diversion around Hazelwood mine. Moderately sinuous reach with steep but stable banks consisting of fine silts. Banks well vegetated with exotics species. Limited riparian zone on left bank, constructed wetlands present on right bank floodplain.
Reach 11 – Traralgon Creek	Site from 2007 study adopted. Approx. 400 m upstream of Mattingley Hill Road, at confluence with Loy Yan discharge channel. (GPS location: -38.253279, 146.542952)	Generally uniform channel geometry with some vegetated benches. Steep left and right banks. Fine silts present (potentially from fires or floods post-fire). Left floodplain generally clear, right floodplain densely vegetated.

Table 40. Site photos – freshwater reaches

Reach 3 representative site (looking downstream)	*Reach 4 representative site (looking downstream)*
	
Reach 5 representative site (looking downstream)	Reach 8 representative site (looking upstream)
	

Reach 9 representative site (looking downstream)

Reach 10 representative site (looking downstream)

Reach 11 representative site (looking slightly upstream)

Appendix C: Groundwater-surface water interactions

Available Literature

The Gippsland Basin is one of the world's major coal and petroleum bearing basins and hence its stratigraphy and structure are well known (Barton et al., 1992). Whilst the deep Tertiary sequence is well understood, the focus of this assessment, is the shallower and less productive (both from a mining and groundwater development perspective) water table aquifer.

The water table aquifer in the study area, resides in the Quaternary aged alluvial / fluvial sediments and the Quaternary to early Tertiary aged Haunted Hills Formation. The nature of these shallow aquifers, including their interaction with surface water features, is poorly understood.

Whilst the coal mine operators produce detailed groundwater reports every five years, as part of their groundwater extraction licenses (Geo-Eng, 2000; GHD, 2006; GHD, 2011; GHD, 2016) the reports provide negligible detail regarding the shallow aquifer or groundwater dependent ecosystems. The reports are supported by the outcomes of the Latrobe Valley Regional Groundwater Model (GHD, 2016b) and indicate the impacts of mine depressurisation on GDEs are expected to be limited by the fact that the greatest extraction volumes occur at depth from the regional Traralgon Formation aquifer which extend over the whole of the Basin and discharges (at least originally) offshore. The vertical hydraulic connection is also expected to be limited by the depth of the coal bearing units and also from the presence of low permeability clays and coals in the shallower units (i.e. the Yallourn and Haunted Hills Formations), thus limiting potential impacts on GDEs.

Beverley et al. (2015) developed the Gippsland groundwater model to understand the potential impacts of future onshore gas developments on groundwater and surface water in Gippsland. There is limited discussion regarding the interaction between groundwater and surface water in the model report. As part of the model calibration process, baseflow separation and analysis using a digital filtering technique, was undertaken for all stream flow data in the model area. These BFIs (there are a total of 13 in the study area) have been incorporated into this FLOWS assessment, as a source of information to inform groundwater contributions to stream flows. This set of BFIs will complement those available from the SKM (2013) dataset, which included seasonal and annual baseflow estimates for all suitable stream gauges in Victoria and provides 2 BFIs in the study area.

GHD (2013) also quantified BFIs for selected rivers across Victoria using a similar digital baseflow filtering technique, however also incorporated electrical conductivity (EC) data into the analysis, to help constrain the calculated BFIs. The study included an assessment of the Latrobe River and found there was a pattern of losing to variable, to strongly gaining river conditions, down the Latrobe River from between Thoms Bridge (near Morwell) and Kilmany (near Sale). The pattern was attributed to either geological structure, or depressurisation of the deeper mined aquifers.

GHD (2018) produced a conceptual hydrogeological model for the Hazelwood mine, to support the closure planning for Hazelwood. The conceptual model notes that the implications of regulation and water management activities on the Latrobe River, means that characterizing the nature of groundwater and surface water interaction is highly uncertain. Furthermore, the limited groundwater data for the shallow aquifer means the interaction between shallow groundwater and GDEs is not well understood. GHD (2018) recommended additional data collection to inform the identified data gaps. Nonetheless, a review of existing literature was undertaken and GHD (2018) summarised the following;

- Baseflow gains occur for the mid-Latrobe River between Scarnes Bridge (226033) and Rosedale (226228);
- Baseflow gains occur for the lower-Latrobe River between Rosedale (226228) and Kilmany South (226227);
- Baseflow gains occur for the Morwell River at Yallourn (226408); and
- Baseflow gains occur for Traralgon Creek at Traralgon South (226415).

For the Morwell River, an analysis of three shallow bores was undertaken to further investigate the likely relationship between groundwater and surface water in the vicinity of the mine. This indicated the Morwell River is potentially disconnected from the aquifer as a result of mine depressurisation effects.

As part of the Bioregional Assessment Program, a number of wetland conceptual models were developed for the Gippsland Basin (Jacobs, 2015) including the Gippsland Lakes and the Latrobe River.

For the Latrobe River (from Morwell to downstream of Rosedale) it was determined that coal mining in the area had affected groundwater levels through dewatering, which had in-turn affected river flows (via a reduction in baseflow) in the Morwell and Latrobe River. Jacobs (2015) stated that sections of the Latrobe River gain groundwater for most of the time, however under certain conditions it can change to losing conditions. For example, if river flows are high enough (i.e. during flood events) or alternatively if groundwater levels are low enough (i.e. during drought conditions). Whilst groundwater discharge to the Latrobe River could be significant, the regulation of river flow via releases from Blue Rock Dam, means ecosystems are potentially less sensitive to changes in groundwater discharge, relative to unregulated systems.

For the Sale Common, the Heart and the Dowd Morass, Jacobs (2015) concluded:

- The contribution of groundwater was likely to be small relative to surface water inflows.
- The most likely process of groundwater and surface water interaction to be occurring, are variably gaining/losing wetlands. This means the wetlands leak water to the aquifer during flooding and gain groundwater during dry periods when the groundwater is elevated relative to the lake levels.
- Groundwater inflows – though small – may still be significant in providing environmental benefits. This might include the maintenance of wetland saturation, which could limit the potential for acid sulfate soil generation and the provision of fresher groundwater at the rooting depths of less salt tolerant plants.

Available Data

A critical input dataset to an assessment of groundwater and surface water connection, is groundwater level monitoring data in proximity to surface water level data. This allows comparisons of the relative height of groundwater adjacent to surface water features, which can inform the direction of water flux to a river (i.e. gaining river conditions) or away from a river (i.e. losing river conditions). The water level measurements are required in meters relative to the Australian Height Datum (AHD).

A review of the data available in the study area indicates that there are 32 monitoring bores that meet the following selection criteria:

- Bore is within 3 km of the study reach
- Bore is less than 30 m deep
- Bore has timeseries water level measurements that extend up to at least 2014.

The locations of the monitoring bores are shown in Figure 45.

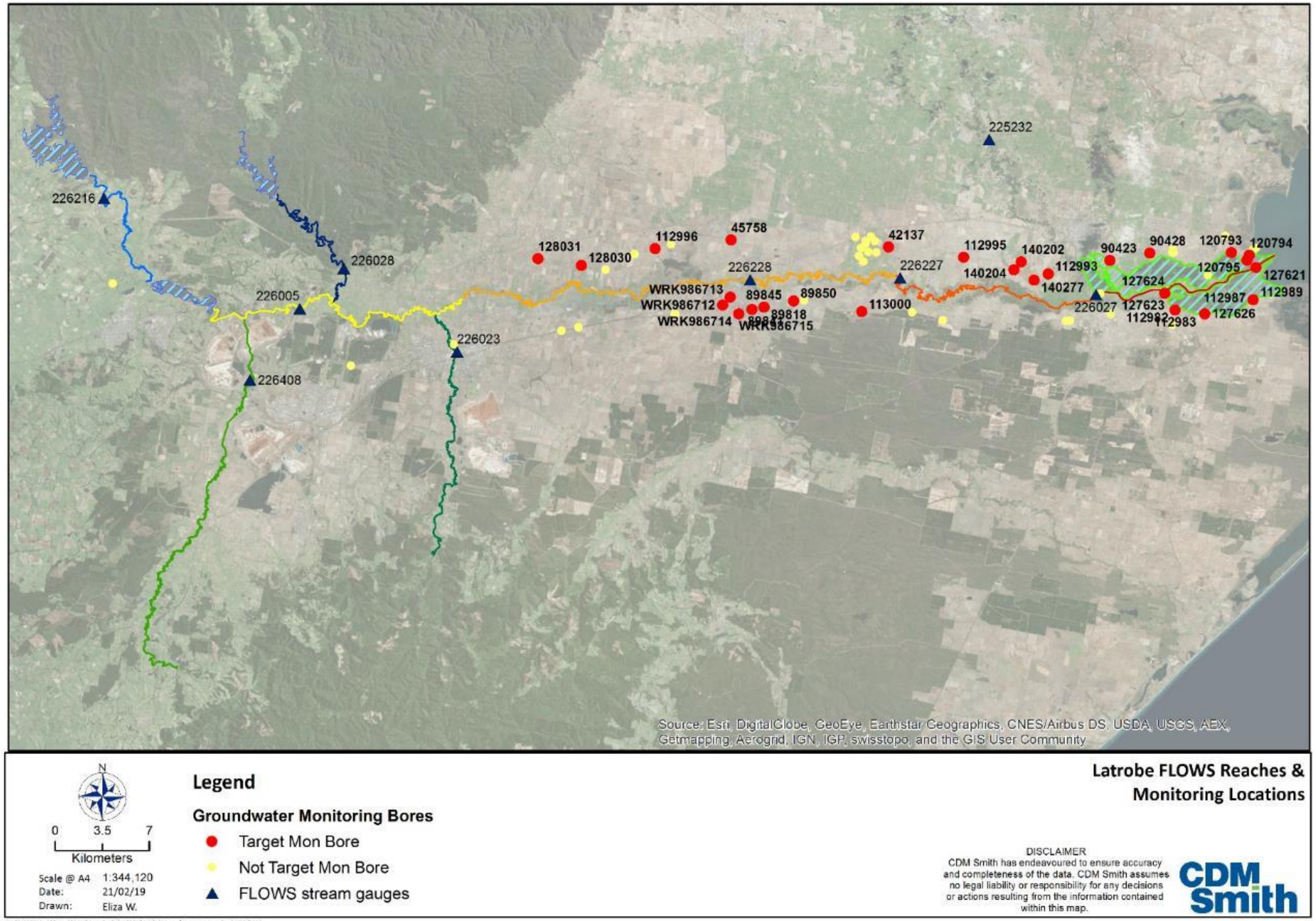

Figure 45. Monitoring locations

Structural Setting & Topography

Figure 46 shows the topographic elevation of the study area, and important structural features within the broader Gippsland Basin.

The Latrobe River and tributaries mainly reside within the Latrobe Valley Depression, which lies between the Eastern Highlands to the north, the Narracan Block to the west, the Balook Block to the south and opens to the broader Lake Wellington Depression to the east, around Sale. The boundary between Latrobe Valley and Lake Wellington Depressions coincide with the limit of fluvial and marine sedimentation, respectively.

The Latrobe Valley Depression is best known for its extensive deposition of coal-bearing Tertiary Latrobe Valley Group strata, which can attain thickness of at least 770 m (Brumley & Reid, 1982). The Latrobe Valley Group strata generally thin and rise against the Eastern Highlands, the Balook Block and Narracan Block and are sometimes exposed in the valleys. Relatively minor unconfined aquifers occur in the shallow Haunted Hills Gravel and the Recent alluvial deposits.

The Baragwanath Anticline complex is an east-plunging uplifted structural block that separates the Latrobe Valley - Lake Wellington Depressions in the north, from the Seaspray depression in the south (Schaeffer, 2008).

The topographic elevation map shows that the Tanjil River, Tyers River, Morwell River and Traralgon Creek, all originate and flow through topographically elevated landscapes of the Eastern Highlands and the Balook Block. Conversely, the Latrobe FLOWS reaches considered in this study, transect lower lying alluvial valley and floodplain environments. The inset map shows the wetlands (Sale Common, Heart Morass and Dowd Morass) reside in a low-lying landscape.

The Tanjil River and Tyres River dissect the steep terrain of the Eastern Highlands for most of their length. The Morwell River and Traralgon Creek initiate in elevated terrain of the Balook Block and then emerge onto flatter landscape of the Latrobe Valley Depression. The Latrobe River FLOWS reaches dissects relatively flat topography of the Latrobe Valley and Lake Wellington Depressions.

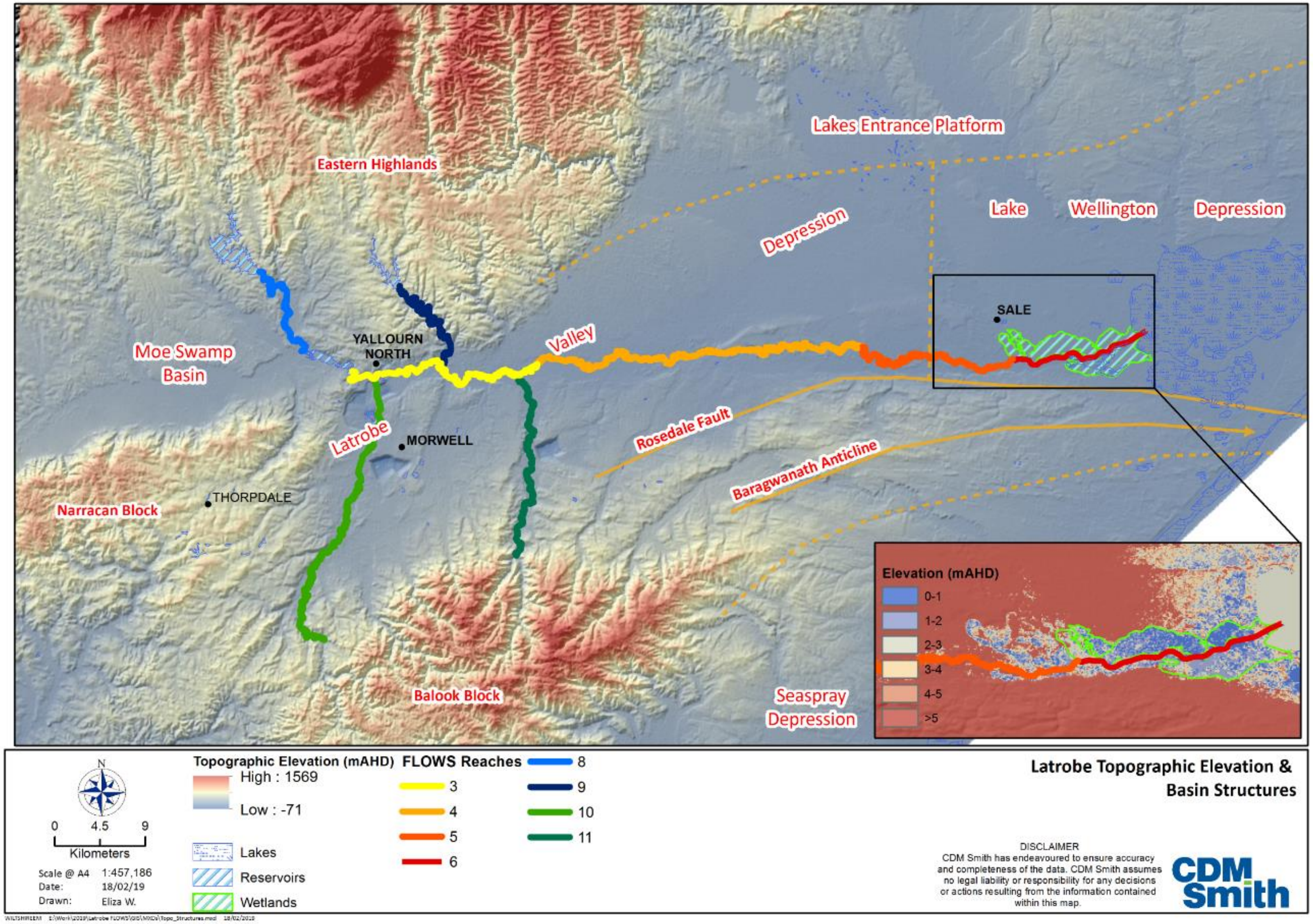

Figure 46. Topographic Elevation and Basin Structures (structures after Schaeffer, 2008)

Geology

The Gippsland Basin is a large sedimentary basin of Tertiary age. The oldest sediment sequence is found at depths of nearly 1000 m below the ground surface in this study area and is referred to as the Traralgon Formation. The Traralgon Formation consists of deltaic sand, clay and brown coal deposits and is overlain by sediments varying from (east to west) the sand, clays and coals of the Latrobe Valley Group (Morwell, Yallourn and Hazelwood Formations) in the Latrobe Valley, a narrow barrier beach sequence of sands of the Balook Formation and marl and limestone deposits of the Seaspray Group (the Lakes Entrance Formation and Gippsland Limestone) in the Lake Wellington Depression. The Haunted Hills Formation occurs across most of the study area and is in-turn covered by Pleistocene sediments in the alluvial valleys of the rivers and creeks. An east-west cross-section (Figure 47) is included below.

A simplified map of surface geology is shown in Figure 47 and shows that the Tanjil River, Tyers River, Morwell River and Traralgon Creek, flow through consolidated fractured rock in their upper reaches (i.e. Palaeozoic bedrock and Mesozoic volcanic geology) and unconsolidated alluvial sediments in their lower reaches. The Latrobe River and the wetlands incise alluvial sediment geology.

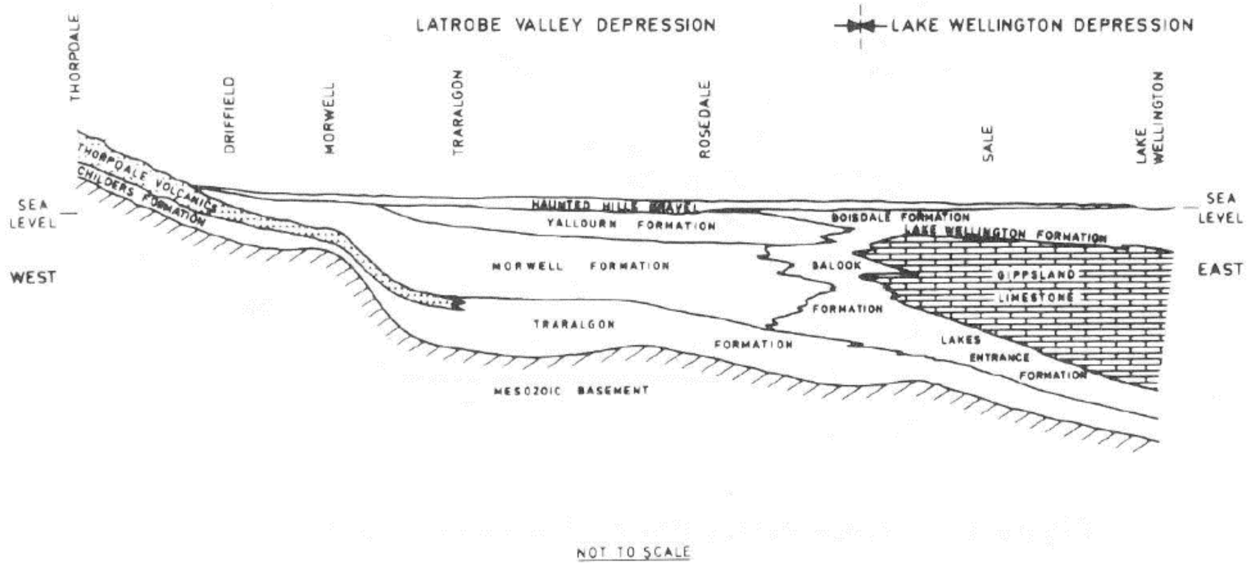

Figure 47. Geological section from Thorpdale to Lake Wellington (from Brumley and Reid, 1982).

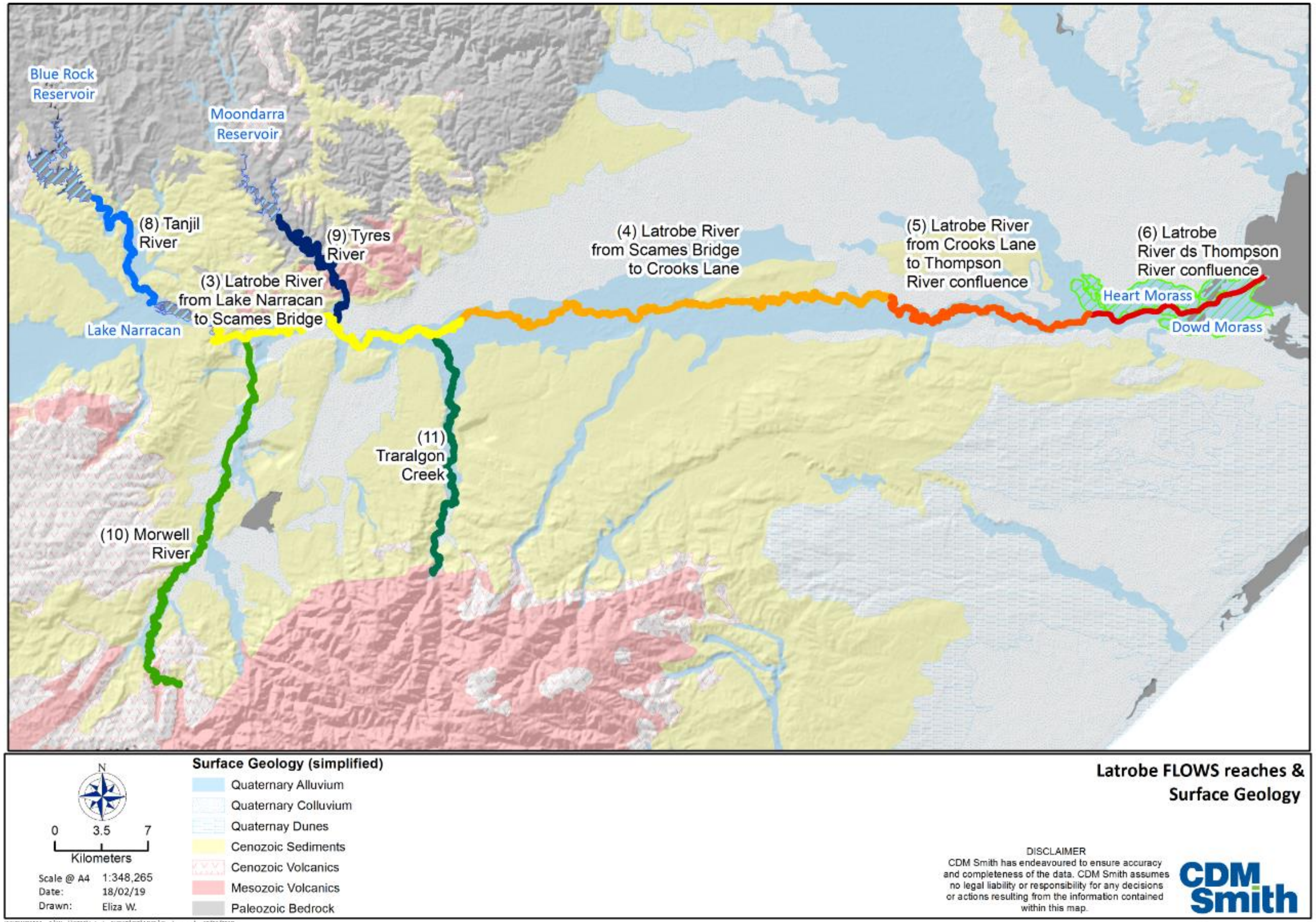

Figure 48. Surface Geology

Hydrogeology

Aquifers

The shallow water table aquifer comprises Quaternary alluvials and Haunted Hills Formation. Beverley et al. (2015) noted that the Quaternary alluvial aquifer is relatively thin, but extensive across the plains of the Gippsland Basin. The unconfined aquifers are usually 5 to 15 m thick and have variable hydraulic conductivities, ranging from 0.1 to 50 m/day (Beverley et al., 2015).

The Haunted Hills Formation is comprised of similar material (i.e. sands, gravels and clays) and overly the older coal-bearing units across most of the Gippsland Basin. This aquifer is not as heavily utilized as the underlying aquifers, as they have lower yield potential. GHD (2018) estimated the typical thickness of the Haunted Hills Formation, as 9-16 m thick around the Hazelwood Mine.

Groundwater Levels and Flow

Declines in potentiometric surfaces for the Traralgon Formation and Morwell Formation Aquifer systems, occur as a consequence of groundwater extraction for mine depressurisation. GHD (2016) undertook a five-year review of the impact of the groundwater extraction that occurred from 2010/11 to 2014/15, which equated to a total of 142 GL. The potentiometric surfaces for the two deep aquifer systems were reviewed and some general observations included;

- lower rates of aquifer pressure decline occur on the basin margins;
- typical pressure declines in the central Latrobe Valley area (from Loy Yang to Sale) for the Traralgon Formation are in the range of 0.8 m to 1.2 m; and
- the highest rate of decline is centred on the Hazelwood and Loy Yang Mines.

GHD (2006) note that the impact of the mine depressurisation on groundwater dependent ecosystems would be expected to be limited by the fact that the greatest extraction volumes occur at depth from the regional Traralgon Formation aquifer which extends over the whole of the Gippsland Basin, where groundwater discharge was likely to originally have occurred offshore. The depth of the Morwell Formation and Traralgon Formation aquifers and the presence of low permeability clays and coals limits the vertical hydraulic connection of the deeper interseams with the shallower aquifers, thus limiting the potential impact on GDEs in the Latrobe Valley.

There is no water table elevation contour map developed as part of the Latrobe Valley regional monitoring network (unlike the deeper aquifers), given there is an insufficient number of bores and measurements (GHD, 2018). It is possible that the impact of mine depressurisation on the water table aquifer will be limited due to the presence of thick low permeability coal seams and the absence of direct pumping from the water table aquifer. However, some limited data suggests the water table aquifer is locally dewatered to the east of the Hazelwood Mine (GHD, 2018).

Beverley et al. (2015) produced a regional water table elevation map, as part of the numerical groundwater flow modelling for the Gippsland Bioregional Assessment. The water table dataset has been included in Figure 49 below, with some groundwater flow direction arrows annotated to assist in the interpretation of possible groundwater flow directions. It is evident that groundwater flow in the water table aquifer is similar to the elevation map, which is typical of a water table map, which often presents as a subdued reflection of topography. Groundwater flow can be expected to move from the elevated areas towards the creeks, rivers and wetlands.

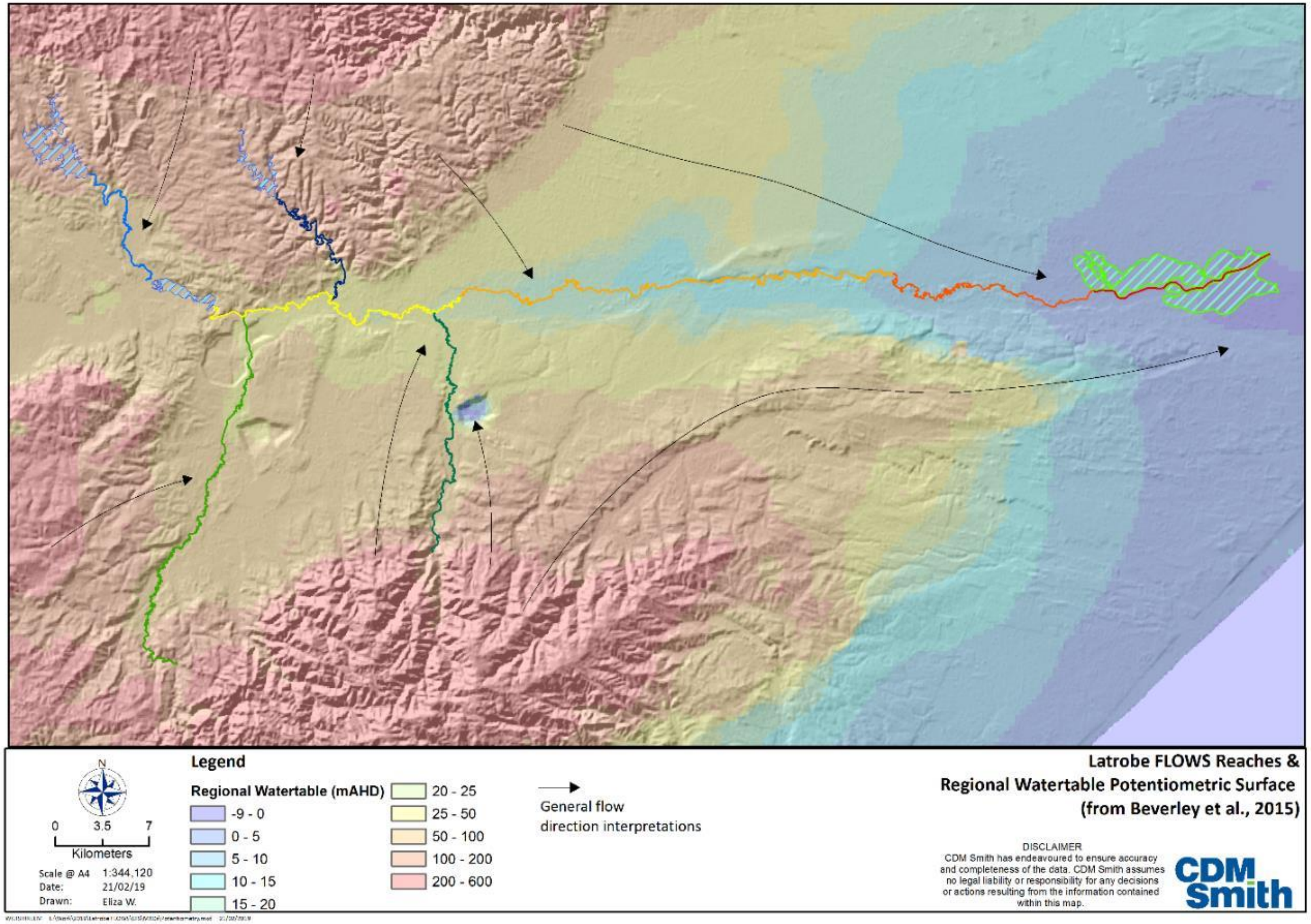

Figure 49. Modelled water table elevation (m AHD) from the Gippsland Groundwater Model (Beverley et al., 2015)

Nature of groundwater and surface water connection

The nature of groundwater and surface water connection is described in the following chapter and draws upon the following:

- Topography
- Geology
- Hydrogeology (including aquifers, groundwater levels and flow directions)
- Previous groundwater and surface water studies (results summarised in Figure 50).

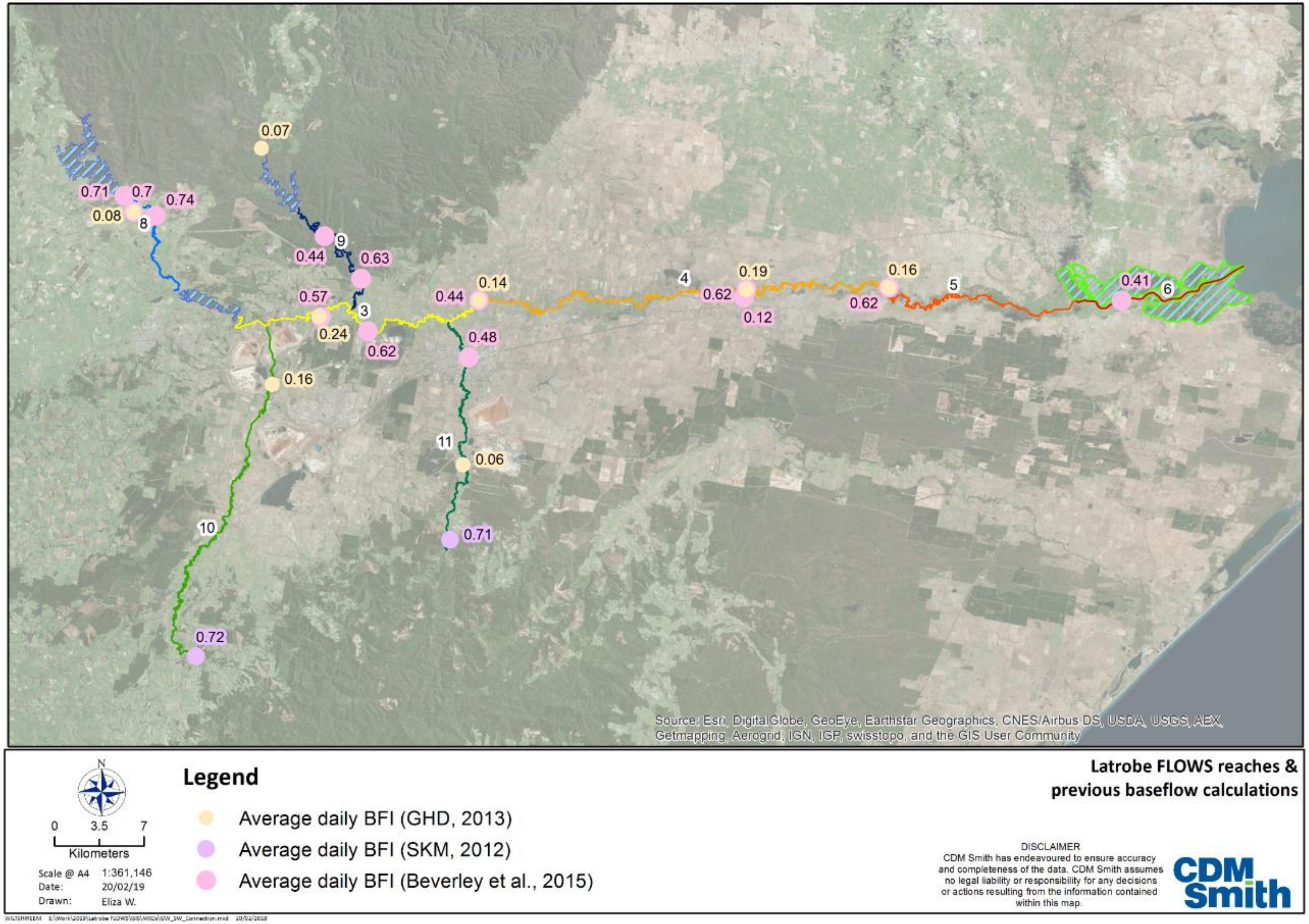

Figure 50. Groundwater and surface water connection – summary of previous calculations

Reach 8 Tanjil River

The Tanjil River dissects the steep terrain of the Eastern Highlands and likely interacts with groundwater contained in the outcropping bedrock aquifer and the thin alluvial sequence that has developed along the water course. Groundwater levels are not expected to have been impacted by mine dewatering in this reach, given it resides in the basin margin, where lower rates of aquifer depressurisations are observed.

The flow regime of the Tanjil River is impacted by the upstream Blue Rock Reservoir, which is likely to lead to less flow variability than would have been experienced under natural conditions. During winter periods, the process of reservoir filling is likely to subdue the naturally high river flows and during the summer months, the low / no flow periods are likely to be maintained at a more constant low flow rate supported by discharge from the reservoir.

There are no groundwater monitoring bores within 3 km of this river reach and hence no direct comparison between groundwater and surface water levels can be made. Two previous studies have been undertaken for this reach, that included baseflow index estimates and these suggest groundwater contributes between 8% (GHD, 2013) and 70 to 74% (Beverley et al., 2015) of average daily stream flows. GHD (2013) noted there was minimal seasonal fluctuation in BFI or baseflow and this was attributed to the upstream reservoir. The GDE Atlas (BOM, 2018) maps the Tanjil River and a small area of surrounding riparian vegetation as having a high potential for groundwater interaction. However, the site visit undertaken as part of this FLOWS assessment indicates the reach is impacted by floodplain agriculture and the riparian zone is largely cleared of native vegetation.

Groundwater is likely to contribute to the Tanjil River reach. Groundwater contributions to rivers are usually most important during dry, low flow conditions. However, given the upstream reservoir is likely to help maintain river flows during drier periods, this reach is likely to be less sensitive to changes in groundwater baseflow, than it may have been under natural conditions.

Reach 9 Tyres River

The Tyres River dissects the steep terrain of the Eastern Highlands and likely interacts with groundwater contained in the outcropping bedrock aquifer, which was noted during the site visit for this FLOWS assessment. There is negligible alluvial sediment developed in this area. Groundwater levels are not expected to have been impacted by mine dewatering in this reach, given it resides in the basin margin, where lower rates of aquifer depressurisations are observed.

Similar to the Tanjil River, the Tyres River is also regulated by an upstream reservoir (the Moondarra Reservoir) and hence doesn't experience the same flow variability that it may have under natural conditions.

There are no groundwater monitoring bores within 3 km of this river reach and hence no direct comparison between groundwater and surface water levels can be made. A previous study has been undertaken for this reach, that included baseflow index estimates and these suggest groundwater contributes between 44% and 63% of average daily stream flows (Beverley et al., 2015). The GDE Atlas (BOM, 2018) maps the Tyres River as having a high potential for groundwater interaction and surrounding riparian vegetation as having a moderate potential for groundwater interaction.

Groundwater is likely to contribute to the Tyres River reach. Groundwater contributions to rivers are usually most important during dry, low flow conditions. However, given the upstream reservoir is likely to help maintain river flows during drier periods, this reach is likely to be less sensitive to changes in groundwater baseflow, than it may have been under natural conditions.

Reach 10 Morwell River

The Morwell River initiates in the Balook Block, which comprises forested outcropping volcanic rocks. The river no longer flows along its original course, due to a number of channel diversions that have occurred for mining purposes. The Morwell River now flows between the Yallourn and Hazelwood open cut pits, within the Latrobe Valley Depression.

There are no groundwater monitoring bores within 3 km of this river reach and hence no direct comparison between groundwater and surface water levels can be made. GHD (2018) developed a conceptual model for the Hazelwood Mine and reported that there were three shallow bores (owned and operated by the mine company) near the Morwell River that can provide some indication of the interaction between groundwater and surface water. The range of depth to water table readings for the bores suggest the aquifer is disconnected from the river, in the vicinity of the Hazelwood Mine, in-part due to mine depressurisation effects.

Two previous studies have been undertaken for this reach, that included baseflow index estimates and these suggest groundwater contributes 72% of average daily stream flows in the upper reaches (SKM, 2012) and 16% in the lower reaches (GHD, 2013). GHD (2013) noted that the baseflow indices varied little over the period of record, either seasonally or inter-annually.

The GDE Atlas (BOM, 2018) maps the Morwell River as having a high potential for groundwater interaction, particularly in its upper reaches. There is negligible groundwater dependent riparian vegetation.

Groundwater is likely to contribute to the Morwell River in the upper reaches. Groundwater and surface water interaction is likely to be negligible in the lower reaches, due to the artificially deep water table depth resulting from mine depressurisation activities.

Reach 11 Traralgon Creek

The Traralgon Creek originates in the Balook Block and then flows past the Loy Yang Mine within the Latrobe Valley Depression. The upper reaches are dominated by outcropping volcanic rocks, whilst the lower reaches incise alluvial sediments. The flow regime of the creek may be impacted by the discharges from the nearby mine and power station (i.e. Loy Yang) which provides a constant flow into Traralgon Creek.

There are no groundwater monitoring bores within 3 km of this river reach and hence no direct comparison between groundwater and surface water levels can be made.

GHD (2016) noted that the highest rate of potentiometric surface declines for the deep coal bearing aquifers were around the Hazelwood and Loy Yang Mines. As noted in the section above, three water table monitoring bores around Hazelwood mine indicate significant groundwater declines and hence it is reasonable to assume that similar depressurisation effects could be occurring around the Loy Yang Mine (and therefore Traralgon Creek).

Three previous studies have been undertaken for this reach, that included baseflow index estimates and these suggest groundwater contributes 71% in the upper reach (SKM, 2012), 6% in the middle reach (GHD, 2013) and 48% of average daily stream flows in the lower reach of Traralgon Creek (Beverley et al., 2015).

The GDE Atlas (BOM, 2018) maps the Traralgon Creek as having a high potential for groundwater interaction and indicates there is negligible groundwater dependent riparian vegetation.

Groundwater is likely to contribute to the Traralgon Creek in the upper reaches, where mine depressurisation effects are absent. Groundwater and surface water interaction is likely to be negligible in the lower reaches, if the same deep water tables are occurring around Loy Yang mine, that have been observed at Hazelwood mine.

Reach 3, 4, 5, 6 Latrobe River

The Latrobe River FLOWS reaches are highly regulated, with a significant portion of land used for intense agricultural and mining activities. There are eight bulk and environmental entitlement holders that share the water resources available in the system and three major storages located upstream of Reach 3. The Latrobe River flows are higher in the months of June to November than in the months of December to May, for the main stem and tributaries.

Reach 3 - Latrobe River from Lake Narracan to Scarnes Bridge

Reach 3 of the Latrobe River is initially confined and abuts the Eastern Highlands, but eventually widens onto the floodplain, downstream of the Tyres River confluence, where alluvial and colluvial sediments occur.

There are no groundwater monitoring bores within 3 km of this river reach and hence no direct comparison between groundwater and surface water levels can be made.

GHD (2013) indicate baseflow accounts for 24% of average daily streamflow; however, Reach 3 was classified as overall losing, with the largest losses occurring when the stream flows were the highest. The Latrobe River was estimated to lose ~26.8 GL/year baseflow overall on this reach on average (Figure 51). The losing behaviour could be associated with the effects of coal mines depressurisation of the Tertiary aquifers which subcrop in the shallow subsurface in this western end of the Latrobe Valley. This study also noted that there was minimal seasonal fluctuation in baseflow due to the influence of the upstream Blue Rock Reservoir & Lake Narracan.

This reach of the Latrobe River is dominantly losing in nature, which may be a result of reduced water table levels associated with the depressurisation of the deeper aquifers.

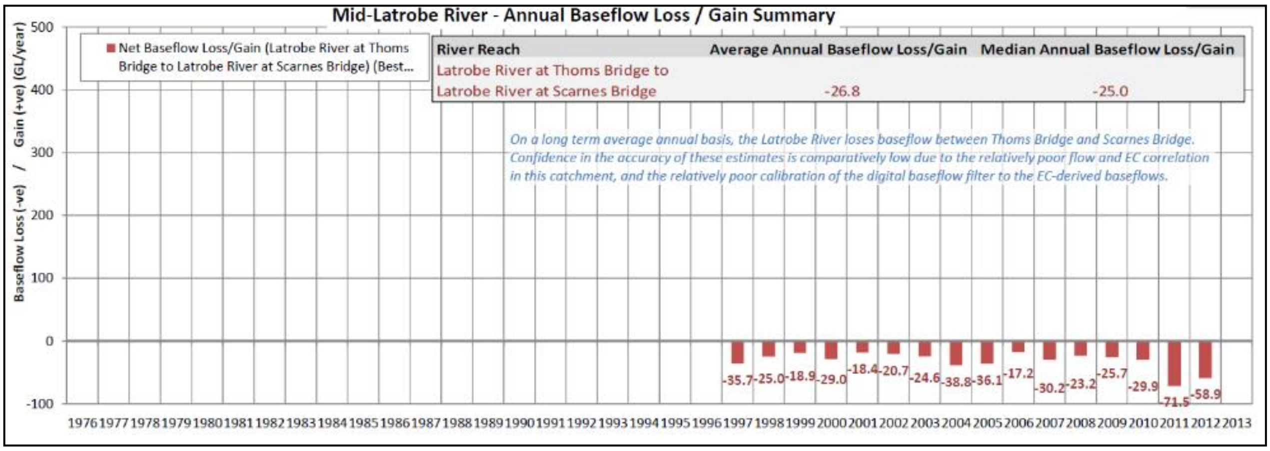

Figure 51. Annual baseflow loss/gain summary for the Latrobe River from Thoms Bridge to Scarnes Bridge (from GHD, 2013)

Reach 4 - Latrobe River from Scarnes Bridge to Crooks Lane

Reach 4 of the Latrobe River flows through a broad, flat floodplain environment, dominated by alluvial sediments. The reach is heavily impacted by grazing, river regulation and channel straightening works.

GHD (2013) indicate there are variable baseflow conditions along the upper half of this reach (up to Rosedale), with the river overall gaining at 4.3 GL/year on a long term average annual basis (Figure 53). For the lower half of the reach (Rosedale to Kilmany South) the river was classified as gaining, with 55.1 GL/year groundwater contribution to streamflow (Figure 54). The groundwater contribution largely occurs over the winter-spring high flow period.

Monitoring data exists for this river reach, such that the groundwater levels recorded for bore 89841 (9 m deep observation bore located approximately 2km south of the river gauge) can be compared with the river levels at stream gauge 226228. Figure 52 shows the groundwater levels are elevated relative to the river levels and this suggests gaining river conditions at this location.

This reach of the Latrobe River progresses from low to high gaining along its length. The groundwater contribution is greatest during the winter-spring period.

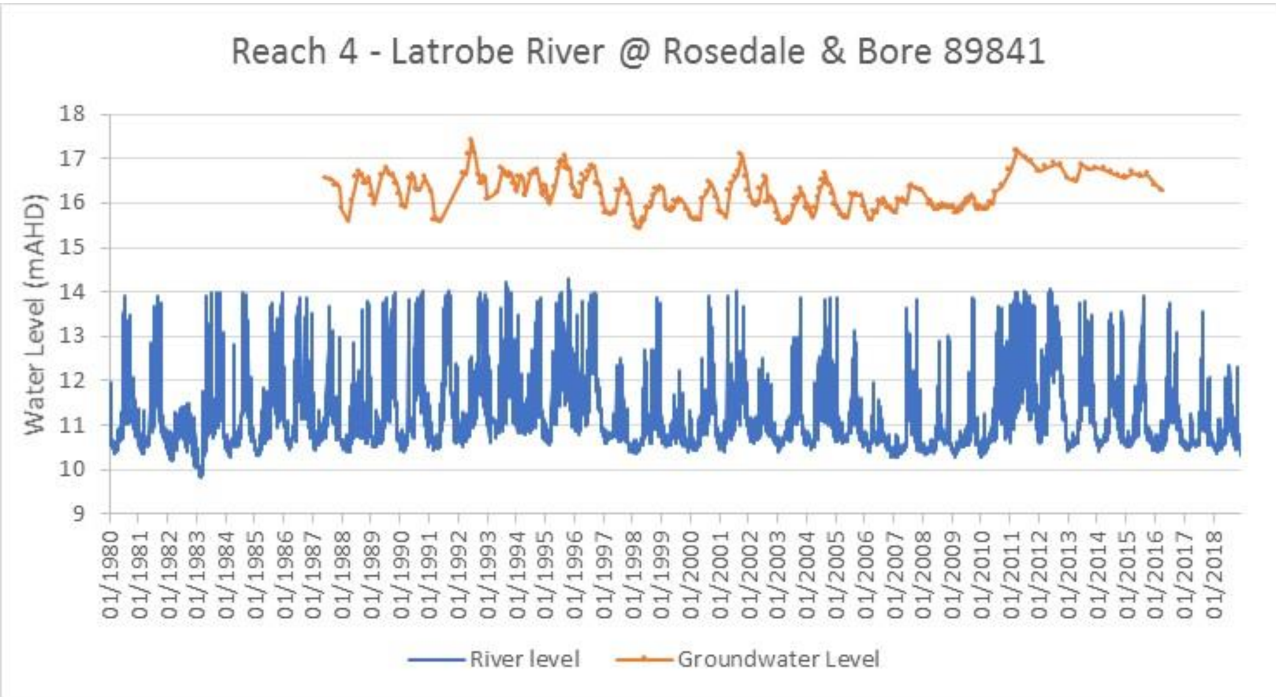

Figure 52. Groundwater and river levels at Reach 4

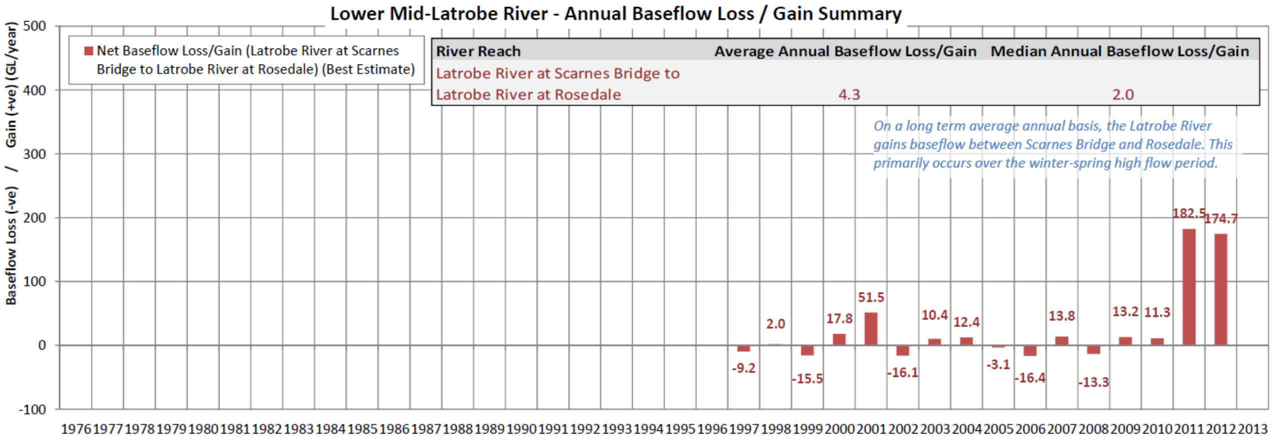

Figure 53. Annual baseflow loss/gain summary for the Latrobe River from Scarnes Bridge to Rosedale (from GHD, 2013)

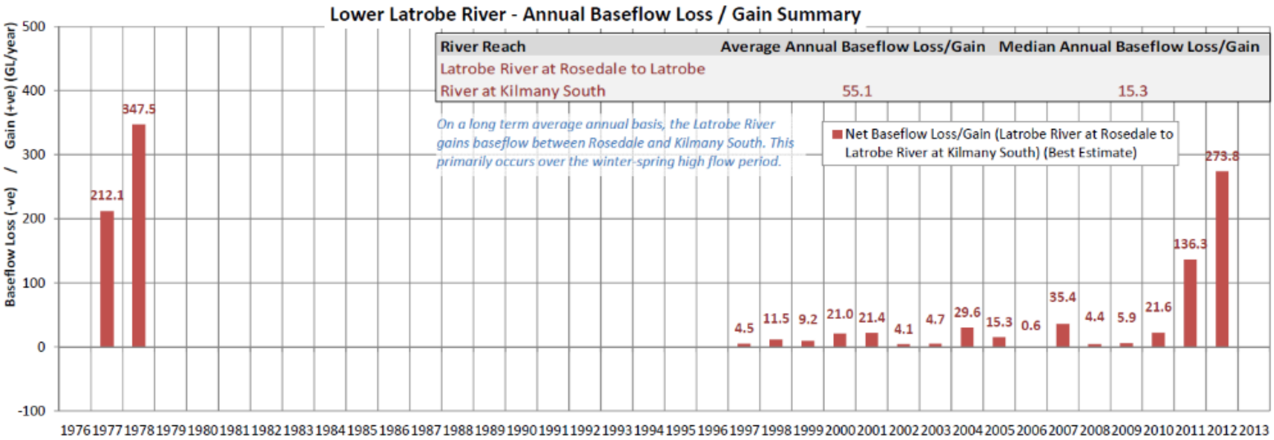

Figure 54. Annual baseflow loss/gain summary for the Latrobe River from Rosedale to Kilmany South (from GHD, 2013)

Reach 5 - Latrobe River from Crooks Lane to Thompson River Confluence

Reach 5 of the Latrobe River flows through a broad, flat floodplain environment, dominated by alluvial sediments. Although the reach has undergone channel straightening works, meander reinstatement has also occurred. No previous groundwater and surface water interaction studies have been undertaken for this river reach.

Monitoring data exists for this river reach, such that the groundwater levels recorded for bore 42137 (10 m deep observation bore located approximately 2.5km north of the river gauge) can be compared with the river levels at stream gauge 226227. Figure 55 shows the groundwater levels are elevated relative to the river levels and this suggests gaining river conditions at this location.

This reach of the Latrobe River is likely to gain groundwater.

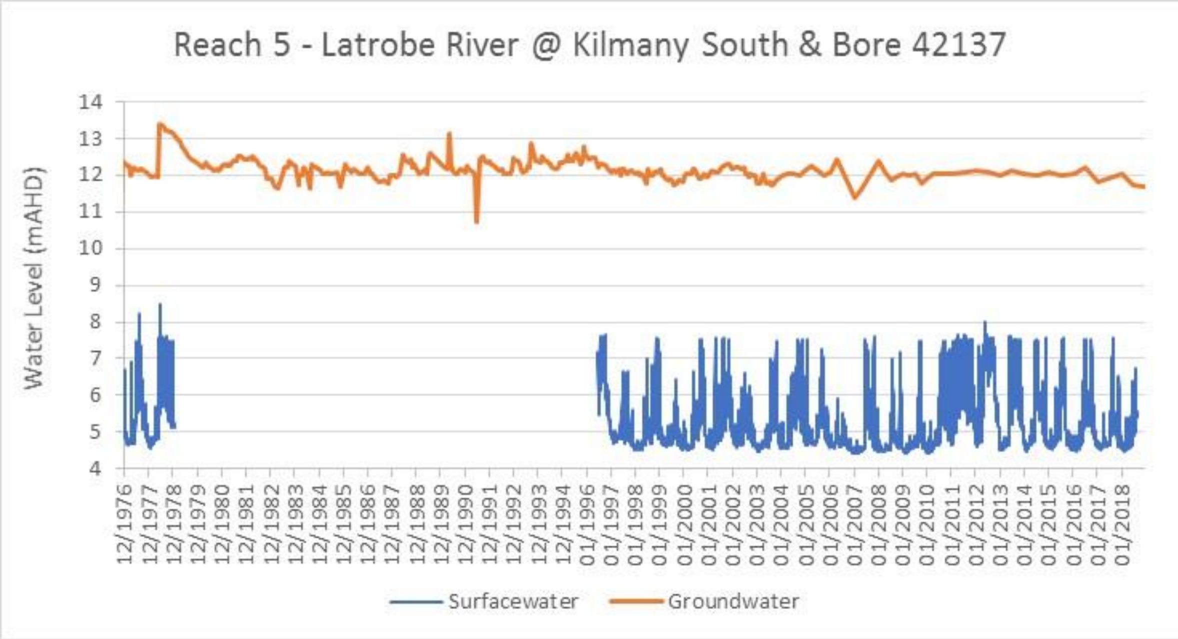

Figure 55. Groundwater and river levels at Reach 5

Latrobe River estuary

The Latrobe River is estuarine in this reach, with its main inflows from the Latrobe and Thomson River. Water levels in the estuary don't correlate linearly with these river inflows however, as the estuary is more heavily influenced by the water levels in Lake Wellington.

This reach sits low in the landscape, upon a well-developed alluvial aquifer. Beverley et al. (2015) undertook a baseflow assessment in this reach, which suggests groundwater contributes 41% average daily stream flow.

This reach of the Latrobe River is likely to gain groundwater.

Sale Common

Sale Common is a deep freshwater marsh wetland, with structures in place to control flows into the wetland. The wetland receives water from the Thomson and Latrobe Rivers via overtopping of banks during high rainfall and through an existing regulator at the north bank of the Latrobe River located between Swing Bridge and Flooding Creek. Lake Wellington water levels impact the levels in Sale Common, based on backwater, tidal and wind affects.

The Sale Common experiences a regime of flooding in late winter and early spring, followed by drying over summer.

Jacobs (2015) developed a conceptual model for the Sale Common and highlighted that the relatively flat topography is likely to lead to a low water table gradient, which in-turn would result in only small fluxes of groundwater to the Sale Common. Jacobs (2015) concluded that it was likely that the wetland operates in a variably gaining/losing nature, with wetland losing conditions during flood events when water levels in the wetland are higher than groundwater and wetland gaining conditions during dry periods when the water level in the wetland is below the groundwater elevation.

Groundwater fluxes to the Sale Common are likely to be small relative to the other sources of water to the wetland and hence are not likely to be critical. However, the groundwater flux may act to extend the saturation of the wetland during drier periods and provide fresher water to fringing wetland vegetation.

Heart and Dowd Morass

The Heart Morass is a freshwater marsh, whilst the Dowd Morass is a brackish water marsh. They reside in flat, low-lying topographic landscape. The Heart Morass is ephemeral and receives water only during relatively major flood events from the Latrobe River and backwater effects and water level variations from Lake Wellington. It is considered a gaining wetland, at an average groundwater discharge rate of 0.5 ML/day (Jacobs, 2015).

The Dowd Morass is considered a permanent wetland. It receives most of its water from the Latrobe River during overbank flows, as well as water from Lake Wellington, rainfall and control structures (including gravity flow drains) between the Latrobe River and the morass. The Dowd Morass gains only a negligible flux of groundwater (SKM, 2003, cited in Jacobs, 2015).

The latest depth to groundwater levels (ranging from 2003 to 2019) for shallow (<5 m deep) monitoring bores show groundwater levels vary from slightly artesian, to 4.5 m below ground surface (Figure 56). The depth to groundwater appears to increase with distance from Lake Wellington.

Timeseries groundwater level data for a shallow bore (127626; 5m deep) is shown in Figure 56 and shows a strong correlation between the two. The fluctuations observed in the Dowd Morass water levels can also be observed in the depth to water level in the monitoring bore, which suggests good hydraulic connection between groundwater and surface water for the Morass at this location.

A similar comparison is not useful for the Heart Morass, as the surface level data is limited to only a two-year period and the frequency of groundwater monitoring is too sparse.

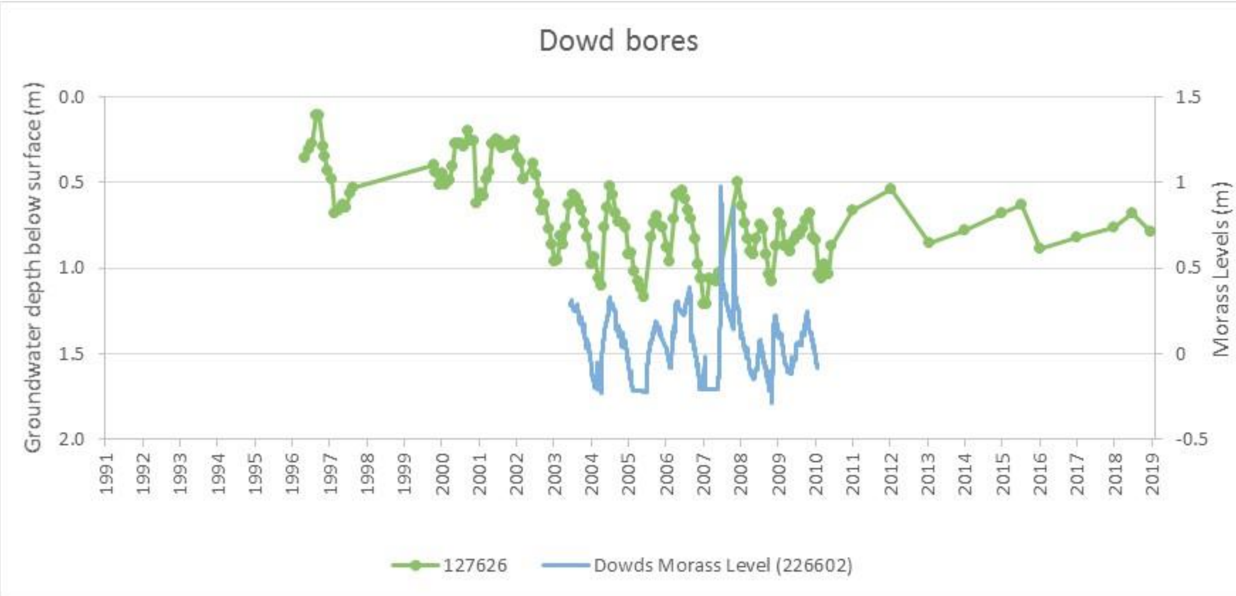

Figure 56. Groundwater and surface water levels at Dowd Morass

The contribution of groundwater flow to the Heart and Dowd Morass are likely to be small relative to the inflows from the adjacent rivers. However, the fresh groundwater inflows may still provide environmental benefits, such as; maintaining saturation of the wetlands (which could limit the potential for acid sulfate soil generation) and sustaining less salt tolerant plants from the repeated inundation of more salty water, if the plants roots had access to fresher groundwater.

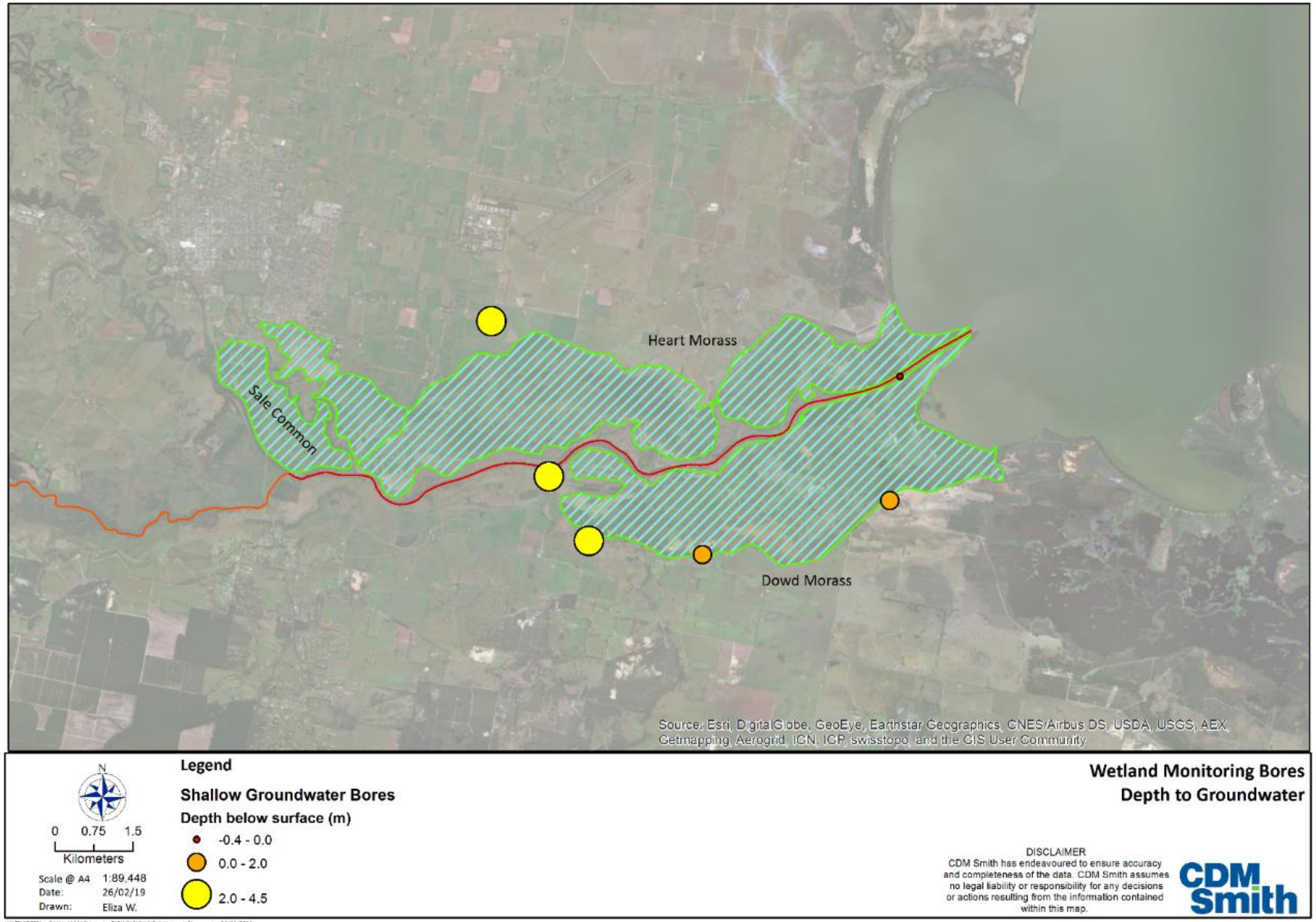

Figure 57. Depth to Groundwater for Wetland Monitoring Bores

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Appendix D: Vegetation condition information

An overview of the vegetation in each reach / wetland is provided below.

Reach 3 – Latrobe River from Lake Narracan to Scarnes bridge
The vegetation in the lower section of the reach at the site inspection location is a narrow zone not extending far from the top of bank. It is highly modified with very low native diversity and the ground layer dominated by exotic grasses and herbs. The predicted riparian vegetation community (*EVC56 Floodplain Riparian Woodland*) is not well represented.

The submerged aquatic Eel Grass *(Vallisneria australis)* was present in isolated patches with *Phragmites australis* the only emergent native in the channel or lower bank. *Persicaria decipiens* occupied <5% of the channel toe. Silver Wattle (*Acacia dealbata*) and Tree-violet (*Melicytus dentata*) provide approximately 10% cover on the banks with isolated Swamp Gum (*Eucalyptus ovata)* present. Some revegetation has been undertaken.

Willows, blackberry and exotic grasses (e.g. *Phalaris aquatica*) dominate the waterway bank. The floodplain is disturbed by mining or agricultural practices with Billabong Wetland Aggregates in poor condition if they are still present.

The vegetation present is a reflection of the modified channel and low structure diversity to support a diverse vegetation community.

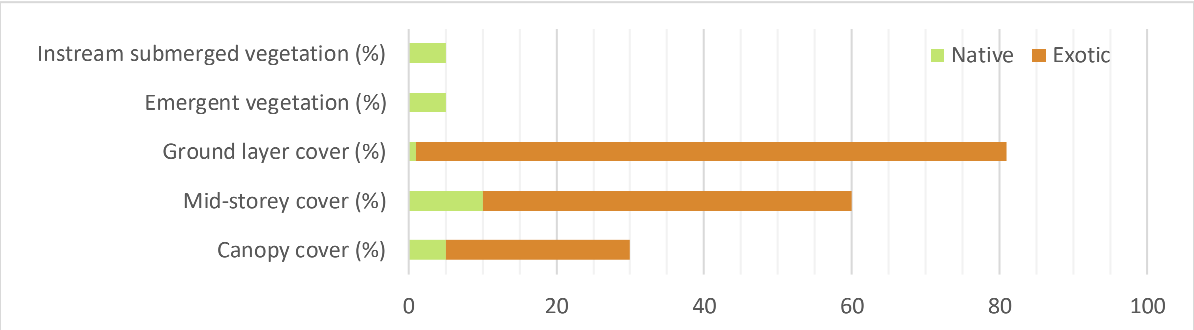

Figure 58. *Overview of vegetation structures observed within reach 3*

This reach would benefit from channel disturbance to stimulate regeneration of the riparian species and establish some morphology in the channel to enable emergent vegetation to establish.

Reach 4 – Latrobe River from Scarnes bridge to Kilmany South
The native vegetation in this reach is highly modified with the floodplain cleared and utilised for agricultural activities. It is highly modified with very low native diversity and the ground layer dominated by exotic grasses and herbs. The predicted riparian vegetation community (*EVC56 Floodplain Riparian Woodland*) is not well represented.

Submerged aquatic vegetation was not observed and is considered to be absent or at low levels. Emergent species covered less than 5% of the channel toe and included *Eleocharis acuta, Juncus sp, Persicaria decipiens* and *Phragmites australis.* Isolated Swamp Gum (*Eucalyptus ovata*), Red-Gum (*Eucalyptus camaldulensis*) are present with Silver Wattle (*Acacia dealbata*) provide approximately 10% cover on the banks.

Willows, blackberry and exotic grasses (e.g. *Phalaris aquatica*) dominate the waterway bank at >50% cover. Exotic herbs such as Dock (Rumex sp), Fat Hen (*Chenopodium album*), Wild Radish (*Raphanus raphanistrum*), Spear Thistle (*Cirsium vulgare*), *Solanum nigrum, Solanum pseudo-capsicum* are present at up to 25% cover. Management should be targeted to enable revegetation and not aim for full removal of the weeds.

The floodplain is disturbed by agricultural practices with Billabong Wetland Aggregates in poor condition if they are still present.

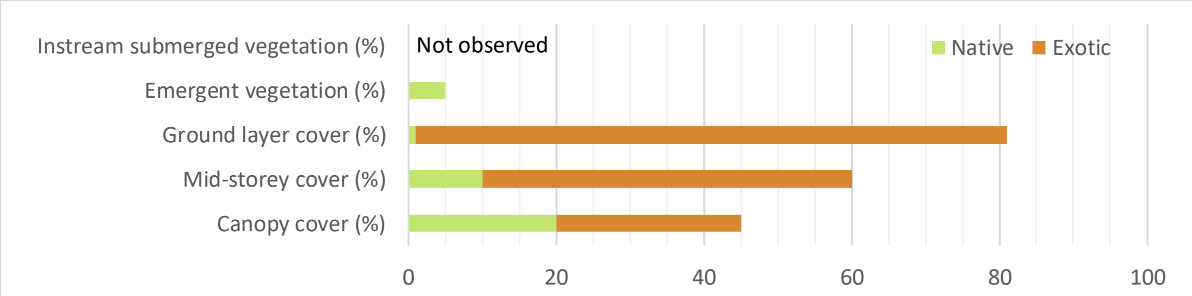

Figure 59. *Overview of vegetation structures observed within reach 4*

This reach would benefit from channel disturbance to stimulate regeneration of the riparian species and establish some morphology in the channel to enable emergent vegetation to establish.

Reach 5 – Latrobe River: Kilmany South to Thomson River confluence

The vegetation in this reach has been impacted by agricultural usage of the landscape. The riparian vegetation width and fencing varies along the waterway, but stock are largely restricted from the waterway. The predicted riparian vegetation communities are EVC55 Swamp Scrub and *EVC56 Floodplain Riparian Woodland*). These have representative species present. Some of the meander cut-offs have been blocked off enabling reconnection of the river to the old meanders and more natural process to occur in the channel and riparian zones.

At the site inspection location, the canopy species *Eucalyptus camaldulensis* provided >50% cover with evidence of recruitment occurring. Mid-storey species *Acacia melanoxylon, Acacia dealbata, Melicytus dentata* were present – natural recruitment is occurring. *Melaleuca ericifolia* and *Phragmites australis* occupied approximately 5% of the channel toe. Submerged aquatics were not observed.

Overbank flows will support the riparian and floodplain vegetation with soil moisture for growth

Willows are present with Blackberry and exotic grasses (e.g. *Phalaris aquatica*) dominate the waterway bank at >50% in places. Management should be targeted to enable revegetation and not aim for full removal of the weeds. Natural recruitment can be enabled with weed control opening spaces for seed germination.

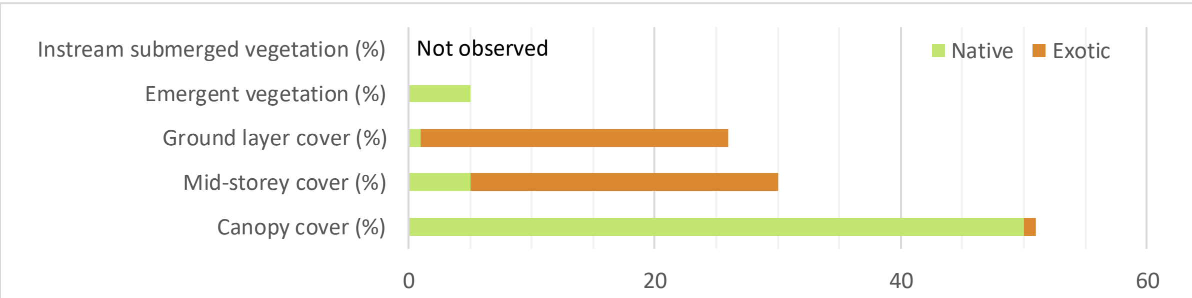

Figure 60. *Overview of vegetation structures observed within reach 5*

Reach 6 –Latrobe River Estuary: Thomson River confluence to Lake Wellington and lower Thomson River

This reach has the waterway passing between floodplain wetlands and with some agricultural properties. The predicted riparian vegetation communities are *EVC10 Estuarine wetland, EVC55 Swamp Scrub, EVC56 Floodplain Riparian Woodland, EVC821 Tall Marsh* and wetland formations.

The riparian zone comprises a narrow band on natural levees. The canopy species is Gippsland Red-Gum (*Eucalyptus tereticornis*) vegetation with Swamp Paperbark (*Melaleuca ericifolia*) thickets along the waterway with fringing Common Reed (*Phragmites australis*) beds. Areas of Submerged Aquatic Herbland (*Vallisneria australis* (Eel Grass) are expected to occur within the channel – these were not observed during the site visit. The Submerged vegetation will be responding to changes in the salinity levels with the species composition adjusting to the conditions. *Vallisneria* can tolerate salinity up to 10,000mg/L but this is uncommon and is more commonly found in water <3000mg/L.

The floodplain wetlands behind the levees have had their drainage modified or have been impacted by changes in salinity within Lake Wellington.

The lower section of the Thomson River winds into an endangered Floodplain Riparian Woodland (EVC56) with extensive paleo-channels and billabong features. Other common EVCs are the Billabong Wetland Aggregate (EVC334) and Deep Freshwater Marsh (EVC681). The vegetation adjacent to the floodplain is the endangered Plains Grassland (EVC132) or Plains Grassy Woodland (EVC55).

Most of the floodplain vegetation has been cleared for agriculture with only a narrow riparian woodland retained and much of the understorey replaced with exotic pastures.

Weeds are less of a problem in this reach although Blackberry and exotic grasses (e.g. *Phalaris aquatica*) are still common with the exotic grasses dominating the ground layer in many places.

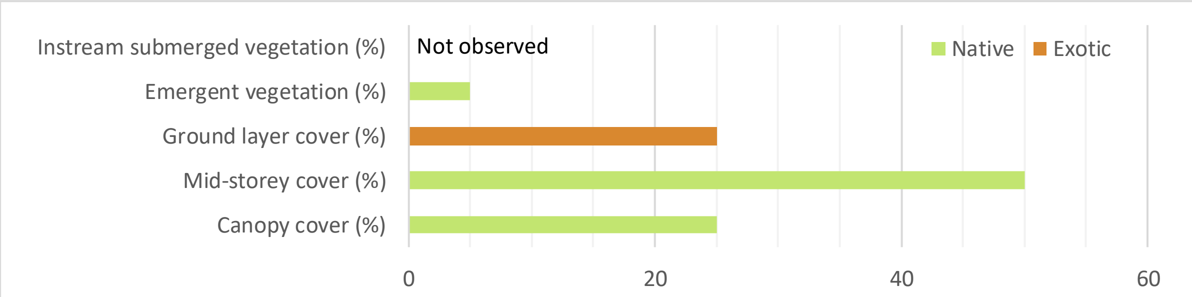

Figure 61. *Overview of vegetation structures observed within reach 6*

Reach 8 – Tanjil River

The Tanjil River flows out of the foothills (Highland Southern Fall Bioregion) through Riparian and Lowland Forests onto the Gippsland Plain into a Floodplain Riparian Woodland.

The foothills vegetation is less disturbed – this section of the reach was not assessed in this study.
The vegetation on the plain has been cleared for agricultural usage. The riparian zone <10m wide or cleared and stock have access to the waterway. The predicted riparian vegetation community is *EVC56 Floodplain Riparian Woodland* with small pocket of *EVC18 Riparian Forest*. Some of the representative species are present in low numbers but the EVC structure has been disrupted.

At the site inspection location there were no canopy species present. Downstream of the site Manna Gum (Eucalyptus viminalis) was present indication Riparian Forest. Mid-storey Silver Wattle (*Acacia dealbata*) and *Kunzea ericoides* were present at <5% cover. *Persicaria decipiens* and *Juncus* sp were present on the lower bank. Submerged aquatics occupied >20% of the channel (*Myriophyllum sp, Lepilaena sp, Potamogeton* sp) which indicates more stable channel conditions than other reaches in the system.

Exotic pasture grasses and herb occupy >80% of the ground layer. Blackberry and Willows dominate patches of the riparian zone and can be kept to <10% cover with management.

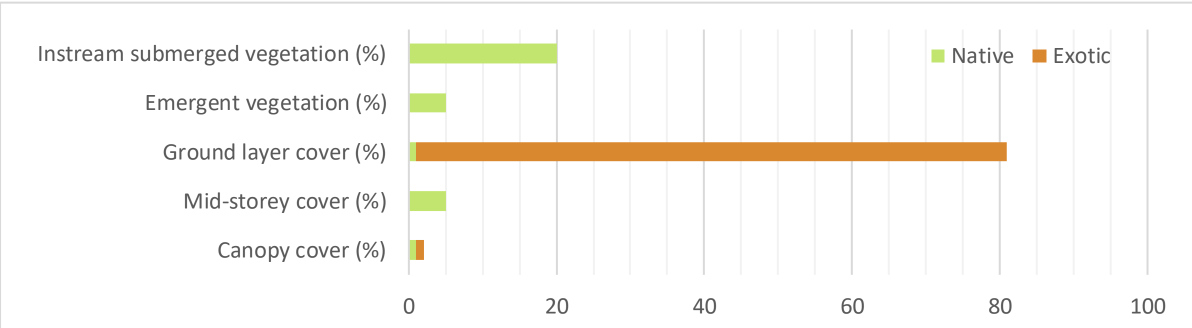

Figure 62. *Overview of vegetation structures observed within reach 8*

Reach 9 – Tyers River
The Tyers River flows from Moondarra reservoir through protected areas of Boola State Forest and Tyers Regional Park. The riparian zone is *EVC 18 Riparian Forest* or *EVC 29 Damp Forest* surrounded by *EVC16 Lowland* forest on the more exposed hill slopes.

The vegetation at the site visit location was largely intact representative species of a Riparian Forest and Lowland Forest. The waterway was confined by steep slopes and bedrock. Canopy Eucalypt sp and Acacia dealbata were present in the proportions expected. Shrub species along the channel included; *Leptospermum scoparium, oprosma quadrifida, Myrsine howittiana, Kunzea ericoides*. Sedges along the channel bank and on rock bars included *Carex appressa* and *Lepidosperma laterale*. Submerged aquatic species (*Myriophyllum* sp) occupied approximately 10 of deeper areas. Rough Tree ferns (Cyathea australis) and ground ferns such as *Asplenium* sp were present in damp protected areas.

Pittosporum undulatum was present and this should be checked to see if it is within the natural range. If it isn't it should be controlled but otherwise this was not posing a great threat.

Blackberry was present at <5% cover and targeted weed control by an experienced bushland contractor could be undertaken to maintain it at low levels.

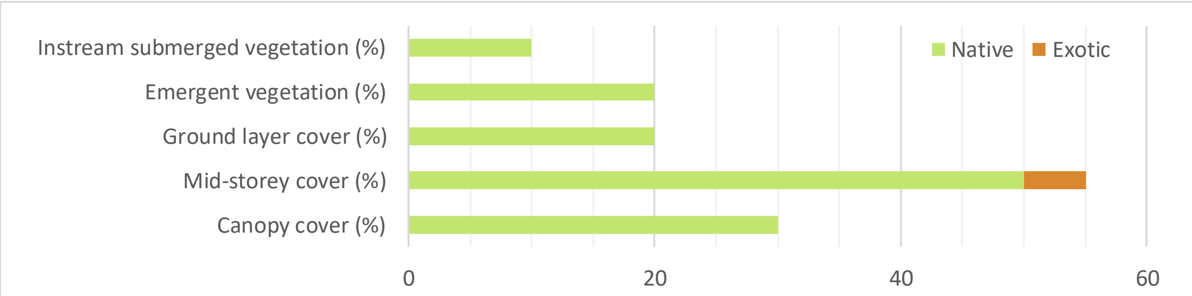

Figure 63. *Overview of vegetation structures observed within reach 9*

Reach 10 – Morwell River
The vegetation in this reach has been cleared for mining or agriculture. The riparian zone vegetation is mostly from revegetation programs.

The left side of the waterway has a narrow band (<10m) of revegetation leading to grazed fenced pasture. The right bank has no grazing and an extended vegetated buffer with flood flows spilling into constructed wetlands to the east of the waterway.

Revegetation species include: Eucalyptus sp, Acacia dealbata, Pomaderris aspera, Callistemon sieberi, Goodenia ovata, Melicytus dentata. Some regeneration of Melicytus dentata is occurring.

No instream submerged vegetation was observed at the site visit. The channel bank is dominated by Phalaris aquatica and P arundinacea. Blackberry and Willow are present at <10% cover. Groundcover above the top of bank is exotic grasses and herbs such as Wild Mustard (R*apistrum rugosum*), Wild Turnip (Raphanus raphanistrum) and Plantain (Plantago lanceolate).

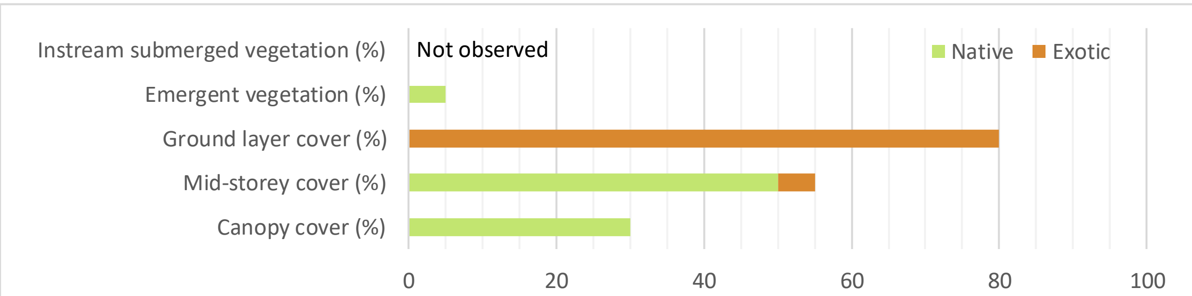

Figure 64. *Overview of vegetation structures observed within reach 10*

Reach 11 – Traralgon Creek

The vegetation in this reach has been impacted by mining and agricultural usage of the landscape. There is a mine discharge channel into the waterway which provides the dominate flow to the waterway in dry conditions. Downstream of the mine water discharge point submerged aquatic plants (Eel Grass - *Vallisneria australis*) and filamentous algae are present.

The riparian vegetation was mostly from earlier revegetation activities with fenced plantings 5 - 20m wide. Species planted include Eucalyptus species and Silver Wattle (Acacia dealbata). Stumps of large remnant Eucalyptus sp are present on the site indicating that a significant woodland *EVC56 Swampy Riparian Woodland* occupied the site pre-disturbance. The channel benches and toe has native emergent plants such as *Juncus sp, Carex appressa, Alisma plantago-aquatica, Persicaria decipiens* providing approximately 10% of the cover.

Blackberry covers up to 50% of the channel banks with exotic grasses (Phalaris aquatica) and herbs dominating the ground layer. Weeds present include Hemlock (*Conium maculata*), Spear Thistle (*Cirsium vulgare*), Nightshade (*Solanum nigrum*), Drain Flat-sedge (Cyperus eragrostis).

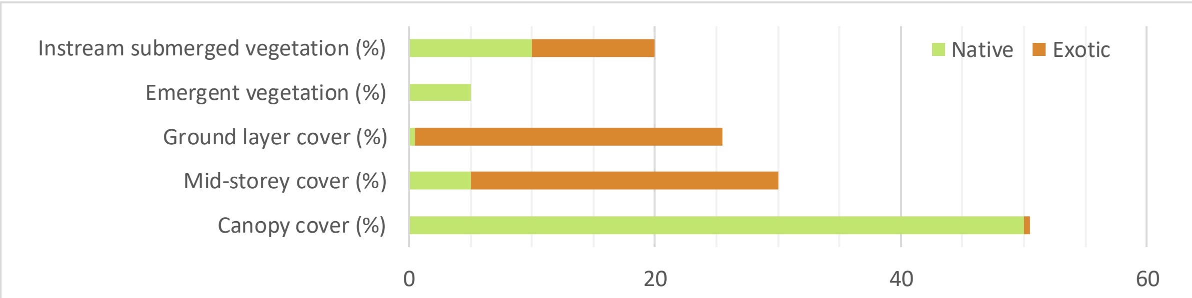

Figure 65. *Overview of vegetation structures observed within reach 11*

Lower Latrobe wetland - Sale Common

Sale Common is one of only two remaining freshwater wetlands in the Gippsland Lakes system and provides important habitat for a diverse range of fauna (WGCMA 2018). Past vegetation assessment completed by Frood (2015) found that there is a wide and complex range of vegetation communities present in Sale Common. In the same survey, the dominant Ecological Vegetation Classes are: Floodway Pond Herbland (EVC810)/Open Water (EVC990) mosaic, Tall Marsh (EVC821), Aquatic Sedgeland (EVC 308), Swamp Scrub (EVC53), Floodplain Riparian Woodland (EVC56), Aquatic Herbland (EVC653), (Frood et al. 2015). It should be noted that majority of these EVCs are captured in DELWP NatureKit as 'Deep Freshwater Marshes (681), which is a generic wetland term to capture many EVCs that are seasonally present within the wetland depending on the water availability of the wetland. These dominant EVCs change in extent and abundance depending on the water availability and flooding regime of the site.

Previous inundations of the site have seen extensive stands of *Juncus ingens* (Giant Rush) to establish across the Sale Common which reduced the diversity and views across the site (WGCMA). Shallow summer inundation may favour Giant Rush over other species - although this will also advantage species such as Typha sp (Bull Rush). New seedings of Giant rush can be drowned by flooding but this requires water to flood the site to >300mm deep. Maintaining deep water to control Giant Rush has been achieved in the past (assisted via natural flooding, Keogh pers comm). To repeat this water retention strategy may not be a practical strategy. The best method of maintaining diverse vegetation communities on the Common would be to have a late winter to spring fill of the wetland and allow the site to dry over summer. A varying water regime will encourage a diversity of species and build resilience to invasions by one species. If a summer event fills the wetland monitoring of Giant Rush and Typha should occur to determine if management needs to occur.

The objective for the Sale Common is to maintain a mosaic of habitats and vegetation communities. If hydrological conditions are not allowed to vary over the seasons or inter years (i.e. permanent inundation or perpetual low water levels) the current mosaic of wetland EVCs will evolve to a less diverse system.

Lower Latrobe wetland - Heart Morass
The western and central sections of the Heart Morass were, until recently, governed by private landholders and have been subject to past grazing and vegetation clearing for agricultural purposes. The land was purchased by Wetlands Environmental Taskforce (WET) Trust between 2006 and 2013 and conservation and restoration works have been undertaken since the land purchase.

During the millennial drought the wetland dried up and was completely dry in 2006. This impacted the site with most of the area losing the ground layer and wetland vegetation at the time. The vegetation has recovered across most of the site showing resilience of the vegetation to changes in the availability of water. Increasing salinization is occurring in some areas which will affect the vegetation communities and dominant species. Acid sulfate soils are present (Frood et al. 2015) which are an ongoing threat to the health of vegetation and biota generally in those areas. The hydraulic control structures at Heart Morass are described in Section 2.3.

The dominant EVCs observed by Frood et al. (2015) are: Tall Marsh (EVC821), Aquatic Herbland (EVC653), Swamp Scrub (EVC53), Floodplain Riparian Woodland (EVC56), Coastal Saltmarsh Aggregate (EVC9), Estuarine Scrub (EVC953), Brackish Wetland (EVC656), Brackish Herbland (538) and Brackish Grassland (EVC934). It should be noted that majority of these EVCs are captured in DELWP NatureKit as 'Deep Freshwater Marshes (681), which is a generic wetland term to capture many EVCs that are seasonally present within the wetland depending on the water availability of the wetland.

The vegetation in Heart Morass is showing signs of increasing salinization with saline tolerant species observed across most of the site. Increased freshwater flows (salinity <1g/L) and shallow inundation across the Morass would help flush some salts from the system and provide opportunity for the grasslands and herb-lands to rejuvenate.

The objective for Heart Morass is to maintain a mosaic of habitats and wetland vegetation communities with surrounding Floodplain Woodland.

Lower Latrobe wetland - Dowd Morass
Dowd Morass is a 1,500 ha brackish wetland located on the southern shore of the Latrobe River. Like Heart Morass, acid sulfate soils are present in some areas of the Dowd Morass (Frood 2015). This could potentially pose a problem when managing flooding and drying regime of the wetland due to the risk of exposure affecting downstream ecosystem (Frood 2015).

The dominant EVCs are: Tall Marsh (EVC821), Swamp Scrub (EVC53), Floodplain Riparian Woodland (EVC56), Coastal Saltmarsh Aggregate (EVC9), Estuarine Scrub (EVC953), Brackish Wetland (EVC656) and Open Water (EVC990) (Frood 2015). It should be noted that majority of these EVCs are captured in DELWP NatureKit as 'Deep Freshwater Marshes (681), which is a generic wetland term to capture many EVCs that are seasonally present within the wetland depending on the water availability of the wetland.

The vegetation reflects an increasing gradient of salinity from west to east. There is more diverse and spatially complex vegetation in the fresher areas in the western areas progressing to Open Water, *Phragmites australis* Tall Marsh and Swamp Scrub in the central areas. The eastern area near Lake Wellington experiences higher salinities with Estuarine Scrub dominating and saltmarsh communities occurring at the upper edge of the wetland perimeter

The vegetation in Dowd Morass has been affected by the prolonged flooding and increased salinity seen across the site since the 1970s (Slater et al, 2010). Prior to changes to the system in the 1970s Dowd Morass was estimated to dry out approximately every 5 years (Boon et al. 2008) which would have enabled the plants to recover and undergo sexual reproduction. With the prolonged flooding the Swamp Paperbark plants (*Melaleuca ericifolia*) can only rejuvenate via vegetative reproduction/recovery and are showing signs of decline as a result. The increased salinity also introduces another stress on the plants further impacting on their long-term survival. These conditions reduce the species diversity as less plants can tolerate the static conditions. The flat topography of Dowd's Morass means there is little variation in depth across the site. The remaining Swamp Paperbark are growing on their own root pedestals which stand up to the water surface level. This enables the plants to access oxygen but is the only place they can sexually regenerate. Expansion from these pedestals is not possible with permanent deep (>400mm) inundation. If sexual regeneration was to occur in a wetland drawdown the juvenile Swamp Paperbark would drown with the returning of the water level to the current depth. Recruitment of the Melaleuca is occurring from vegetative expansion and this will be facilitated by seasonal water fluctuations.

The objective for Dowd Morass is to maintain/restore the mature Swamp Paperbark and fringing Tall Marsh (*Phragmites australis* reed beds).

Appendix E: Water quality condition information

Information on water quality was collected from three main sources:

- The Index of Condition Site (http://ics.water.vic.gov.au/ics/) which contains the results of the Index of Stream Condition (ISC) program. The ISC is a composite indicator of river condition covering 23 indicators that integrate five major themes (hydrology, water quality, streamside zone, physical form, and aquatic life);
- Victoria's *Water Measurement Information System* (WMIS) (http://data.water.vic.gov.au/monitoring.htm), the primary point to search, access and download surface water and groundwater monitoring data collected by the Department of Environment, Land, Water and Planning (DELWP) and its partners; and
- Waterwatch Victoria's data portal (http://www.vic.waterwatch.org.au/water_data_portal.php), providing data gathered from the Waterwatch community engagement program.

Not all reaches had information from all three of the above sources. Available information from the above sources was combined to provide a characterisation of each reach's water quality and stream health condition.

Reach 3 – Latrobe River from Lake Narracan to Scarnes Bridge

Index of Stream Condition: Reach 3 of this study, from Lake Narracan to Scarnes Bridge, contains ISC reach 4 in the Latrobe Basin (Basin 26). This reach is noted in the most recent ISC assessment (DEPI 2013) as being extremely flow stressed and was rated as being in 'Very Poor' condition. The water quality and physical form of the reach both received good scores (8 and 7 out of 10, respectively), however the hydrology rating (1) and the poor aquatic life score (4) impacted the reach's overall rating.

Water Measurement Information System: The WMIS data base has one site in Reach 3, at Thoms Bridge approximately 10 km (river kilometres) downstream of Lake Narracan. The site has monthly water quality data for the period from 1990 to 2002 for pH, dissolved oxygen, electrical conductivity, turbidity, total phosphorus, oxides of nitrogen (nitrate and nitrite) and total Kjeldahl nitrogen (Table 41). Turbidity and pH were both within their SEPP (Waters) objectives for the coastal plains. Electrical conductivity, total nitrogen and total phosphorus all triggered their SEPP (Waters) objectives, although did not reach levels considered to be harmful (Newall and Tiller 2015).

Dissolved oxygen was recorded in mg/L and therefore is not readily comparable to the SEPP objective, which is presented in percent saturation. However, the dissolved oxygen concentrations recorded during that period (Table 41) were indicative of well-oxygenated waters.

Table 41. Summarised water quality data from the WMIS data base, for the Latrobe River at Thoms Bridge.

Green shading indicates result meets SEPP objectives; orange shading indicates result does not meet SEPP objective without reaching harm thresholds and red shading indicates result does not meet SEPP objectives and may reach harm thresholds.

Indicator		pH	Electrical conductivity (µS/cm)	Turbidity (NTU)	Total nitrogen (µg/L) ɣ	Total phosphorus (µg/L)	Dissolved oxygen (mg/L)
1990 - 2002	25th percentile	6.7	NA	NA	NA	NA	9.0
	75th Percentile	7.3	280	24	1190	90	10.8
SEPP (Waters) objective (Coastal Plains)	25th percentile	≥6.7	NA	NA	NA	NA	*
	75th Percentile	≤7.7	≤250	≤25	≤1100	≤55	*

*Dissolved oxygen data was only available in mg/L, which does not have a SEPP (Waters) objective.

Waterwatch: There were no active Waterwatch sites in the reach. The Waterwatch site with the most site visits was also Thoms Bridge. The Waterwatch site at Thoms Bridge had data from 2005 to 2012 (Table 42) and showed generally similar pH and electrical conductivity results to those from the WMIS database, collected in the previous decade. In contrast, the turbidity measures in the Waterwatch database were more than double those recorded for the site in the WMIS database approximately a decade earlier. Field notes prepared during the Waterwatch sampling often noted high flows during sampling and/or rainfall events in the week prior to sampling, particularly in the 2010 to 2012 period.

Table 42. Water quality data gathered by Waterwatch for the Latrobe River at Thoms Bridge.

Green shading indicates result meets SEPP objectives; orange shading indicates result does not meet SEPP objective without reaching harm thresholds and red shading indicates result does not meet SEPP objectives and may reach harm thresholds.

Indicator		pH	Electrical conductivity (µS/cm)	Turbidity (NTU)
25th percentile		6.9	NA	NA
75th Percentile		7.5	317	53
SEPP (WoV) objective (Coastal Plains)	25th percentile	>6.7	NA	NA
	75th Percentile	<7.7	<250	<25

Reach 4 – Latrobe River from Scarnes Bridge to Kilmany South

Index of Stream Condition: Reach 4 of this study, from Lake Narracan to Kilmany South, contains ISC reach 3 in the Latrobe Basin (Basin 26). This reach is noted in the most recent ISC assessment (DEPI 2013) as having poor water quality, with highly elevated levels of turbidity and phosphorus, and was rated as being in 'Poor' condition. Despite having a high score for physical form (9 out of 10) and moderate condition streamside zone (6 out of 10) the very poor hydrology (2) and poor water quality and aquatic life of the reach (both received 4 out of 10, respectively) impacted the reach's overall rating.

Water Measurement Information System: The WMIS data base has one site in Reach 4, at the end of the reach in Rosedale. The site has monthly water quality data for the period from 1990 to 2018 for pH, dissolved oxygen, electrical conductivity, turbidity, total phosphorus, oxides of nitrogen (nitrate and nitrite) and total Kjeldahl nitrogen, as well as a range of metals. The oxides of nitrogen and the total Kjeldahl nitrogen were combined to give total nitrogen, which is assessable against SEPP (Waters) (Table 43). pH was within the SEPP (Waters) objectives for the coastal plains. Electrical conductivity, turbidity, and total nitrogen total phosphorus all triggered their SEPP (Waters) objectives without reaching levels expected to be harmful, whereas total phosphorus exceeded SEPP objectives and did reach levels considered to be harmful (Newall and Tiller 2015).

Dissolved oxygen was recorded in mg/L and therefore is not readily comparable to the SEPP objective, which is presented in percent saturation. However, the dissolved oxygen concentrations recorded during that period (Table 43) were indicative of well-oxygenated waters.

Table 43. Summarised water quality data from the WMIS data base, for the Latrobe River at Rosedale.

Green shading indicates result meets SEPP objectives; orange shading indicates result does not meet SEPP objective without reaching harm thresholds and red shading indicates result does not meet SEPP objectives and may reach harm thresholds.

Indicator		pH	Electrical conductivity (µS/cm)	Turbidity (NTU)	Total nitrogen (µg/L)	Total phosphorus (µg/L)	Dissolved oxygen (mg/L)
1990 - 2018	25th percentile	6.9	NA	NA	NA	NA	8.2
	75th Percentile	7.2	360	43	1160	100	10
SEPP (Waters) objective (Coastal Plains)	25th percentile	≥6.7	NA	NA	NA	NA	*
	75th Percentile	≤7.7	≤250	≤25	≤1100	≤55	*

*Dissolved oxygen data was only available in mg/L, which does not have a SEPP (Waters) objective.

Waterwatch: There was one active Waterwatch site in the reach: Latrobe River at the Highway Park site in Rosedale. The site had data during most of the 1990s and early 2000s, becoming less frequent with only one sample after 2006, in March 2018. The site showed similar results to those from the WMIS database, with pH meeting the SEPP objectives, electrical conductivity and turbidity triggering the objectives without reaching harmful levels, and total phosphorus being highly elevated (Table 44). At this site, dissolved oxygen had been recorded in percent saturation and was therefore able to be compared against the SEPP objectives. Also similar to the WMIS site, the dissolved oxygen concentrations were at healthy levels.

Table 44. Water quality data gathered by Waterwatch the Latrobe River at Highway Park.

Green shading indicates result meets SEPP objectives; orange shading indicates result does not meet SEPP objective without reaching harm thresholds and red shading indicates result does not meet SEPP objectives and may reach harm thresholds.

Indicator		pH	Electrical conductivity (µS/cm)	Turbidity (NTU)	Dissolved oxygen (%sat)	Total phosphorus
25th percentile		7.0	NA	NA	79	NA
75th Percentile; Max for dissolved oxygen		7.2	350	38	116	130
SEPP (WoV) objective (Coastal plains)	25th percentile*	≥6.7	NA	NA	≥75	NA
	75th Percentile*	≤7.7	≤250	≤25	≤130	≤55

Reach 5 – Latrobe River from Kilmany South to Thomson River confluence

Index of Stream Condition: Reach 5 of this study is the same as reach 2 in the ISC study. The reach is rated as 'Very Poor', with hydrology, water quality and aquatic life all scoring below 5 out of 10. The reach was identified as showing highly elevated levels of phosphorus and turbidity, and being flow stressed.

Water Measurement Information System: Reach 5 has one active site in the WMIS data base: Latrobe River at Kilmany South. There were few data before 2003 but the data for several SEPP objectives were collected between 2003 and 2018 and are presented in Table 45. Similar to the Latrobe River at Rosedale, there were water quality data water quality data for pH, dissolved oxygen, electrical conductivity, turbidity, total phosphorus, oxides of nitrogen (nitrate and nitrite) and total Kjeldahl nitrogen. The oxides of nitrogen and the total Kjeldahl nitrogen were combined to give total nitrogen, which is assessable against SEPP (Waters). Also similar to the Latrobe River at Rosedale, pH measurements was measured as being within the SEPP (Waters) objectives for the coastal plains, while electrical conductivity, turbidity and total nitrogen all triggered their SEPP (Waters) objectives, without reaching levels considered to be harmful (Newall and Tiller 2015). Total phosphorus exceeded SEPP objectives and exceeded levels considered to be harmful.

Dissolved oxygen was recorded in mg/L and therefore is not readily comparable to the SEPP objective, which is presented in percent saturation. However, the dissolved oxygen concentrations recorded during that period (Table 45) were indicative of healthy, well-oxygenated waters.

Table 45. Summarised water quality data from the WMIS data base, at Kilmany on the Latrobe River.

Green shading indicates result meets SEPP objectives; orange shading indicates result does not meet SEPP objective without reaching harm thresholds and red shading indicates result does not meet SEPP objectives and may reach harm thresholds.

Indicator		pH	Electrical conductivity (µS/cm)	Turbidity (NTU)	Total nitrogen (µg/L) ɣ	Total phosphorus (µg/L)	Dissolved oxygen (mg/L)
2003 - 2018	25th percentile	7.0	NA	NA	NA	NA	8.0
	75th Percentile	7.3	383	40	1320	130	10
SEPP (Waters) objective (Coastal Plains)	25th percentile	≥6.7	NA	NA	NA	NA	*
	75th Percentile	≤7.7	≤250	≤25	≤1100	≤55	*

*Dissolved oxygen data was only available in mg/L, which does not have a SEPP (Waters) objective.

Waterwatch: There was one active site found on the Latrobe River in this reach: the Latrobe River at Longford (Table 46). The site had data for periods that varied by indicator, although most indicators were sampled from mid- to late-1990s to a period between 2005 and 2015. The site showed mostly similar results to those from the WMIS database, with pH meeting the SEPP objectives and electrical conductivity triggering the objectives without reaching harmful levels. Turbidity and total phosphorus both exceeded the SEPP objectives and reached their potential harm thresholds (Table 46). At this site, dissolved oxygen had been recorded in percent saturation and was therefore able to be compared against the SEPP objectives. Also similar to the WMIS site, the dissolved oxygen concentrations were at generally healthy levels although the 25th percentile did trigger the SEPP objective for the 25th percentile, indicating potential oxygen stress at times.

Table 46. Water quality data gathered by Waterwatch the Latrobe River at Highway Park.

Green shading indicates result meets SEPP objectives; orange shading indicates result does not meet SEPP objective without reaching harm thresholds and red shading indicates result does not meet SEPP objectives and may reach harm thresholds.

Indicator		pH	Electrical conductivity (µS/cm)	Turbidity (NTU)	Dissolved oxygen (%sat)	Total phosphorus
25th percentile		6.9	NA	NA	73	NA
75th Percentile; (Max for dissolved oxygen)		7.3	420	60	107	160
SEPP (WoV) objective (Coastal Plains)	25th percentile*	≥6.7	NA	NA	≥75	NA
	75th Percentile*	≤7.7	≤250	≤25	≤130	≤55

Reach 8 – Tanjil River

Index of Stream Condition: In this study the Tanjil River is a single reach (Reach 8) which is represented in the ISC study it by reach 23 (Tanjil River below Blue Rock Lake), rated as 'Moderate' (with hydrology being the primary stressor).

Water Measurement Information System This reach had one active site currently measuring water quality, located at Tanjil Junction, well upstream of the Blue Rock Lake. The data was mostly collected from 1991 to 2018, except for nutrients which were collected from 2002 to 2018.

Water quality data water quality data were available for pH, electrical conductivity, turbidity, total phosphorus, oxides of nitrogen (nitrate and nitrite), total nitrogen and dissolved oxygen. The oxides of nitrogen and the total nitrogen were combined to give total nitrogen, which is assessable against SEPP (Waters) (Table 47). No measures triggered their SEPP (Waters) objectives, indicating a healthy waterway.

Dissolved oxygen was recorded in mg/L and therefore is not readily comparable to the SEPP objective, which is presented in percent saturation. However, the dissolved oxygen concentrations recorded during that period were indicative of well-oxygenated waters.

Table 47. Summarised water quality data from the WMIS data base for Tanjil Junction on the Tanjil River.

Green shading indicates result meets SEPP objectives; orange shading indicates result does not meet SEPP objective without reaching harm thresholds and red shading indicates result does not meet SEPP objectives and may reach harm thresholds.

Indicator		pH	Electrical conductivity (µS/cm)	Turbidity (NTU)	Total nitrogen (µg/L) ɣ	Total phosphorus (µg/L)	Dissolved oxygen (mg/L)
2003 - 2018	25th percentile	6.8	NA	NA	NA	NA	9.6
	75th Percentile	7.3	55	6	435	17	11.7
SEPP (Waters) objective (Uplands A)	25th percentile	≥6.4	NA	NA	NA	NA	*
	75th Percentile	≤7.6	≤100	≤15	≤900	≤35	*

*Dissolved oxygen data was only available in mg/L, which does not have a SEPP (Waters) objective.

Waterwatch: There are no Waterwatch sites on the Tanjil River.

Reach 9 – Tyers River

Index of Stream Condition: In this study the Tyers River (Reach 9) is represented in the ISC study by reach 16 (Tyers River below the Moondarra Reservoir).

The reach was identified as having excellent water quality results; however, it was noted to have experienced extreme flow stress, including highly altered summer high and low flows and winter low flows. These flow stresses may reflect the timing of the ISC data (2004 to 2010), a substantial amount of which occurred during the 'millennium drought'.

Water Measurement Information System: This reach has five active WMIS sites. The common water quality measures used in SEPP (Waters) are measured at the Tyers River at the Pumphouse and this site also provides information on the quality of the water from the Tyers River close to its confluence with the Latrobe River. The data from this site are presented in Table 48. The data were collected approximately monthly from 2006 to 2018.

Table 48. Summarised water quality data from the WMIS data base, for the Tyers River at the Pumphouse.

Green shading indicates result meets SEPP objectives; orange shading indicates result does not meet SEPP objective without reaching harm thresholds and red shading indicates result does not meet SEPP objectives and may reach harm thresholds.

Indicator		pH	Electrical conductivity (µS/cm)	Turbidity (NTU)	Total nitrogen (µg/L)	Total phosphorus (µg/L)	Dissolved oxygen (mg/L)
2006 - 2018	25th percentile	6.8	NA	NA	NA	NA	8.3
	75th Percentile	7.0	90	11	360	16	10.8
SEPP (Waters) objective (Uplands A)	25th percentile	≥6.4	NA	NA	NA	NA	*
	75th Percentile	≤7.6	≤100	≤15	≤900	≤35	*

*Dissolved oxygen data was only available in mg/L, which does not have a SEPP (Waters) objective.

None of the water quality objectives measured at the site triggered the SEPP (Waters) objectives (Table 48), most likely reflecting the upstream source (Moondarra Reservoir) and the fact that below the reservoir the river runs through a mostly forested catchment and is still in the uplands of the basin.

Waterwatch: There was one active Waterwatch site on the Tyers River and that site was near the WMIS Pumphouse site. This was at the Wirilda Reserve (Table 48), with data collected monthly from approximately 2009 to 2017. Although the turbidity data from the site was generally similar to the corresponding WMIS site (Table 48), none of the indicators at the WMIS site triggered the SEPP objectives, whereas three of the four indicators in Table 49 did trigger (albeit by a small margin for pH and electrical conductivity). The most concerning result, however, is the reactive phosphate, which not only exceeds the SEPP objective for the region (35 µg/L) but also exceeds the level for potential harm in the region (50 µg/L, Newall and Tiller 2018). This may be partly due to location, where the WMIS Pumphouse site appears to be approximately 200 m upstream of the Waterwatch site, with dirt roads and local loss of tree cover between the two sites.

Table 49. Water quality data gathered by Waterwatch from the Tyers River at Wirilda Reserve off Tyers-Yallourn Nth Rd.

Green shading indicates result meets SEPP objectives; orange shading indicates result does not meet SEPP objective without reaching harm thresholds and red shading indicates result does not meet SEPP objectives and may reach harm thresholds.

Indicator		pH	Electrical conductivity (µS/cm)	Turbidity (NTU)	Reactive phosphate* (µg/L)
25th percentile		6.0	NA	NA	NA
75th Percentile; (Max for dissolved oxygen)		6.9	110	10	60
SEPP (WoV) objective (Uplands A)	25th percentile*	>6.4	NA	NA	NA
	75th Percentile*	<7.6	<100	<15	NA

*The SEPP objective is for total phosphorus. Reactive phosphorus is a component of total phosphorus and therefore if the reactive phosphorus concentration exceeds the objective, the total phosphorus must also exceed the objective.

Reach 10 – Morwell River

Index of Stream Condition: In this study the Morwell River is a single reach (Reach 10) whereas in the ISC study it was divided into two reaches. The most downstream reach is ISC reach 18, which runs from the river's confluence with the Latrobe River to its confluence with Middle Creek. This ISC reach was rated as 'Poor', with extreme flow stress and highly elevated levels of turbidity and phosphorus. Upstream of its confluence with Middle Creek, the ISC reach 19 extends to near the Strzelecki Ranges and has a rating of 'Moderate', with its most significant difference to the downstream reach being a much higher hydrology score.

Water Measurement Information System: The Morwell River at Yallourn WMIS site in Reach 10 is located adjacent to the Yallourn Open Cut and is approximately 2km upstream of the Morwell River's confluence with the Latrobe River. There were monthly data from 2004 to 2018, presented in Table 50. There were water quality data water quality data for pH, dissolved oxygen, electrical conductivity, turbidity, total phosphorus, oxides of nitrogen (nitrate and nitrite) and total nitrogen. The oxides of nitrogen and the total nitrogen were combined to give total nitrogen, which is assessable against SEPP (Waters). The pH measurements were within the SEPP (Waters) objectives for the coastal plains, while electrical conductivity, total phosphorus and total nitrogen all triggered their SEPP (Waters) objectives, without reaching levels considered to be potentially harmful (Newall and Tiller 2015). Turbidity exceeded SEPP objectives and exceeded levels considered to be harmful.

Dissolved oxygen was recorded in mg/L and therefore is not readily comparable to the SEPP objective, which is presented in percent saturation. However, the dissolved oxygen concentrations recorded during that period (Table 50) were indicative of healthy, well-oxygenated waters.

Table 50. Summarised water quality data from the WMIS data base, for the Morwell River at Yallourn.

Green shading indicates result meets SEPP objectives; orange shading indicates result does not meet SEPP objective without reaching harm thresholds and red shading indicates result does not meet SEPP objectives and may reach harm thresholds.

Indicator		pH	Electrical conductivity (µS/cm)	Turbidity (NTU)	Total nitrogen (µg/L) ɤ	Total phosphorus (µg/L)	Dissolved oxygen (mg/L)
2003 - 2018	25th percentile	7.0	NA	NA	NA	NA	8.1
	75th Percentile	7.4	607	59	1280	92	10.1
SEPP (Waters) objective (Coastal Plains)	25th percentile	≥6.7	NA	NA	NA	NA	*
	75th Percentile	≤7.7	≤250	≤25	≤1100	≤55	*

*Dissolved oxygen data was only available in mg/L, which does not have a SEPP (Waters) objective.

Waterwatch: There were three active Waterwatch sites on the Morwell River, one in the upper reaches, one in the mid-reaches and one in the lower reaches. The mid-reach site was used for this site paper. This site has similar pH to the WMIS site at Yallourn, and substantially lower electrical conductivity and turbidity results. In contrast, the reactive phosphate results are nearly five times higher at the Waterwatch site (Table 51) than the total phosphorus concentrations further downstream at Yallourn (Table 50). High reactive phosphorus in the reach may be a function of an agricultural catchment, although these levels are very high, and it is interesting that they diminish as much as they do by the time the Morwell River flows through Yallourn.

Table 51. Water quality data gathered by Waterwatch from the Morwell River at Apex Park Boolarra.

Green shading indicates result meets SEPP objectives; orange shading indicates result does not meet SEPP objective without reaching harm thresholds and red shading indicates result does not meet SEPP objectives and may reach harm thresholds.

	Indicator	pH	Electrical conductivity (µS/cm)	Turbidity (NTU)	Reactive phosphate*
2006 - 2018	25th percentile	6.7	NA	NA	NA
	75th Percentile;	7.5	205	12	450
SEPP (Waters) objective (Coastal Plains)	25th percentile*	≥6.7	NA	NA	NA
	75th Percentile*	≤7.7	≤250	≤25	NA

*The SEPP objective is for total phosphorus. Reactive phosphorus is a component of total phosphorus and therefore if the reactive phosphorus concentration exceeds the objective, the total phosphorus must also exceed the objective.

Reach 11 – Traralgon Creek

Index of Stream Condition: Traralgon Creek, Reach 11 in this study, comprises two ISC reaches – ISC reaches 11 and 12. The downstream reach was ISC reach 11, which runs north from near the base of the Strzelecki Ranges downstream to the creek's confluence with the Latrobe River; with ISC reach 12 being mostly within the Strzelecki Ranges. ISC reach 11 was rated as 'Moderate' and ISC reach 12 was rated as 'Excellent', with slightly better aquatic life and substantially better streamside zone ratings.

Water Measurement Information System: Traralgon Creek had three active WMIS sites, but only one with sufficient water quality data – Traralgon Creek at Traralgon South – which had water quality data from 2002 to 2007 (Table 52). The site is situated downstream of the Strzelecki Ranges. There were water quality data water quality data for pH, dissolved oxygen, electrical conductivity, turbidity and total phosphorus. Total phosphorus was measured approximately every 3 to 4 months, whereas the other indicators were measured approximately weekly to fortnightly. All water quality indicators were indicative of a healthy ecosystem with the exception of electrical conductivity, which marginally exceeded the SEPP (Waters) objective.

Table 52. Summarised water quality data from the WMIS data base, for the Traralgon Creek at Traralgon South.

Green shading indicates result meets SEPP objectives; orange shading indicates result does not meet SEPP objective without reaching harm thresholds and red shading indicates result does not meet SEPP objectives and may reach harm thresholds.

Indicator		pH	Electrical conductivity (µS/cm)	Turbidity (NTU)	Total phosphorus (µg/L)	Dissolved oxygen (mg/L)
2002 - 2007	25th percentile	6.9	NA	NA	NA	5.9
	75th Percentile	7.2	280	12	50	9.5
SEPP (Waters) objective (Coastal Plains)	25th percentile	≥6.7	NA	NA	NA	*
	75th Percentile	≤7.7	≤250	≤25	≤55	*

*Dissolved oxygen data was only available in mg/L, which does not have a SEPP (Waters) objective.

Waterwatch: There was one active Waterwatch site on Traralgon Creek, with data from 2007 to 2018 (Table 53). This site has similar pH to the WMIS site at Traralgon South but had substantially higher electrical conductivity and turbidity readings. Although the reactive phosphorus was below the objective for total phosphorus, it is not possible to determine whether the total phosphorus of the site would also have met the objective.

Table 53. Water quality data gathered by Waterwatch from the Traralgon Creek at Atherley Close.

Green shading indicates result meets SEPP objectives; orange shading indicates result does not meet SEPP objective without reaching harm thresholds and red shading indicates result does not meet SEPP objectives and may reach harm thresholds.

Indicator		pH	Electrical conductivity (µS/cm)	Turbidity (NTU)	Reactive phosphate*
2007 - 2018	25th percentile	6.7	NA	NA	NA
	75th Percentile;	7.0	558	41	30
SEPP (Waters) objective (Coastal Plains)	25th percentile*	>6.7	NA	NA	NA
	75th Percentile*	<7.7	<250	<25	NA

*The SEPP objective is for total phosphorus. Reactive phosphorus is a component of total phosphorus and therefore if the reactive phosphorus concentration exceeds the objective, the total phosphorus must also exceed the objective.

Latrobe River estuary

Index of Stream Condition: Reach 6 of this study is the same as reach 201 in the ISC study. The reach is rated as ‘Poor’, with aquatic life and hydrology scoring 2 and 3 out of 10. The aquatic life score was the poorest in the basin and was attributed to the influence of the surrounding cleared stretch of land on the Latrobe River. There was no water quality score derived for the site. In contrast to the other scores, physical form was rated as being in excellent condition.

Water Measurement Information System: This reach had no active sites in the river channel and only one closed site has any water quality information – electrical conductivity in the Latrobe River at Dowd Morass Gate, from November 2014 to July 2016. The data collected was instantaneous and summarised as a daily mean for each day of the sampling period. The 75th percentiles of the daily means are presented in Table 54. Similar to other sites upstream, electrical conductivity triggered the SEPP (Waters) objectives without reaching levels considered potentially harmful.

Table 54. Summarised water quality data from the WMIS data base, at Dowd Morass Gate on the Latrobe River.

Green shading indicates result meets SEPP objectives; orange shading indicates result does not meet SEPP objective without reaching harm thresholds and red shading indicates result does not meet SEPP objectives and may reach harm thresholds.

Indicator		Electrical conductivity (µS/cm)
2003 - 2018	75th Percentile	348
SEPP (Waters) objective (Coastal Plains)	25th percentile	NA
	75th Percentile	≤250

*Dissolved oxygen data was only available in mg/L, which does not have a SEPP (Waters) objective.

Waterwatch: There was one active site found on the Latrobe River in this reach and it was also at Dowd Morass. The available data was generally collected at 2-monthly intervals between approximately 1996 and 2008, then at 6-monthly intervals between approximately 2012 and 2018. The data are displayed in Table 55 and show pH meeting the SEPP objectives and electrical conductivity and turbidity triggering the objectives without reaching harmful levels. Total phosphorus exceeded its SEPP objective and reached the potential harm threshold. Dissolved oxygen concentrations were at generally healthy levels although the 25th percentile did trigger the SEPP objective for the 25th percentile, indicating potential oxygen stress at times.

Table 55. Water quality data gathered by Waterwatch the Latrobe River at Highway Park.

Green shading indicates result meets SEPP objectives; orange shading indicates result does not meet SEPP objective without reaching harm thresholds and red shading indicates result does not meet SEPP objectives and may reach harm thresholds.

Indicator		pH	Electrical conductivity (µS/cm)	Turbidity (NTU)	Dissolved oxygen (%sat)	Total phosphorus
25th percentile		6.9	NA	NA	66	NA
75th Percentile; (Max for dissolved oxygen)		7.3	1120	40	97	160
SEPP (WoV) objective (Coastal Plains)	25th percentile*	≥6.7	NA	NA	≥75	NA
	75th Percentile*	≤7.7	≤250	≤25	≤130	≤55

Thomson River Estuary

Index of Stream Condition: The Thomson River Estuary is presented as reach 201 in the ISC study and flows into Lake Wellington. The reach was rated as 'Poor' with poor ratings for hydrology and aquatic life, and no water quality data. Physical form for the reach was rated 10 out of 10.

Water Measurement Information System: Very few data were found on the WMIS data base for the Thomson River Estuary. Information that was found included:

- Latrobe River at Dowd Morass: electrical conductivity measured from 2013 to 2015 had a maximum of 3308 µS/cm and a minimum of 130 µS/cm; and
- Latrobe River at Heart Morass: electrical conductivity measured from 2014 to 2015 had a maximum of 2383 µS/cm and a minimum of 169 µS/cm.

Wetlands

A report card on the natural assets of the Gippsland Lakes (Ladson and Tilleard 2011) reported Index of Wetland Condition (IWC) scores allocated to lake and wetland habitats in the study area for this site paper, including Sale Common, Heart Morass and Dowd Morass. The scores and their basis are provided below. The most pertinent sub-indices used in the IWC for this site paper are ‘Hydrology’ (based on change in water regime) and ‘Water Properties’ (based on evidence of change in salinity and nutrient enrichment activities).

Sale Common: Sale Common received an overall rating of ‘Moderate’. The sub-index ‘water properties’ was rated as excellent, as was physical form. Hydrology, however, was rated as ‘Very Poor’, while the wetlands biota, soil and surrounding catchment were rated as ‘Moderate’.

Heart Morass: Heart Morass was rated as ‘Good’. As for Sale Common, the sub-index ‘water properties’ was rated as ‘Excellent’, as were physical form, soils and biota. Again, hydrology was rated as ‘Very Poor’, while the wetland catchment was rated as ’Good’.

Dowd Morass: Similar to Sale Common, Dowd Morass was rated as ‘Moderate’ with water properties rated as excellent, along with physical form and soils. The wetland’s catchment was rated as ‘Moderate’ and the biota as ‘Poor’.

Appendix F: Hydraulic and hydrologic analysis

1D hydraulic models for river reaches

The magnitudes of the flow required to achieve the flow functions were estimated using one-dimensional hydraulic models. The HEC-RAS modelling software, developed by the US Army Corp of Engineers, has been used as the hydraulic modelling platform for this part of the investigation.

Four new models were developed as part of this study based on the new sites selected (see Appendix B) for the Latrobe River reaches (reaches 3,4,5) and the Morwell River site (reach 10). For the other three river reaches (8 – Tanjil River, 9- Tyers River, and 11 – Traralgon Creek) the existing models from the 2007 FLOWS study were reviewed and adopted.

Table 56. Details of models utilised for river reaches.

Reach	Model	Topography data	Hydraulic outputs	Length of model
Reach 3 - Latrobe River from Lake Narracan to Scarnes Bridge	New model	Feature survey (2018)	Depth, velocity, shear stress	801 m – 12 cross sections
Reach 4 – Latrobe River from Scarnes Bridge to Kilmany South	New model	Feature survey (2018)	Depth, velocity, shear stress	661 m –10 cross sections
Reach 5 – Latrobe River from Kilmany South to Thomson River confluence	New model)	Feature survey (2018)	Depth, velocity, shear stress	1203 m – 11 cross sections
Reach 8 – Tanjil River	2007 FLOWS study models	Feature survey (2007)	Depth, velocity, shear stress	225 m – 23 cross sections
Reach 9 – Tyers River	2007 FLOWS study models	Feature survey (2007)	Depth, velocity, shear stress	130 m – 13 cross sections
Reach 10 – Morwell River	HEC-RAS (1D)	Feature survey (2018)	Depth, velocity, shear stress	708 m – 12 cross sections
Reach 11 – Traralgon Creek	2007 FLOWS study models	Feature survey (2007)	Depth, velocity, shear stress	390 m – 40 cross sections

Hydraulic parameters

Table 57 lists the boundary conditions and hydraulic roughness adopted for each model. These parameters were adopted on the basis of field observations, aerial photography, LiDAR analysis and calibration based on water level on survey date. No changes to the Manning's roughness values for all 2007 FLOWS study models (i.e. Reach 8, 9 and 10). Manning's roughness for the new survey reaches (Reaches 3, 4, 5 and 10) are based on field observations and experience of the project team and referenced from Hicks and Mason (1991).

Table 57. Hydraulic parameters (Manning's n values and downstream boundary conditions) used in the river models

Reach	Manning's n values			DS Boundary
	Channel	*Floodplain (Left Bank)*	*Floodplain (Right Bank)*	*Slope for normal depth*
Reach 3 - Latrobe River from Lake Narracan to Scarnes Bridge	0.05	0.045	0.045	0.0005
Reach 4 – Latrobe River from Scarnes Bridge to Kilmany South	0.05	0.06	0.06	0.0003
Reach 5 – Latrobe River from Kilmany South to Thomson River confluence	0.055	0.10	0.06 (downstream of xs 633) 0.1 (upstream of xs 633)	Rating curve (see below)
Reach 8 – Tanjil River	0.045	0.045	0.045	0.001
Reach 9 – Tyers River	0.06	0.10	0.10	0.003
Reach 10 – Morwell River	0.045	0.08	0.08	0.001
Reach 11 – Traralgon Creek	0.045	0.035	0.06	0.003

Reach 5 hydraulic modelling

The Reach 5 representative site is located upstream of the Latrobe estuary and is therefore influenced by the fluctuations in water level driven by Lake Wellington. Therefore, for developing the hydraulic model, this needs to be taken into account at the downstream boundary condition.

A rating curve was developed based on the range of water levels and flow rates in the one-dimensional hydrodynamic model of the estuary (see below) at the upstream extent of the model ('Upper Latrobe' reporting location). Due to the nature of the flow – water level relationship, two different curves were fitted to the data, one for flows less than 7,000 ML/day and one for those above 7,000 ML/day. The flow – water level relationship was adjusted to reflect the water level and flow on the day of survey (329 ML/day and 0.2 m AHD), this included an increase of 0.2m AHD to reflect the distance upstream of the site compared to the hydrodynamic model – this was applied consistently across the range of flow rates.

Given the variability in water levels that can occur, two rating curves were developed. One rating curve was based on the typical water level that occurs in the modelled results (hydrodynamic model timeseries results), while the other was based on an upper bound of water levels identified for a given flow rate. The resultant rating curves used in the reach 5 models are provided below (Figure 66).

Two separate hydraulic models were developed for reach 5 with the 2 different rating curves. In general, the 'upper bound' water level for a given flow rate is only exceeded 5-10% of the time. The model with typical water levels as the rating curve was used for the lower flow recommendations (Summer Autumn Baseflow, Summer / Autumn Fresh, Winter / Spring Baseflow), while both models were used to inform the higher flow recommendations (Winter / Spring Fresh, Bankfull, Overbank).

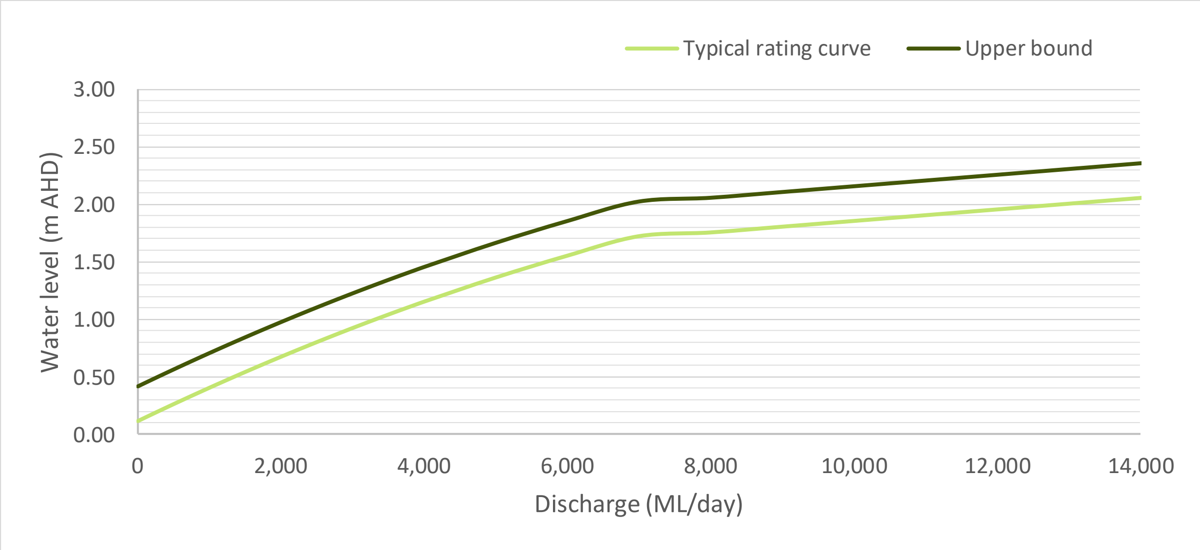

Figure 66. *Rating curves adopted as downstream boundary condition in Reach 5 models*

Note that the values shown above in the rating curves are discharge and water level values at the reach 5 representative site (Hec-Ras model). For reference, the equivalent water level values at the upstream extent of the hydrodynamic model and at Swing Bridge are provided for some flow rates below.

Table 58. Selected water levels used for Reach 5 hydraulic model (m AHD)

Model	Flow rate	Water level at Reach 5 representative site	Water level at upstream extent of Hydrodynamic model (Latrobe River)	Water level at Swing Bridge
Typical water level	1,000 ML/day	0.40	0.20	0.15
	2,000 ML/day	0.67	0.47	0.35
	3,000 ML/day	0.92	0.72	0.50
Upper bound	1,000 ML/day	0.70	0.50	0.46
	2,000 ML/day	0.97	0.77	0.69
	3,000 ML/day	1.22	1.02	0.90

1D hydrodynamic model for Latrobe estuary

The one-dimensional hydrodynamic model of the Latrobe estuary was developed by Water Technology 2013. The model was updated to reflect the following inputs:

- Daily data (disaggregated from REALM model) for natural (unimpacted) and current scenarios, time period: 1975 – 2017, for Latrobe River (Reach 5) and Thomson inflows
- Lake Wellington water level, historic gauge data (Bull Bay, 15-minute data)
- Evapotranspiration – class A pan evaporation for East Sale Airport. Pan factor of 0.65 adopted to align with monthly total evaporation from previous model inputs.

The layout of the 1D model is provided below (Figure 67). For a full model description, refer to Water Technology 2013.

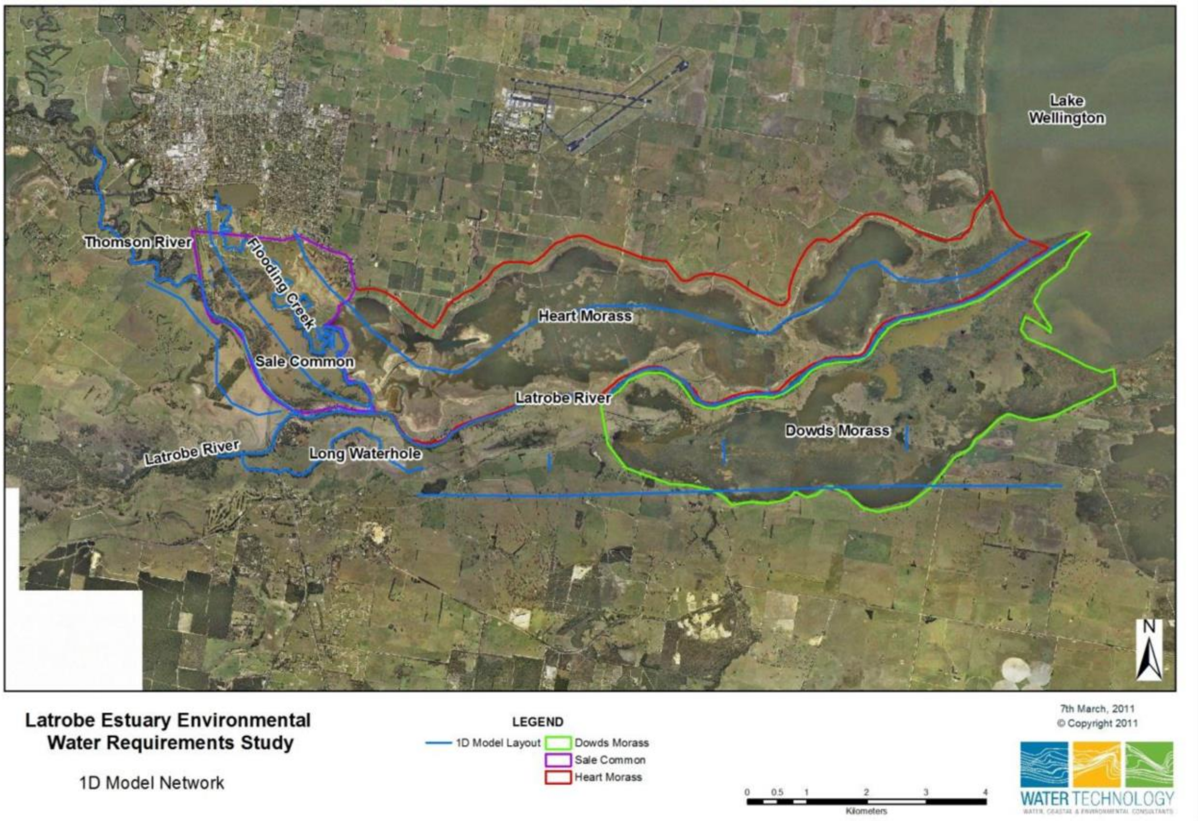

Figure 67. 1D model overview (Water Technology 2013)

3D hydrodynamic model for Latrobe estuary

A 3-D hydrodynamic model of the estuary was developed by Water Technology 2013 to understand the estuary tidal dynamics and salinity structure, and its sensitivity to variations in inflow discharges. This included testing low flow conditions and flushing flows.

A summary of the results from the 3D model used in this study are provided in Table 59.

Environmental flow response monitoring

Environmental flow response monitoring was undertaken from 2014 – 2016 (Water Technology 2017). This monitoring included salinity monitoring at multiple locations throughout the estuary and within the water column at each location. This monitoring work has provided additional information about the flows required to create freshwater conditions at different locations throughout the estuary and also the response time for the salt wedge to return after a flow event. For example, Figure 68 shows

The following is a summary provided in Water Technology 2017 about the environmental flow response monitoring outcomes.

Upper estuary

The salt wedge in the lower Latrobe and Thomson River system can be present in the upper estuary when flows are less than 930 ML/d for a prolonged (>4weeks) period. Flows greater than 930 ML/d would fully flush this zone.

Mid Estuary

For the mid-estuary from the confluence to the Swing Bridge site:

- Part Flushing Flows – flows greater than 1500 ML/d ensure flushing of saline water from the upper portion of the cross-section.
- Full Flushing Flows – flows greater than 2200 ML/d are required to completely flushed the salt wedge from the mid estuary. When flows reduce below this threshold the salt wedge can rapidly return to the mid estuary zone.

For the mid estuary downstream of the Swing Bridge site:

- Part Flushing Flows – flows greater than 2200 ML/d ensure flushing of saline water from the upper portion of the cross-section.
- Full Flushing Flows – flows greater than 2900 ML/d are required to completely flushed the salt wedge from the mid estuary. When flows reduce below this threshold the salt wedge can rapidly return to the mid estuary zone.

The response time of the salt wedge (i.e. the time it takes to reform and move upstream after a 'flushing' flow) showed a clear response to the duration of the high flow/flush event. The prolonged period of flows> 2000 ML/d suppressed and flushed the salt wedge from throughout the system. The duration of any flushing type flow event is critical in maintaining flushed or part-flushed conditions.

Lower Estuary

For the lower estuary:

- Part Flushing Flows – flows greater than 2200 ML/d ensure flushing of saline water from the upper portion of the cross-section. The upper portion of the cross-section in the lower estuary refers to the first 2-3m below the surface. Unless flows are significantly above this threshold or extend over a prolonged period the salt wedge can rapidly return once the flows reduce.
- Full Flushing Flows – flows greater than 2900 ML/d are required to completely flushed the salt wedge from the mid estuary. When flows reduce below this threshold the salt wedge rapidly returns to the lower estuary zone. Flows greater than around 3500 ML/d to 4000 ML/d are required to provide maintain fully flushed conditions

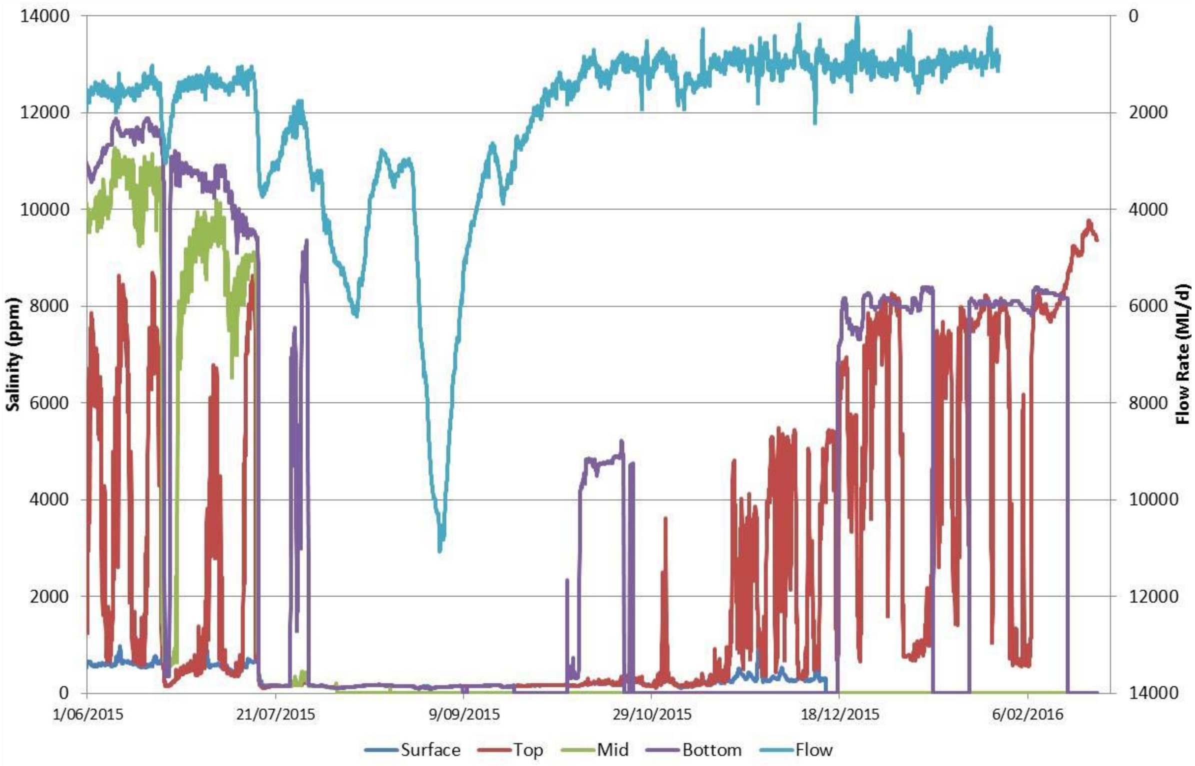

Figure 68. *Continuous salinity record for the Dowd regulator (Gauge 226250) and flow record at Swing Bridge (Gauge 226027) .*

Table 59. Flushing behaviour as reported in Water Technology (2013). NF = Not Flushed; UF = Upper Flushed; FF = Fully Flushed

Flow rate (ML/d)	Days	(2) McArdles Gap	(3) Upper Thomson Midway	(5) Swing Bridge	(6) Flooding Creek	(7) Central Heart Morass Structures	(8) Middle Estuary	(9) Dowd Morass/Eastern Heart Morass Inflows	(10) Parks Victoria Boat Ramp	(11) River Mouth
<250	60	NF	NF	NF	NF	NF	NF	NF	NF	NF
250[3]	3	UF (1m)	NF	NF	NF	NF	NF	NF	NF	NF
250[1]	4	FF	NF	NF	NF	NF	NF	NF	NF	NF
340	30 - 60	FF	NF	NF	NF	NF	NF	NF	NF	NF
430[1]	5	FF	UF (2m)	NF	NF	NF	NF	NF	NF	NF
600	30	FF		NF	NF	NF	NF	NF	NF	NF
930[1]	2	FF	FF	NF	NF	NF	NF	NF	NF	NF
1100	5 -20	FF	FF	UF (2.5m)	UF (2.5m)	NF	NF	NF	NF	NF
1100	30	FF	FF			NF	NF	NF	NF	NF
1500	4	FF	FF	FF		NF	NF	NF	NF	NF
1500	5 - 10	FF	FF	FF	FF	NF	NF	NF	NF	NF
2200	4	FF	FF	FF	FF	UF (2.5m)	NF	NF	NF	NF
2200	5	FF	FF	FF	FF		UF (2.5m)	NF	NF	NF
2900	3	FF	FF	FF	FF	FF	FF	NF	NF	NF
2900	5	FF	FF	FF	FF	FF	FF	UF (2.5m)	NF	NF
3200	4	FF	FF	FF	FF	FF	FF	FF	NF	NF
3900	5	FF	FF	FF	FF	FF	FF	FF	UF (2.5m)	NF
4100	5	FF	FF	FF	FF	FF	FF	FF	FF	NF
4100	6	FF	FF	FF	FF	FF	FF	FF	FF	UF (2m) /FF

[3] Flows in Thomson River only. All other flow rates refer to combined flow from Thomson and Latrobe Rivers at Swing Bridge (Water Technology 2013)

Water level calculations for Lower Latrobe Wetlands

The following tables provide additional information on the recommended water levels for each wetland watering component based on water level of reference EVCs present in each wetland.

Table 60. Water requirements for reference EVCs for Sale Common

Component	Reference level (m AHD)	Reference EVC (Frood et al 2015)	Recommended level (m AHD)
Wetting flow - Partial fill	0.2	Inundate **Tall Marsh** (EVC 821) / **Open water EVC** by 100 mm	0.3
Wetting flow – Fill	0.3 – 0.4	Inundate upper levels of **Swamp Scrub** (EVC 53) and **Bolboscheonus Tall Marsh** (EVC 821) to 100 mm depth	0.4 – 0.5
Flushing flow		Flushing flow	0.5
Drawdown 1	-0.1	Drying out of **seasonal mudflats** (EVC 990/810) 100mm over seasonal mudflats	-0.2
Drawdown 2	-0.1	**Seasonal mudflats** drawdown more than 200mm	-0.3

Table 61. Water requirements for reference EVCs for Heart Morass

Component	Reference level (m AHD)	Reference EVC (Frood et al 2015)	Recommended level (m AHD)
Wetting flow - Partial fill	-0.3	100 mm below seasonal mudflats	-0.3
	Brackish Wetland: 0 (central & western) 0.1 - 0.2 (eastern) Tall Marsh/Open Water: -0.4 Swamp Scrub: 0	200 mm over **Brackish Wetland** (EVC 656) and Inundation 300 mm over **Tall Marsh / Open water** EVC areas upper levels of **Swamp Scrub** (EVC 53) to 200 mm depth	0.2 (central & western) 0.3 (eastern)
Wetting flow – Fill	Floodplain Riparian Woodland: 0.4 - 0.6 Brackish Grassland: 0.4	100mm over (**Floodplain Riparian Woodland** EVC 56 and **Brackish Grassland** EVC934)	0.5
Flushing flow		Flushing flow	0.6
Drawdown 1	-0.3	Drying out of **seasonal mudflats** (EVC 990/810) – 100 mm below seasonal mudflats	-0.3

Table 62. Water requirements for reference EVCs for Dowd Morass

Component	Reference level (m AHD)	Reference EVC (Frood et al 2015)	Recommended level (m AHD)
Wetting flow – Partial fill 1	0.1	200 mm over **Brackish Wetland** (EVC 656) Inundate **Tall Marsh /Swamp Scrub** EVC areas for 100 mm	0.3
Wetting flow – Fill	0.5	Fringing vegetation and riparian zones (**Floodplain Riparian Woodland** EVC 56), 100mm over **Estuarine Scrub** (EVC 953)	0.6
Flushing flow		Flushing flow	1.0
Drawdown 1	0.1	**Swamp Scrub and Tall marsh** zones <100 mm. Expecting seasonal mudflats to partially dry out at natural rate	0
Drawdown 2		Expose wetland fringe and create shallows (less than 200 mm)	-0.1

Volume calculations for Lower Latrobe Wetlands

The following tables provide additional information on levels, volume to fill, average depth and surface area for each wetland watering component.

Table 63. Sale Common volume, surface area information

Component	Level (m AHD)	Volume to fill (above drawdown level of -0.3m AHD)	Average depth	Surface area (relative to fill area)	Inputs
Wetting flow - Partial fill 1	0.2	490 ML	0.35 m	85%	Volume to fill based on Water Technology 2011.
Wetting flow - Partial fill 2	0.3	690 ML	0.4 m	90%	Volume to fill based on Water Technology 2011.
Wetting flow – Fill 1	0.4	900 ML	0.5 m	95%	Volume to fill based on Water Technology 2011.
Wetting flow – Fill 2	0.5	1,130 ML	0.56 m	100%	Volume to fill based on Water Technology 2011.
Flushing flow	0.5	3,400 ML	0.56 m	-	Based on 3 times fill volume
Drawdown 1	-0.2	-	0.20 m	30%	No calculation required
Drawdown 2	-0.3	-	0.16 m	20%	No calculation required

Table 64. Sale Common volume information [Water Technology 2011]

	Sale Common	
Average Depth (m)	***Volume (ML)***	***Water Surface Elevation (m AHD)***
0.1	0.2	-0.8
0.2	298	-0.03
0.3	567	0.14
0.4	839	0.28
0.5	1123	0.41
0.6	1439	0.55
0.7	1776	0.69
0.8	2066	0.78
0.9	2334	0.86
1	2608	0.94
1.1	2886	1.03

Table 65. Heart Morass volume, surface area information

Component	Level (m AHD)	Volume to fill (above drawdown level)	Average depth	Surface area (relative to fill area)	Inputs
Wetting flow - Partial fill 1	-0.3	1,390 ML to fill, plus up to 3,349 ML/ year to maintain water level	0.21 m Central, Western 0.18 m Eastern	60%	Volume to fill based on Water Technology 2014. Maintain water level based on effective evaporation of 283 mm / year at Sale East Airport (875 evapotranspiration – 592 rainfall), multiplied by area at -0.3 m of 1,183 ha
Wetting flow - Partial fill 2	0.2 (central, western) 0.3 (eastern)	7,400 ML	0.56 m	90%	Volume to fill based on Water Technology 2014.
Wetting flow - Fill	0.5	12,150 ML	0.7 – 0.8 m	100%	Volume to fill based on volume to fill to 0.4 m AHD (Water Technology 2014) plus DEM analysis for 0.5 m – 0.4 m.
Flushing flow	0.6	28 – 42 GL	1.0 m	-	Two-three times volume to fill. 14 GL to fill to 0.6m (based on Water Technology 2014 plus LiDAR) Average depth from Water Technology 2009
Drawdown	-0.3	-	0.21 m Central, Western 0.18 m Eastern	60%	No calculation required

Table 66. Heart Morass volume information [Water Technology 2014]

	West Heart Morass		Central Heart Morass		East Heart Morass	
Water Surface Elevation (m AHD)	*Volume (ML)*	*Average Depth (m)*	*Volume (ML)*	*Average Depth (m)*	*Volume (ML)*	*Average Depth (m)*
-0.5	0	0	214	0.12	32	0.11
-0.4	274	0.15	336	0.16	248	0.14
-0.3	472	0.21	527	0.21	391	0.18
-0.2	782	0.23	803	0.28	591	0.24
-0.1	1690	0.31	1128	0.34	830	0.3
0	2656	0.39	1480	0.41	1109	0.37
0.1	3622	0.48	1847	0.48	1393	0.44
0.2	4531	0.56	2245	0.56	1698	0.5
0.3	5384	0.65	2673	0.64	2018	0.56
0.4	6151	0.72	3059	0.71	2436	0.61

Table 67. Dowd Morass volume, surface area information

Component	Level (m AHD)	Volume to fill (above drawdown level)	Average depth	Surface area (relative to fill area)	Inputs
Wetting flow - Partial fill	0.3	2,990 ML	0.3 – 0.4 m	80%	Volume to fill based on Water Technology 2014.
Wetting flow - Fill	0.6	5,360 ML	0.4 – 0.5 m	100%	Volume to fill extrapolated based on Water Technology 2014.
Flushing flow	1.0	22 – 33 GL	> 0.5m (limited information)	-	Two-three times volume to fill. 11 GL to fill to 1m AHD (based on Water Technology 2014 plus LiDAR)
Drawdown 1	0	-	0.2 – 0.4 m	60-70%	No calculation required
Drawdown 2	-0.1	-	0.2 – 0.4 m	< 50%	No calculation required

Table 68. Dowd Morass volume information [Water Technology 2014]

Water Surface Elevation (m AHD)	**West Dowd Morass**		**North Dowd Morass**		**East Dowd Morass**	
	Volume (ML)	*Average Depth (m)*	*Volume (ML)*	*Average Depth (m)*	*Volume (ML)*	*Average Depth (m)*
-0.3	0	0	98	0.13	92	0.16
-0.2	0	0	614	0.4	189	0.19
-0.1	34	0.18	696	0.41	330	0.23
0	54	0.22	778	0.42	509	0.28
0.1	74	0.26	859	0.43	700	0.34
0.2	94	0.3	941	0.44	918	0.41
0.3	141	0.3	1337	0.44	1507	0.34
0.4	297	0.34	1706	0.43	1924	0.35
0.5	441	0.41	2146	0.43	2588	0.36

Appendix G: Sea level rise sensitivity analysis

Model configuration and scenarios

The model configuration used in the 2013 analysis has been adopted for this study (Water Technology, 2013). Each of the flow recommendation magnitudes for freshes and baseflows were testes, with sea level rise increases of 0.1 m and 0.27 m applied to the downstream tidal boundary. Therefore, there were 8 scenarios:

- 1,100 ML/day; 0.1 m SLR
- 2,200 ML/day; 0.1 m SLR
- 3,200 ML/day; 0.1 m SLR
- 4,500 ML/day; 0.1 m SLR
- 1,100 ML/day; 0.27 m SLR
- 2,200 ML/day; 0.27 m SLR
- 3,200 ML/day; 0.27 m SLR
- 4,500 ML/day; 0.27 m SLR

The model boundaries from the previous assessment (Water Technology, 2013) were used in the analysis:

- Lake Wellington Salinity - BullBay_Salinity_Jun10-Jan11
- Lake Wellington Water Level - BullBay_WL_Jun10-Jan11_SLR_BND

Water level data was increased by 0.1 and 0.27 m for each of the SLR scenarios. These scenarios were selected to align with the Dowd Morass Salinity assessment (Hale et al 2018):

- From recent scaled-down climate change models for Victoria's south east region there is very high confidence that mean sea level is likely to increase by 2050 by 0.1 – 0.27 m over present levels (Timbal et al. 2016).
- 0.1 m is considered a conservative estimate, based on substantial reductions in global CO2 emissions, while 0.27 m is based on only a small reduction in global CO2 emissions.

The model results were assessed in the same way as the original hydrodynamic model scenario: the upper and lower parts of the water column was were categorised as Fully Flushed or Not Flushed. Flushed is considered as salinity of < 1ppt. Where the upper part of the water column is Fully Flushed and the lower part is Not flushed, the overall state is referred to as 'Upper Flushed'.

Results: Estuary flow recommendations

The model results for the sea level rise scenarios are summarised in Table 69. For the 0.1m sea level rise scenario, the modelled outcomes for the flow recommendations align with the no sea level rise outcomes. For the 0.27m sea level rise scenario, the same modelled outcomes are still achieved for Summer Autumn fresh 2 and Winter / Spring Fresh 1.

For Summer / Autumn Fresh 1, a longer duration than the flow recommendations to achieve fully flushed conditions throughout the middle estuary under 0.27m sea level rise conditions; the flow recommendations would still be expected to achieve fully flushed conditions for some of the Middle Estuary.

For Winter / Spring Fresh 2, the wet and dry year duration recommendations will still achieve fully flushed conditions throughout the Lower Estuary under 0.27m sea level rise conditions; however, given the longer duration required to flush the estuary, the overall duration may not be sufficient to meet the objectives. The dry and drought year recommendations will only achieve upper flushed conditions in the Lower estuary and may not achieve the environmental objectives.

Table 69. Summary of Modelled outcomes for estuary flow recommendations under sea level rise scenarios

Flow component	Flow recommendation	Sea level rise scenario	Changes under SLR scenarios
Baseflow (all year)	1,100 ML/day (minimum duration 5 days)	0.1 m sea level rise	Same modelled outcomes achieved.
		0.27m sea level rise	Under the 0.27m SLR, a longer minimum duration is required (20 days); however, as this is a baseflow recommendation, the minimum duration does not need to be reconsidered.
Summer / Autumn Fresh 1	2,200 ML/day (minimum duration 5 days)	0.1 m sea level rise	The same outcomes are achieved for the Middle Estuary under the 0.1m SLR scenario. Lower Estuary not flushed, but no specific criteria for lower estuary for this flow component.
		0.27m sea level rise	A longer duration is required to achieve Upper Flushed in the Mid estuary – 22 days is required. The estuary recommendations will Fully Flush the estuary to model location 7 (Central heart Morass structures, but not Location 8 'Middle Estuary')
Summer / Autumn Fresh 2	3,200 ML/day (minimum duration 4 days)	0.1 m sea level rise	The same outcomes are achieved for the Middle Estuary and lower Estuary. This is achieved with a minimum duration of 3 days.
		0.27m sea level rise	The same outcomes are achieved for the Middle Estuary and Lower Estuary. This is achieved with a minimum duration of 4 days.
Winter / Spring Fresh 1	3,200 ML/day (minimum duration 4 days)	0.1 m sea level rise	The same outcomes are achieved for the Middle Estuary and lower Estuary. This is achieved with a minimum duration of 3 days.
		0.27m sea level rise	The same outcomes are achieved for the Middle Estuary and lower Estuary. This is achieved with a minimum duration of 4 days.
Winter / Spring Fresh 2	4,500 ML/day (minimum duration 6 days)	0.1 m sea level rise	The Fully Flushed conditions through the estuary (up to Location 11 - River Mouth) are achieved with a minimum duration of 4 days.
		0.27m sea level rise	Upper Flushed conditions through the estuary (up to Location 11 - River Mouth) are achieved with a minimum duration of 4 days. Fully Flushed conditions through the estuary to Location 10 (Boat Ramp), and Upper flushed at Location 11 (River Mouth) are achieved with a minimum duration of 18 days. The flow recommendations for average and wet years (25 days and 30 days respectively), will achieve the Fully Flushed conditions through the estuary. For Dry and Drought years (6 and 10 days respectively) the water column will only be 'Upper Flushed' in the Lower Estuary.

Results: Wetland infrastructure

The sea level rise results were also assessed to consider whether the changed conditions in the estuary will impact on the existing and proposed wetland infrastructure. There are two ways that sea level rise may impact on the ability to operate the wetland infrastructure:

1. Supply of freshwater to water the wetlands – this is covered in the results above
2. Ability to drain the wetlands for drawdown periods – this is discussed below.

The lowest drawdown recommendations for the wetlands are:

- Heart Morass: -0.3 m AHD
- Dowd Morass: -0.1m AHD

The outlet structures will also be used to flush the wetlands, this will occur under the following water levels:

- Heart Morass: 0.5-0.6 m AHD
- Dowd Morass: 0.6-1.0m AHD

The average water level results below show that under the sea level rise conditions, the average water levels at the outlet locations will increase. These increases in water level will make the drawdown of wetlands using outlet structures increasingly challenging. This means that the outlet gates will only be useful to some extent, with the remaining drawdown to be achieved with evaporation. For flushing the wetlands, this will typically be achievable to some extent for Heart Morass and Dowd morass under 0.1m sea level rise but will become difficult to achieve a head differential under 0.27m sea level rise, particularly for Heart Morass.

Table 70. Summary of water levels at outlets under sea level rise scenarios

Location	Sea level rise scenario	Average water level (baseflow of 1,100 ML/day) Drawdown reference	Average water level (4,500 ML/day) Flushing flows reference
Middle Estuary (Heart Morass and Dowd Morass outlets)	Current conditions	0.12 m AHD	0.25 m AHD
	0.1 m sea level rise	0.35 m AHD	0.38 m AHD
	0.27m sea level rise	0.53 m AHD	0.55 m AHD