MID-TERM REVIEW

Healthy Waterways Strategy 2018-2028
Port Phillip & Westernport, Victoria

Interventions

A Technical Report to inform the
Healthy Waterways Strategy Mid-term Review

This Technical Report has been developed for Melbourne Water as part of the Healthy Waterways Strategy Mid-term Review through a collective effort with many organisations and individuals. In particular, Melbourne Water thanks:

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Cite this report as:
Melbourne Water (2023), *Interventions: A Technical Report to inform The Healthy Waterways Strategy Mid-term Review*. Melbourne Water, Docklands, Victoria, Australia.

Front page image credit: Karen White

Contents

Glossary of terms and abbreviations

BAU	business as usual
eDNA	environmental DNA
EPA	Environment Protection Authority
GED	general environment duty
GPT	gross pollutant trap
HSM	habitat suitability model
HWS	Healthy Waterways Strategy 2018
KEQ	key evaluation question
LWD	large woody debris
MERI	Monitoring Evaluation Reporting and Improvement
MW	Melbourne Water
MWRPP	Melbourne Waterway Research Practice Partnership
OPLE	Officer for the Protection of the Local Environment
ROMP	restoration outcomes monitoring protocol
SQRAT	sewage quality risk assessment toolbox
Strategy	refers in this instance as the Healthy Waterways Strategy 2018
WSUD	water sensitive urban design

Acknowledgement of Traditional Owners

The rivers, wetlands and estuaries of the Port Phillip and Westernport region are part of Country belonging to the Bunurong, Gunaikurnai, Taungurung, Wadawurrung and Wurundjeri Woi-wurrung peoples. These Traditional Owners have lived in and been connected to the land, water, plants and animals of this area for many thousands of years, and we offer our respect to their Elders past and present.

1. Introduction

The Healthy Waterways Strategy 2018-2028 establishes a region-wide plan to protect and improve the health of rivers, wetlands and estuaries across the Port Phillip and Westernport catchment. The Strategy considers the health of waterways using a framework of *waterway values* and *waterway conditions*. Ten-year sub-catchment and regional *Performance Objectives* were established to guide on-ground actions, initiatives and collaborations that progress towards the 50 year long-term targets.

This report is one of several background reports informing the Healthy Waterways Strategy (HWS) mid-term review Science Inquiry. It presents an evaluation of a selection of interventions used as part of HWS implementation.

The evaluation has focused on one key evaluation question (KEQs) and a sub-KEQ:

- KEQ - To what extent have the delivery methods of the Strategy been appropriate, effective, and efficient?
    - 4a. To what extent are interventions appropriate and effective for achieving outcomes?

Some background and contextual information is presented in Table 1 relating to the HWS development and implementation to date along with an overview of how each of the KEQs are covered in this report.

Table 1. Summary of the mid-term evaluation KEQs and the extent to which they are represented in this report

KEQ	Sub-KEQ	Relevance to this report
1 – To what extent have the performance objectives of the Strategy been achieved?	1a. To what extent has collaboration and co-delivery contributed to achieving the Performance Objective targets so far?	Not in scope for this document An evaluation of collaboration and co-delivery is presented in the Implementation Inquiry (Melbourne Water, in prep).
	1b. To what extent is strategy delivery on track to achieve the Performance Objective targets by 2028?	Not in scope for this document This is addressed in the Implementation Inquiry (Melbourne Water, in prep).
3 – What is the state of waterway values?	3a. To what extent are key values on the target trajectory?	Not in scope for this document Information provided in the values technical reports and the Science Inquiry (Melbourne Water, 2023a)
	3b. What other spatial and temporal trends and patterns for key values are of significance for implementation?	Not in scope for this document Information provided in the values technical reports and the Science Inquiry (Melbourne Water, 2023a)
2 – To what extent has progress been made towards the longer-term	2a. What environmental conditions (e.g. Water quality) and external conditions (e.g. policy) help explain current key value trends?	Not in scope for this document Information provided in the values technical reports and the Science Inquiry

KEQ	Sub-KEQ	Relevance to this report
environmental condition targets for rivers, wetlands and estuaries?	2b. To what extent have projected known and emerging future threats changed from 2018? Have any assumptions about impacts to key values changed?	Not in scope for this document Evaluation of threats is provided in the Threats technical report (Melbourne Water 2023b)
4 -To what extent have the delivery methods of the Strategy been appropriate, effective, and efficient?	4a. To what extent are interventions appropriate and effective for achieving outcomes?	An intervention stocktake is provided in this document and evaluates the effectiveness and appropriateness of the different evaluation techniques used in the region.
	4b. What are the key remaining knowledge gaps that need to be addressed in the next 5 years to improve strategy delivery or prepare for the next HWS?	Section 4 provides a summary of knowledge gaps research relating to interventions. Identification of remaining knowledge gaps is outlined in the Science Inquiry (Melbourne Water, 2023a)
	4c. How can collaborative governance enable effective and efficient delivery of the Strategy?	Not in scope for this document This will be answered through the implementation Inquiry (Melbourne Water, in prep).

2. Overview of management interventions

Background

Various definitions exist for the term intervention across the literature but many typically highlight that interventions are context-specific, covering private and public actions, policy, or project-based activities. The Merriam-Webster online dictionary defines intervention as:
“the act of interfering with the outcome or course especially of a condition or process (as to prevent harm or improve functioning)” (Merriam-Webster, 2018).

In the context of this HWS mid-term review, an intervention is defined as:
“an action taken to protect or improve the condition (e.g. vegetation extent) or reduce a threat to an asset (e.g. river) to support a key value.”

HWS interventions are typically undertaken in the effort to ultimately support a key value (e.g. platypus) to meet the expectations of stakeholders and the community to achieve the targets outlined in the HWS. While there are a wide variety of interventions currently used, they typically fall into two categories;

1. On ground – for example physical or structural actions such as revegetation, weed management
2. Administrative – for example statutory functions, projects, planning and policy

Interventions have been included in the HWS mid-term evaluation to understand:

1. If interventions are effective
2. If investment is being spent on the right interventions
3. If certain interventions are more appropriate in certain locations than others

This section includes a high level summary of the different interventions which are used to implement the HWS.

Program logic & conceptual models

A program logic is a planning, implementation, monitoring and evaluation tool. It depicts how actions are expected to lead to the desired outcomes. The HWS program logic is based on the concept that many of the values (environmental, economic, cultural and social) provided by waterways rely on the environmental and social conditions of waterways. When a condition is degraded, some of these values may be diminished or lost (DEPI 2013). Maintaining or improving social and environmental conditions of waterways forms the focus of management activities and interventions to support waterway values.

The program logic for the HWS describes how management actions and outputs will be delivered by agencies over the life of the strategy to achieve particular outcomes (i.e. targets) for waterway condition and ultimately, values. Over time, these outputs and outcomes (targets) will collectively contribute to meeting the goals and ultimately the vision.

The overarching program logic for the HWS is displayed in Figure 1 to demonstrate the anticipated cause-and-effect relationships. Interventions typically sit with performance objectives in the program logic because they are one of the mechanisms used to improve the environmental conditions that support the key values. Some interventions do directly support key values, such as translocating a population of frogs or fish but most tend to support values indirectly.

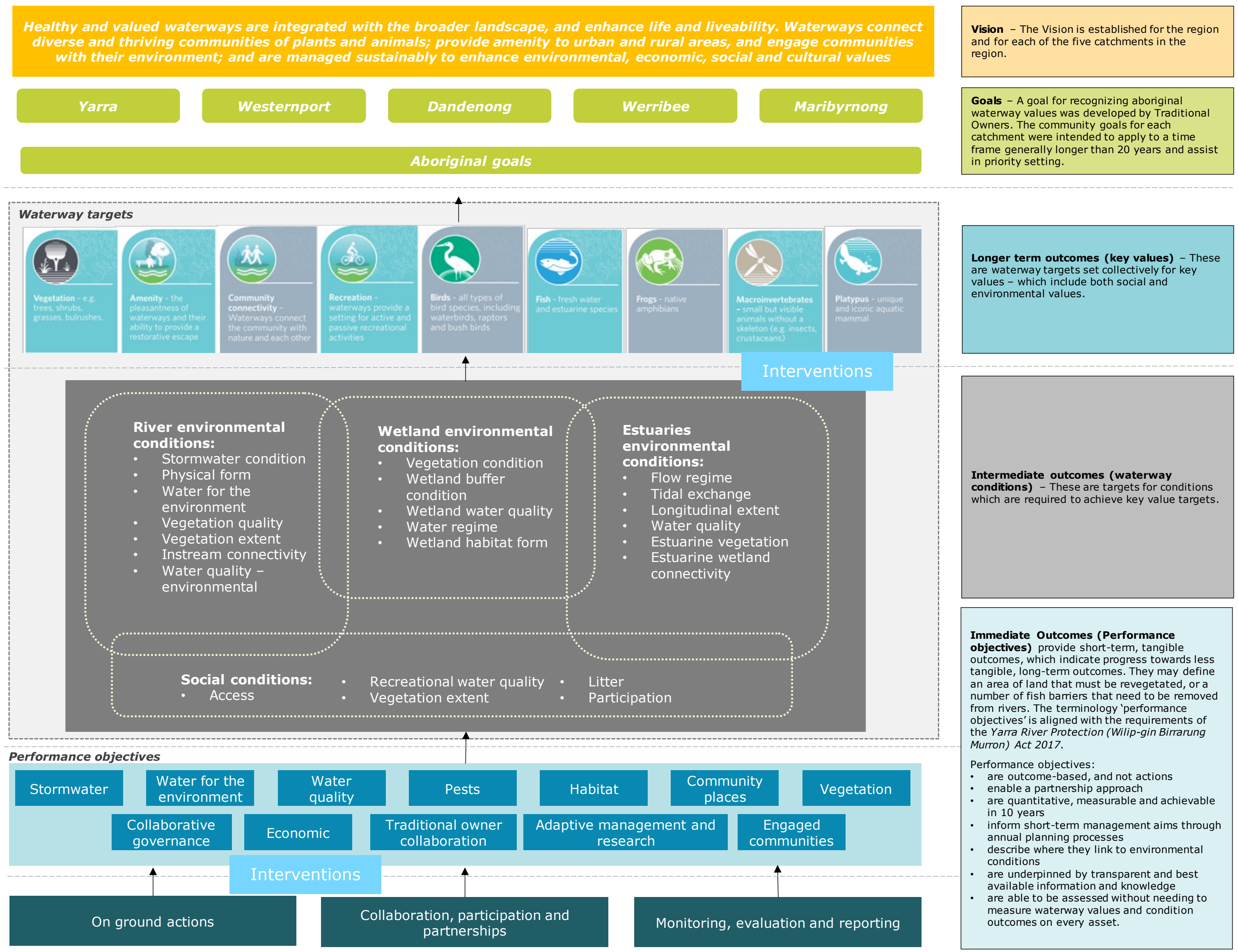


Figure 1. Adaption of HWS program logic to show where interventions typically sit (adapted from Melbourne Water 2019)

The way in which interventions for the HWS are anticipated to support key values is depicted in conceptual models in the form of management levers (Figure 2). The management levers are linked to particular environmental or social conditions that support the value, with some conditions having a stronger relationship than others. Although conceptual model database (Alluvium 2017) details the evidence of the relationships between conditions and values, a HWS targets tool (Alluvium 2018) only outlines the relevant management levers for key values. Note that the foundation activities management lever often included administrative or non-structural interventions.

The HWS did not outline the various interventions that make up the management levers as the strategy focused on prioritising what needed to be done to improve conditions and values through the 10 year performance objectives, not how it could be done. This was a deliberate approach to provide flexibility for Melbourne Water and the HWS partners to determine the most suitable interventions for different locations and conditions during implementation and to apply research outcomes from programs to maximise adaptive management. The catchment programs included some examples of actions required to achieve outcomes based on discussions at the co-design forums. As such these should not be considered the full suite of actions required to deliver the HWS.

The Habitat Suitability Models (HSMs) were used in the development of the HWS to test a sample of management levers that would be most effective for achieving conditions and key values targets for platypus, fish and vegetation.

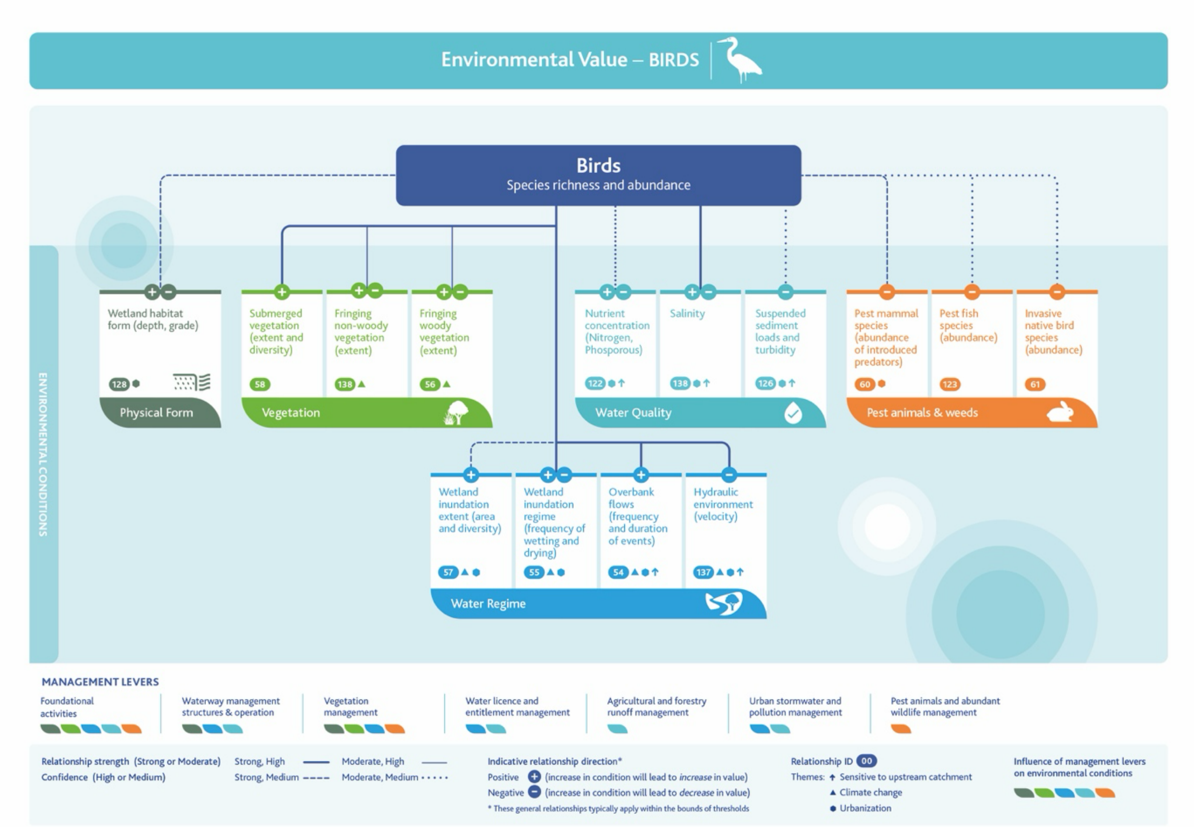


Figure 2. Example of Bird conceptual model with management levers shown.

Summary of HWS management interventions

A list of interventions currently in use for the HWS has been developed based on discussions with Melbourne Water staff and through the Melbourne Waterways Research Partnership.

The list has been organised via the management lever category to create a link to the conceptual models (Table 2). A total of 8 management levers have given rise to 18 intervention groups and 81 techniques.

Table 2. List of interventions currently used in implementing the HWS

Conceptual model mgmt lever	Intervention group	Intervention technique
Vegetation management	Vegetation establishment and maintenance	Tube stock Direct seeding Reprofiling Thinning Burning Fencing
	Weed control	Physical Chemical Alternative chemical Thermal Biological
Pest animal and abundant wildlife management	Pest animal control	Lethal Baiting Fencing Biological Ripping & fumigation Noise
Urban stormwater and pollution management	Stormwater infiltrate	Streetscape WSUD - raingardens, passively watered street trees, swales) Lot scale - raingardens, leaky rainwater tanks, green roofs Regional - constructed wetlands
	Stormwater harvest	same as above but with harvesting objectives
	Industrial pollution management	Lot and streetscape swales and raingardens Property containment measures Precinct toxicant traps Stormwater treatment wetlands Diversion to sewer
	Litter management	Street sweeping Gross pollution traps Floating litter traps Litter vacuum General litter management
	Sediment control	Primary treatment Secondary treatment Tertiary treatment Desilting
	Wastewater management	Wastewater treatment plants Septics Sewerage network management
Waterway management structures and operation	Instream barrier management	Barrier removal Fishways Barrier operation change
	Channel modification	Bank protection Grade control Large Woody Debris reintroduction / fish hotels

Conceptual model mgmt lever	Intervention group	Intervention technique
		Daylighting / naturalisation Artificial estuary opening
Water license and entitlement management	Instream flow management	Environmental Flow release Metering
	Floodplain / wetland flow management	Pumping Levee removal Structure (weirs & pipes)
Agriculture and runoff management	Rural land management	Fencing (multi-purpose) Riparian buffer /swales Off-stream stock watering Farm Track management Gully erosion control Farm dam management Fertilizer and effluent management Shade and shelter belts Feedpad
	Forestry runoff management	Road silt management Buffer strips Temporary drainage crossing points
Community facilities	Access management	New paths New canoe platforms Improving existing access New open space Visitor facilities Signage
Foundational	Administrative	Policy Strategy Guidelines Compliance & enforcement Licencing Education
	Other	Translocation of species

Not all these interventions are used regularly or broadly across the region, and some are in the early adoption phase as part of a research program. Further information about the intervention techniques is outlined in Section 3.

Another perspective on intervention application for the HWS is by linking HWS performance objectives to the intervention group and the threats they are aiming to manage (Table 3). This exercise highlights how several intervention groups are applied within a performance objective theme and how many intervention groups span across multiple performance objective themes. It also identifies the threats the interventions are aiming to manage, further information about threats is outlined in the Threats Technical Report (Melbourne Water, 2023b).

This information provides a useful library reference for the Science Inquiry.

Table 3. HWS interventions linked to performance objectives and threats (R = Rivers, E = Estuaries, W = Wetlands). Note that all PO themes also include Administrative interventions.

Performance Objective Group	Performance Objective Theme	R	E	W	Intervention group	Threats intervention group aims to manage
Community	Increase access to and along waterways, wetlands and estuaries by filling gaps and improving connections to existing path networks.	✓	✓	✓	Access management	
	Increase participation rates around rivers, wetlands and estuaries	✓	✓	✓	Access management	All
Water for environment	Increase environmental water reserve in regulated systems	✓	✓	✓	Instream flow management	Water availability Climate change
	Maintain or improve flow regimes in unregulated systems	✓	✓	✓	Instream flow management Floodplain / wetland flow management	Water availability Climate change
	Water for the Environment continues to be managed and delivered to the region's rivers and wetlands and recovery options continue to be investigated.	✓	✓	✓	Instream flow management Floodplain /wetland flow management	Water availability Climate change
Habitat	Mitigate threats to physical form	✓	✓	✓	Channel modification Vegetation establishment Instream flow management Stormwater infiltrate / harvest	Physical modification
	Improve / increase connectivity for fish passage	✓	✓		Instream barrier management Instream flow management	Barriers Climate change
	Protect specific values and habitat (seasonal herbaceous wetlands, frogs)	✓	✓	✓	Pest animal control Weed control Litter management Vegetation establishment Other (translocation of species)	Pests Weeds Litter Vegetation clearance Climate change
	Re-engage floodplains	✓	✓	✓	Physical modification Floodplain / wetland flow management	Physical modification Climate change
Stormwater	Build stormwater systems to treat new development (harvest & infiltrate)	✓			Stormwater infiltrate Stormwater harvest	Urbanisation (flow and water quality impacts) Climate change
	Treat existing development	✓		✓	Stormwater infiltrate	Urbanisation (flow and water quality impacts)
	Maintain stormwater treatment systems	✓		✓	Weed control Sediment management Litter management	Urbanisation (flow and water quality impacts)

Vegetation	Protect high quality vegetation	✓	✓	✓	Vegetation establishment Weed Control Pest animal control	Vegetation clearing Weeds & Pests Climate change Recreational access
	Increase Vegetation extent	✓	✓		Vegetation establishment Weed Control Pest animal control	Weeds Pests
	Improve or increase wetland buffer			✓	Vegetation establishment Weed Control Pest animal control	Vegetation clearing Weeds Pests
	Maintain or improve vegetation quality	✓	✓	✓	Vegetation establishment Weed control Pest animal control	Vegetation clearing Weeds & Pests Climate change
Water Quality	Improve water quality from agricultural land practices	✓	✓	✓	Rural land management	Agriculture
	Maintain / protect water quality for social values	✓	✓		Litter management Stormwater harvest /infiltrate Rural land management Forestry runoff management	Litter Urbanisation (flow and water quality impacts) Agriculture Forestry
	Maintain or improve quality of Sewerage Treatment Plant discharges	✓			Wastewater management	Wastewater
	Mitigate impacts from septics	✓			Wastewater management	Wastewater Urbanisation (water quality impacts)
	Mitigate impacts from Industrial land uses	✓			Industrial pollution management	Urbanisation (water quality impacts)
	Reduce sedimentation from run-off associated with construction for urban development	✓	✓		Sediment control Stormwater infiltrate / harvest	Urbanisation (water quality impacts) Climate change
	Open estuary mouth if environmental risk is low		✓		Channel modification	Physical modification

Key evaluation questions

Key evaluation questions (KEQs) are used as the basis of framing analysis and judgements about the performance of the Strategy. KEQs were developed in the HWS MERI framework (Melbourne Water, 2019) and the overarching KEQ for this paper is:

4. *To what extent have the delivery methods of the Strategy been appropriate, effective, and efficient?*

While the KEQs provide a high-level focus for evaluation, the sub-question helps to guide the evaluation for each strategy outcome. The sub-KEQs that will guide the evaluation of interventions is:

4a. To what extent are interventions appropriate and effective for achieving outcomes?

The following definitions are provided to clarify how certain terms will be applied in the evaluation.

- **Appropriateness** - The degree to which the design and implementation of interventions meets the needs of HWS partners and the broader community they serve (e.g. how appropriate is to use deer control methods in peri-urban areas?)
- **Effectiveness** – Achievement of interventions in supporting condition and value objectives.(e.g. how effective is the weed control method in reducing or removing weeds?).
- **Efficiency** – The extent to which the Strategy can demonstrate improvements over time including value for money.
- **Outcomes** – Impact of intervention (i.e. change in condition status)(e.g. the outcome of weed removal was increase in survival of planted seedlings)
- **Intervention maturity -** the length of time and extent to which an intervention has been applied in the HWS region to allow learnings for improvements to be made (e.g. interventions that have been extensively applied across the region for more than 10 years are considered as having high maturity).

Structure of report

This report is structured as outlined below.

Section title	Description
Overview	Describes the different elements of the stocktake and outlines the standards used to evaluate a range of criterion for the interventions.
Audit of HWS interventions	Summarises key aspects about the HWS interventions currently used, highlights key learnings from research and monitoring programs and evaluates the effectiveness and appropriateness of the technique for implementation.
Synopsis of stocktake	Summarises the key findings of the stocktake and outlines key knowledge gaps about interventions.
Recommendations	Recommendations to improve how interventions are used to implement the HWS

3. Evaluation approach

Overview

The purpose of the intervention stocktake is to synthesize information about interventions currently used in HWS implementation to develop a shared understanding about:

- what is being applied and why
- how common the intervention is and what different techniques are being used
- the learnings from any related research or monitoring programs in the region
- the level of effectiveness and appropriateness for using the intervention in the region

This will provide important information for the science synthesis which focuses on how interventions may need to be altered, removed or increased to improve implementation of the HWS for key areas of interest (e.g. where the trajectory of key values or condition trajectory are of concern).

The intervention stocktake acts as a foundational piece for the mid-term review as it will:

- Link interventions to management levers and Performance Objectives
- Improve conceptual models
- Identify which intervention techniques are better to use and under what circumstances
- Highlights interventions that need more research / monitoring

The key components of the stocktake are outlined in Figure 3 and represent a high level summary of information from a range of sources.

Stocktake Component	Description
General information	Summary of values and conditions each intervention group is seeking to improve and which assets it is applied to.
Application of use	Collation of information about who uses intervention, how broadly it is used in the region, the different techniques used and their maturity and any current barriers to use or important maintenance requirements.
Potential outcomes	List of the potential beneficial and adverse outcomes for the intervention group
Learning	List of recent and relevant local research / monitoring programs for each intervention and any lessons learned
Effectiveness & appropriateness	Evaluation of the level of effectiveness and appropriateness of the different intervention techniques and the potential to use a technique more broadly than it is currently used.

Figure 3. Components of the intervention stocktake

The intervention stocktake is organised by management lever and then intervention group to help the reader navigate to the intervention of interest. Note that as the foundation management lever underpins all the other management levers, each intervention group also includes a section on the relevant administrative interventions.

Conceptual model management lever	Intervention group
Vegetation management	Vegetation establishment & maintenance
	Weed control
Pest animal and abundant wildlife management	Pest animal control
Urban stormwater and pollution management	Stormwater infiltrate
	Stormwater harvest
	Industrial pollution management
	Litter management
	Sediment control
	Wastewater management
Waterway management structures and operation	Instream barrier management
	Physical modification
Water license and entitlement management	Instream flow management
	Floodplain / wetland flow management
Agriculture and runoff management	Rural land management
	Forestry runoff management
Community facilities	Access management
Foundational	Administrative
	Translocation

Several different standards have been developed to guide the synthesis of information and evaluation of intervention techniques (Table 4). The standards were developed in consultation with the Waterways & Biodiversity and Applied Research team and represent the performance categories of low, medium, high, and unable to assess for the following criterion:

- Maturity of intervention use in region
- Level of effectiveness (effectiveness in meeting the objectives for HWS)
- Level of appropriateness (appropriateness for application in waterways in the region)

Over 120 technical reports and published papers were reviewed to inform the stocktake, drawing on 20 years of research and monitoring undertaken through the Melbourne Water Research Practice Partnerships and other relevant research programs undertaken in the region. This was supplemented with published papers from other parts of Australia or overseas for certain interventions where research and monitoring in the region was limited.

Limitations

There have been several limitations to the intervention stocktake including:

- The stocktake represents a high- level assessment and evaluation of the effectiveness and appropriateness of different intervention techniques used in the HWS region. It does not represent an in-depth literature review.
- The assessment was limited by the information and research provided from Melbourne Water staff. In some cases, information was sourced from grey literature which is not subjected to the same level as peer review as published literature.
- There have been limited inputs to date from Melbourne Water staff and Research partnership staff due to time constraints, the intention is to continue to update the interventions report over time.

Table 4. Standards used to guide the synthesis and evaluation of information for some elements of the intervention stocktake.

Low	Moderate	High	Unable to Assess
Maturity of intervention			
Intervention has had limited use in the region by only being used as part of pilot or research studies over the past 10 years.	Intervention use has been gaining momentum over past 10 years	Intervention has been used regularly and broadly over a minimum of a 10 year period in the region	Uncertain about how the long intervention has been used for
Level of effectiveness			
No or limited evidence available that intervention is achieving intended objectives. AND/OR Studies shown intervention generally not providing successful outcomes	Intervention is showing some signs of achieving the intended objectives but results are not consistent. AND/OR Studies have shown a mixture of success from using intervention in other locations	Intervention has a signficant impact on achieving the intended objectives and provides benefits to other values AND/OR Studies have shown successful outcomes from using intervention in other locations	Timing of intervention is too short to assess against achieving objectives AND/OR Limited studies available of intervention used elsewhere
Level of appropriateness			
Evidence indicates that intervention has negative impacts for other key values when applied. AND/OR Application of intervention poses significant risks to the practioner that needs special permits and tailored H&S practices AND/OR Can only be used in very limited circumstances or conditions	Evidence indicates intervention can have some negative impacts for another key values under some circumstances. AND/OR Application of intervention poses moderate risks to the practioner that can be managed through standard H&S practices AND/OR Can be used under a specific range of circumstances or conditions.	Evidence indicates intervention can have some neglible known negative impacts for another key values. AND/OR Application of intervention poses minor risks to the practioner that can be managed through standard H&S practices AND/OR Can be used across a broad range of locations and conditions.	No potential information available about impacts to other values AND/OR Unclear about any limits to the application of the intervention

4. Intervention stocktake

This section provides a high- level summary of the intervention groups and techniques for each conceptual model management lever (herein referred to as management lever).

Vegetation management

There are two intervention groups within this management lever:

- Vegetation establishment & maintenance
- Weed control

The different techniques within each intervention group are often used in combination to improve environmental conditions at the same time as protecting against threats.

Vegetation establishment & maintenance

Vegetation establishment involves the planting of vegetation along the riparian zone of a waterway or along the edge of wetlands or estuaries and maintenance involves physically maintaining the plant. There are several different techniques of the intervention; tube stock, direct seeding, reprofiling, fencing, thinning and burning (Box 1).

Box 1. Outline of different vegetation establishment techniques

Tubestock refers to plants grown in cells to encourage a root system to develop prior to being planted out. Tubestock are typically used in revegetation programs along riparian zones in waterways and on the edges of wetlands.

Direct seeding involves sowing seed directly into prepared areas in the landscape. It is typically used for large scale revegetation activities.

Reprofiling is a technique used in wetlands and estuaries where the topography of the land is reprofiled to allow water ingress of depressions or channel to encourage natural colonisation of particular plant species such as saltmarsh.

Fencing of riparian zones or revegetated areas is a technique used to protect plants from grazing by rabbits, livestock and deer. Different fencing designs are required to protect plants from the different grazers.

Thinning involves removal of plants that have grown in high density to provide the space for others to grow or for recruitment to occur.

Burning of vegetation to encourage native vegetation regeneration and recruitment is a technique used by Traditional Owners for thousands of years. Cultural burns involve a ‘cool burn” to ensure that the canopy of overstory is retained and just the understorey and ground cover is burned.

The following information and references were used to compile information about the intervention and to support the assessment of the effectiveness and appropriateness of the different intervention techniques currently used in the region.

DELWP (2018). Riparian Intervention Monitoring Program factsheet update – improved riparian condition, https://www.ari.vic.gov.au/__data/assets/pdf_file/0013/334210/RIMP-update-fact-sheet-improved-riparian-condition.pdf accessed July 2023

DELWP (2021) Riparian Intervention Monitoring Program factsheet update 2021, https://www.ari.vic.gov.au/__data/assets/pdf_file/0030/529563/RIMP_fact-sheet_program-update-2021.pdf accessed July 2023

Ede, F. (2020). Direct seeding research project: Progress report 2019 Melbourne Waterway Research Practice Partnership Technical Report 20.5 The University of Melbourne.

Greening Australia (2003). A guide for establishing native vegetation regeneration in Victoria. Greening Australia, Victoria.

Jellinek, S. (2022). MERI Riparian Revegetation – Assessing Restoration Outcomes. A report for the mid-term review A2 projects. Melbourne Water, Australia.

Jellinek, S., Greet, J. & Chee, YE. (2021). A Review of the Works Monitoring Method: Effectively monitoring management interventions into the future. Melbourne Waterway Research-Practice Partnership Technical Report 21.1, Feb 2021.

Jellinek, S., Greet, J. & Chee, YE. (2022) Guidelines for undertaking the Restoration Outcomes Monitoring Protocol (ROMP). Melbourne Waterway Research-Practice Partnership Technical Report 22.1, February 2022.

Jellinek S., Tuck J., Te T. & Harrison P. A. (2020) Replanting agricultural landscapes: How well do plants survive after habitat restoration? Restoration Ecology 28, 1454-63.

Jellinek, S., O'Brien, T. and Bennett, A. (2020). Evaluating revegetation outcomes through community based monitoring. Arthur Rylah Institute for Environmental Research Technical Report Series No. 321. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

Jellinek S, Haslem A, O'Brien T, and Bennett AF (2021) Evaluating restoration outcomes: trial of a community based monitoring protocol. Ecological Management & Restoration 22:284-287

MWRPP (2022) Draft Research Project Summaries: MWRPP Project A2: MERI Riparian Revegetation – Assessing Restoration Outcomes

MWRPP (2022) Draft Research Project Summaries: MWRPP Project 4.6: Evaluating direct seeding as a cost-effective revegetation technique

MWRPP (2022) Draft Research Project Summaries: MWRPP Project D5: Modelling the risk of Key Revegetation Species to a Changing Climate

Water Technology (2015). Capital Works Sites Monitoring Program 2015. Linked PDF Summary Tool prepared for Melbourne Water.

Water Technology (2020). Capital Works Sites Conditions Monitoring – Spring 2019. Report prepared for Melbourne Water.

Water Technology (2022) Capital Works Monitoring Program Review – Final Report. Report prepared for Melbourne Water.

Vegetation establishment	
General Information	
Conceptual model management lever	Vegetation management
Intervention group	Vegetation establishment
Assets intervention group relates to	Rivers, wetlands and estuaries
Conditions intervention potentially supports	Vegetation quality, vegetation extent, physical form, wetland buffer condition
Key values intervention potentially supports	Platypus, fish, birds, macroinvertebrates, vegetation, amenity, recreation
Application of use	
Who is currently using the intervention group	Melbourne Water, Community Groups, Local government, Parks Victoria, Landholders
General use of intervention group in the region	Is used extensively across the region and is part of business as usual
On-ground intervention techniques	Tubestock, direct seeding and topography reprofiling
Relevant administrative interventions	Legislation: *Catchment and Land Protection Act 1994, Flora and Fauna Guarantee Act 1988, Water Act 1989, Environment Protection and Biodiversity Conservation Act 1999* Policy/Strategy: Victorian Waterway Management Strategy 2013, Protecting Victoria's Environment - Biodiversity 2037, Native Vegetation removal regulations 2017, Healthy Waterways Strategy 2018, Port Phillip and Westernport Regional Catchment Strategy 2023, Victorian Planning Provisions (Protection of Biodiversity, Native Vegetation Management, River and riparian corridors, waterways, lakes, wetlands and billabongs, Erosion & landslip, Open space, Yarra River and Waterways of the West). Guidelines: Guidelines for the removal, destruction or lopping of native vegetation 2017, A guide for establishing native vegetation in Victoria 2003
Maturity of techniques used in region	Tubestock: High tends to be default intervention type used and is readily available. Direct seeding: Low only used in specific locations where ground is flat so can be more difficult to use in riparian areas. Reprofiling: Low only used in specific locations at Western Treatment Plant. Fencing: High regularly used across the region to protect vegetation establishment in riparian area from grazing. Thinning: High regularly used across the region as part of vegetation maintenance (particularly from plantings from previous revegetation works) to thin dense plantings to encourage recruitment. Burning: Moderate although regularly used to reduce fire hazard in certain areas, the technique has been used intermittently in the region to encourage vegetation establishment. Cultural burns are growing in application in the region with a recent cultural burn in Coranderrk Station by Wurundjeri elders undertaken to manage weeds and encourage native regeneration.
Current application barriers	On-ground interventions Some of the main barriers to use are related to availability of getting appropriate species of tubestock or direct seeding, particularly in terms of climate adjusted seed. Finding suitable locations for certain techniques such as direct seeding or micro-landscaping and having suitable resources to install the technique

	are also barriers. The results of direct seeding in riparian areas have been variable in the past presenting a barrier to use but recent research has focused on better understanding the factors that influence these outcomes. The barriers to use of burning relate to the potential risks to nearby properties. <u>Administrative</u> Policy levers for deer control is constraining and this has limited vegetation establishment. Challenges with improving vegetation establishment and maintenance on crown land or private land.
Maintenance requirements	Some intervention techniques require protection in the form of fencing, mulch or guards to reduce impacts from grazing livestock, pest animals and weeding to reduce competition for resources for young native seedlings. Fencing requires regular maintenance to ensure integrity is maintained against potential grazers such as rabbits, livestock and deer.
Potential outcomes	
Potential beneficial outcomes	Habitat and resource provision for environmental and faunal values Aesthetics and shading for social values Improved conditions such as bank stability, water quality Improved resilience when increasing small and fragmented vegetation areas
Potential adverse outcomes	Clearing area for revegetation can promote weed growth in short-term Dense planting can lead to overshading Burning leaves soil temporarily exposed and at risk of erosion. Fencing as part of revegetation can restrict access to waterways Fencing near water edge can also trap litter and debris Potential impacts to cultural sites and sensitive species such as spiny crayfish Trees guards can become litter if they are displaced during high flows or windy conditions
Learning	
Relevant research project(s) or monitoring programs in region	Melbourne Water Capital works monitoring program (2011 -2022) MERI Riparian Revegetation Project using ROMP (2020-2022) Evaluating direct seeding as a cost-effective technique for riparian vegetation (2016 – 2021) Modelling the risk of climate change to key revegetation species (2017 – 2022) Monitoring saltmarsh colonisation of the Western Lagoon (2010 – 2019) Other relevant programs in Victoria Riparian Intervention Monitoring Program (2014 – 2021) Evaluating revegetation outcomes through community based monitoring (2018 – 2020)
Lessons learned in application	Lessons from Capital Works Monitoring Program: • The effectiveness of vegetation establishment interventions have been monitored at over 25 locations in the region as part of the Melbourne Water Capital Work Monitoring Program from 2008 to 2019 using the Index of Stream Condition and Works Monitoring Program methods. • The removal, or at least control, of stock grazing pressure on a frontage is vital in the restoration of a grazed rural frontages. • The 10 year progress of revegetation areas has shown trees can dominate if planted too densely. In the past there was a propensity to plant many canopy trees that ultimately outcompete shrubs. Maintaining good structure requires

	intervention to manage weeds and over dominant lifeforms (e.g. trees). • Natural recruitment could be considered to supplement revegetation is there is a residual seed bank or mature trees upstream to provide a seed source. • Hand weeding is recommended at sites where weed competition, soil moisture levels are a concern. Tube stock is preferable in areas with adverse conditions due to the taller plants demonstrating better survival rates. A diverse range of species can reduce risk of failure under variable conditions. Lessons from MERI Riparian Revegetation Project • Using the newly developed Restoration Outcomes Monitoring Protocol (ROMP), this project found that plant survival ranged from 72 – 91%, with two of the five catchments being below the expected 80% plant survival rate after 2 years. Plant survival rates were highest in the Dandenong and Westernport catchments and lowest in the Yarra and Werribee catchments. Aridity strongly influenced plant survival, with plantings in more arid catchments having lower survival. • Where the differences between older revegetated works areas and target habitats were assessed, it was found that works sites had lower native tree and shrub abundance, lower natural recruitment, and lower cover of native shrubs and groundcovers compared to target habitats. Works sites generally had higher weed cover scores and target habitats had a higher diversity of plant lifeforms. Changes have been recommended to revegetation practices based on these results. Lessons from modelling the risk of key revegetation species to a changing climate: • Modelling indicates that climate change will cause wetter and cooler areas in Melbourne to become more arid at a faster rate than currently arid areas, making these areas more vulnerable and in need of prioritized climate adaptation management. • When selecting species for revegetation, species with a broader distribution across climate gradients, such as *Eucalyptus camaldulensis*, should be preferenced over those with a narrower gradient, like *Pomaderris aspera.* • To ensure successful revegetation, it is recommended to source seeds from large, genetically diverse populations following the Florabank guidelines (Commander et al. 2021) and research suggesting large, outbred populations provide the best genetic basis for restoration (e.g., Frankham et al 2019; Pickup et al. 2012). • To achieve a broad genetic basis for successful restoration, an admixture protocol for seeds is suggested using 60% local, 30-35% from hotter and drier climates, and 5-10% from wetter and cooler climates. Climate-adjusted seed should also be collected from analogue locations that reflect predicted conditions for the next 10-30 and 50-70 years, based on quantitative genetic theory favouring a wider genetic basis for traits controlled by multiple genes. Lessons from direct seeding research: • Direct seeding is beneficial when the site is large, relatively flat and accessible. It has been found to be effective when the primary objective is to establish overstory. Weed competition

	is the biggest single limiting factor to successful direct seeding. • Woody weeds should be removed 1 -2 years prior to sowing, other weeds several months prior to sowing. Recent research indicates that the species used in vegetation establishment should consider future climatic conditions. Lessons from reprofiling of Western Lagoon: • Reprofiling and reshaping of the Western Lagoon at the Western Treatment Plant (along with other works) has resulted in the natural recolonisation of saltmarsh through the creation of hydraulic conditions beneficial for the ecological community. Saltmarsh revegetation has rarely been attempted in Australia and efforts have often involved planting of saltmarsh rather than natural recruitment. • The success of the Western Lagoon saltmarsh restoration has demonstrated that a natural recruitment process can be viable if the hydrological characteristics are suitable and saltmarsh is present nearby. If level of permanent inundation is too high, the establishment of saltmarsh is limited. Lessons from Riparian Intervention Monitoring Program: • On average, 3 years after intervention, there was a greater proportional increase in overall native vegetation cover (all strata combined) at intervention sites (~37% increase) than control sites (~14% increase). • Density of native woody recruits (planted and natural recruits combined) increased proportionally by over 1600%, while at control sites they decreased proportionally by ~6 • The stem density of native tree or woody shrubs (irrespective of age class) increased proportionally at intervention sites by over 600%, while at control sites they decreased proportionally by ~42%. • Although the results show that the management intervention improved vegetation condition, responses were variable among individual sites. Lessons learned from Evaluating revegetation outcomes through community based monitoring • The study found that overall survival of plants after the first summer was 61%, which is similar to other studies. • Two attributes, average annual rainfall and whether plants were protected by guards, were strong predictors of plant survival. • Individual species such as wattles (Acacia spp.) and gums (Eucalyptus spp.) were found to have the highest survival rates. It was thought this may be because these species are hardy, less palatable than some other species, and widespread in the state, enabling them to persist in a variety of different soil types and environments
Effectiveness and appropriateness	
Level of effectiveness of intervention technique	Tubestock: Moderate based on monitoring trials conducted at three waterways (Bass River, Emu Creek and Cardinia Creek) over 3 years by Melbourne Waterway Research Partnership and the 10 year works monitoring program of 30 sites. In other cases, tubestock has not been effective due to the smothering of plants by sediment during high flows in lower Yarra River. Level of effectiveness is reduced if complementary interventions (weed control, fencing) are not in place. Direct seeding: Moderate based on monitoring trials conducted at three waterways (Bass River, Emu Creek and Cardinia Creek) over

	3 years indicating that it can have mixed results in locations where conditions are less favourable for plants. Appears to be more effective for establishing overstory compared with mid-story. Reprofiling: High for saltmarsh if it provides the right level of inundation. Monitoring of Western Lagoon has demonstrated that the technique is very successful and is progressing towards a functioning ecosystem comparable to adjoining areas of remnant saltmarsh. Fencing: High providing the fence is designed appropriately for the grazing species seeking to be protected from. Capital works monitoring have demonstrated the effectiveness of stock fencing in protecting vegetation based on difference in vegetation height and density. Deer require a specially designed fence which is effective (see pest control) but stock fencing is less effective. Thinning: High particularly if timed appropriately to thin overstorey species as they grow to encourage understorey and recruitment. Burning: Moderate based on evidence relating to regeneration following bushfires in the region. No monitoring results were available at the time of writing regarding the effectiveness of cultural burns.
Level of appropriateness of intervention technique	Tubestock: High as can be used across a broad range of conditions including adverse conditions and has low H&S risks to its application. Direct Seeding: Moderate as trials have demonstrated successful outcomes when used in locations where there are areas of large, flat topography. Its application is limited along steep riparian corridors. Reprofiling: Moderate for saltmarsh as it would only be suitable under certain hydraulic conditions and the equipment needed for the works would poses moderate risks to the operator that could be managed. Fencing: High can be used across a broad range of landscapes and has low H&S risks to its application. Thinning: Moderate used in specific circumstances where overplanting of trees is limiting the development of understorey. Burning: Moderate due to the need for specific health and safety procedures and that the intervention can only used by in specific circumstances relating to location, weather and landscape setting.
Potential to use an intervention technique more broadly	There is the potential to use direct seeding more broadly as trials have demonstrated successful outcomes when used in appropriate locations.

Weed control

Weed control refers to the removal or reduction of weed species from riparian zones and wetland buffers. There are many different techniques used for weed control and these include; physical control, chemical treatment, alternative chemical treatment, thermal treatment, ringbarking and biological control (Box 2).

Box 2. Description of different weed control techniques

Physical control (also referred to as grooming) ranges from hand removal to mechanical options such as mowing, slashing, cultivation and tilling or machinery assisted removal and tends to be used. Ringbarking is another physical control technique used on mature woody weeds and involves removing an entire strip of bark around the circumference of the tree to induce death.

Chemical treatment using herbicides involves either spraying, injecting or cutting and painting the weeds with a particular chemical so that the weed dies.

Alternative chemical treatment uses biodegradable products such as acetic acid, pelargonic acid and manuka oil to kill weeds

Thermal treatment is a fairly new technique where steam or flame is used to kill or reduce the weed.

Biological controls include invertebrates, pathogens and livestock grazing to control specific weed species.

The following information and references were used to compile information about the intervention and to support the assessment of the effectiveness and appropriateness of the different intervention techniques currently used in the region.

Boyle, R., Odell, E., Pettigrove, V. & Myers, J. (2020), Melbourne Water Weed Control: A Review of Current and Alternative Approaches, Aquatic Environmental Stress Research Group, Technical Report No. 37, RMIT University, Victoria, Australia.

A3P (2022). Draft Research Project Summaries: A3P Project E2.4: What are the effects of chemicals frequently used by Melbourne Water on or near waterways on aquatic ecosystems and public health?

Water Technology (2015). Capital Works Sites Monitoring Program 2015. Linked PDF Summary Tool prepared for Melbourne Water.

Water Technology (2020). Capital Works Sites Conditions Monitoring – Spring 2019. Report prepared for Melbourne Water.

DELWP (2018). Riparian Intervention Monitoring Program factsheet update – improved riparian condition, https://www.ari.vic.gov.au/__data/assets/pdf_file/0013/334210/RIMP-update-fact-sheet-improved-riparian-condition.pdf accessed July 2023

DELWP (2021) Riparian Intervention Monitoring Program factsheet update 2021, https://www.ari.vic.gov.au/__data/assets/pdf_file/0030/529563/RIMP_fact-sheet_program-update-2021.pdf accessed July 2023

Weed control	
General Information	
Conceptual model management lever	Pest animals and weeds
Intervention group	Weed control
Assets intervention relates to	Rivers, estuaries and wetlands
Conditions intervention potentially supports	Vegetation quality, vegetation extent, physical form, wetland buffer condition
Key values intervention potentially supports	Vegetation, Fish, Birds, Macroinvertebrates, Amenity, Recreation
Application of use	
Who is currently using the intervention group	Melbourne Water, Local government, Parks Victoria, Community groups
General use of intervention in the region	Is extensively used by all HWS partners and is part of business as usual
On-ground intervention techniques	Physical control, chemical treatment, alternative chemical treatment, thermal treatment, biological control
Relevant administrative interventions	Legislation: *Catchment and Land Protection Act 1994, Flora and Fauna Guarantee Act 1988, Water Act 1989, Environment Protection and Biodiversity Conservation Act 1999* Policy/Strategy: Victorian Waterway Management Strategy 2013, Port Phillip and Westernport Regional Catchment Strategy 2023, Protecting Victoria's Environment - Biodiversity 2037, Invasive Plants and Policy Framework 2010, Victorian Planning Provisions (Protection of Biodiversity, River and riparian corridors, waterways, lakes, wetlands and billabongs, Open space). Guidelines: Advisory list of environmental weeds in Victoria 2022, Early evader manual 2019, Melbourne Water Pest, Plant, Animal and pathogen guidelines 2020.
Maturity of different techniques used	Physical control: High tends to be used for specific locations or weed varieties and used for maintenance of current and past revegetation works. Chemical treatment: High tends to be default for large areas or ones that are difficult to access and used for maintenance of current and past revegetation works.. Alternative chemical treatment: Low is used by a few councils as an alternative for chemical treatment in suburban areas. Thermal treatment: Low this has been trialled by Melbourne Water as part of research pilot. Biological weed control: Moderate is used for limited weed species or specific locations.
Current application barriers	On-ground interventions The barriers to use relate to the different intervention techniques. For example, some chemicals are not suitable for use near waterways, physical control is resource intensive and thermal treatment is only suitable in specific locations. Administrative Unknown

Maintenance requirements	Maintenance is an important component of weed reduction or removal programs. A key assumption in some rural program sis that landholders will 'take on' maintenance responsibilities after capital works or upfront funds for grants. The frequency of weed control intervention depends on the technique used. Thermal treatment requires more frequent application compared with many chemical treatments.
Potential outcomes	
Potential beneficial outcomes	Improves the extent, structure and diversity of native vegetation Enhances habitat for birds and fauna Improves access and amenity along waterway
Potential adverse outcomes	Removal of weeds may reduce habitat values and shading of waterways Removal of weeds may expose soils to erosion Chemical treatments can have toxicity levels that impact birds, macroinvertebrates, frogs and native vegetation
Learning	
Relevant research project(s) or monitoring programs in region	Melbourne Water Weed Control: A review of current and alternative approaches: A3P 2020 Desert ash control trials along waterways Capital Works Monitoring Program Dandenong Creek Goat Grazing Trial 2015 - 2018 Managing weeds in coastal saltmarshes in Western Port 2012 - 2016
Lessons learned in application	Lessons from Dandenong Goat Grazing Trial: • A trial was conducted in Dandenong Creek to assess the feasibility and effectiveness of using goats as an alternative to physical control and herbicides in an area of degraded riparian vegetation. • Both the goats and physical/herbicide treatments reduced weeds cover however the decline of weeds was more rapid in herbicide treated plots. • Goat grazing was found not to kill the weeds and increased the cover of exotic groundcovers. Heavy grazing on common reeds also led to increase in weed cover. Goats avoided some weeds, potentially because they were not so palatable. • The study concluded that goat grazing was only useful for weed control in areas with adequate fencing and high weed density or in areas inaccessible to machinery or equipment. Lessons from Desert ash Trials: • Desert ash is a weedy deciduous tree found in riparian zones. Very little published information was available regarding suitable control methods, so trials were conducted to determine the effectiveness of herbicides. • Glyphosate was the best performing herbicide with no healthy regrowth arsing from stumps at the end of trial, 35 months after treatment. Lessons from Capital works monitoring program: • Willows in particular, but also many other deciduous exotics, can completely shade out and outcompete native species and often leave the ground layer bare. High threat ground layer weeds, such as Kikuyu, Phalaris, Cocksfoot, Tradescantia and other creepers, can totally suppress existing native plants and recruitment. These high threat weeds need to be controlled prior to, and following, riparian intervention works to ensure ongoing positive outcomes. • Regular and consistent maintenance is required at sites where weed infestation is high

	Lessons from a review of current and alternative approaches: • Herbicides produce the most effective and reliable weed control outcomes but environmental and human health risks vary depending on the product used. • Physical control methods, such as slashing or hand weeding, may be useful as a pre - treatment to reduce the quantity or application volume of herbicides needed to control weeds. Similarly, modifying application volumes and regimes may yield equally effective results with overall less herbicide use or minimal loss to the environment. Lessons from Riparian Intervention Monitoring Program: • At a very small number of sites that included woody weed control, significant reinvasion or reshooting of exotic woody weeds had the potential to render the intervention unsuccessful if further intervention had not been undertaken. This highlights the importance of allocating adequate resources to allow post intervention monitoring and ongoing weed control. Lessons from managing weeds in coastal saltmarshes in Western Port: • Tall wheat grass is one of the more severe and widely distributed weeds of saline coastal wetlands in the region. The study assessed the effectiveness of different intervention techniques such as slashing and different chemical treatment using herbicides. • The herbicide Fluazifop-P was found to be ineffective in controlling tall wheat grass. • The broad spectrum herbicide glyphosate was effective but had undesirable impacts on native plant species and there are also growing health and safety concerns of the use of glyphosate.
Effectiveness and appropriateness	
Level of effectiveness of intervention technique	The level of effectiveness depends on the weed species and the technique applied. Physical control: Moderate overall when used for target weed species and can have mixed results depending on the application. Mowing and slashing are quick and effective where large areas of unwanted grasses, herbs or annual species are growing. Chemical treatment: High based on the 14 different herbicides assessed in the weed control review that found they were effective when used for the target weed species. Alternative chemical treatment: Moderate based on literature review indicating they are most effective on small annuals and broadleaf species but are less effective for the control of large established perennial species or grasses. Best used in combination with other weed control techniques. Thermal treatment: Low due to the need for follow up treatments required typically required every 6 weeks over long term for weed suppression. Steam weeding has been found to be least successful in natural areas. Biological weed control: Moderate depending on the agent used. Invertebrate herbivores (flea beetle and stem boring moth for alligator weed) and fungus (such as blackberry rust for blackberries) have been found to be effective for control of these weeds. The use of livestock grazing using goats has been trialled by Melbourne Water in Dandenong Creek and while weed cover was reduced, it was found that goats avoided some weeds due to proximity to water or were less palatable.

Level of appropriateness of intervention technique	The level of appropriateness depends on the weed species, the location and the technique applied. Physical control: Moderate as tilling and cultivation practices are generally not suitable near waterways due to the potential to lead to soil erosion and sediment input to waterways and damaging cultural heritage values. Mowing and slashing are suitable for large areas but can damage native vegetation and may not be suitable where sensitive non-target vegetation is interspersed among weeds (although this can be managed if undertaken by skilled operators). The high frequency of application required to achieve the level of weed control does have increased cost implications. Ringbarking is suitable for mature woody weeds and is particularly suited where machinery access is challenging or the removal of specific plants and when performed correctly, has minimal environmental or human health impacts. However, dead standing trees left in situ near public areas do pose safety risks if they were to fall. Chemical treatment: Moderate due to the low to moderate toxicity to aquatic organisms and birds and low to moderate potential human health impacts assuming the chemical is used as per label instructions. Herbicides typically require less frequent and low concentration application compared to other techniques. Alternative chemical treatment: Moderate due to the fact they are biodegradable and leave no residues, require application at high concentration (and often repeatedly) compared to herbicides and this can increase the cost. Thermal treatment: Low due to the limited extent of where the technique can be used (typically best on hard surfaces) and the significant health and safety requirements as well as costs to operate the machinery. Biological weed control: Moderate due to the potential risks for unintended consequences in introducing a biological control from another country and the high initial research cost. The high fencing cost for livestock grazing and the potential for impacts on native vegetation indicate that this would only be appropriate in certain situations.
Potential to use certain intervention technique more broadly	An integrated strategy combining intervention techniques may be required in the future to reduce reliance on herbicides due to public concerns of safety to human health and the environment.

Pest animal and abundant wildlife management

There is only one intervention group within this management lever, pest animal control.

Pest animal control

Pest animal control involves removing or reducing pest animals that pose a threat to the conditions and values of waterways. There are six techniques of the intervention used for HWS implementation; biological, removal, baiting, ripping, noise and exclusion fencing and these are mainly used where relevant for deer, foxes, rabbits and feral cats (Box 3). Many of these have legislation and strict controls of their use.

Box 3. Description of different pest animal control techniques

Biological control is mainly used for rabbits and uses RHDV1 (previously known as the rabbit calicivirus) to reduce rabbit populations

Lethal control typically involves on-ground shooting of the pest (such as foxes, rabbits and feral cats) or in the case of deer shooting, via helicopter in closed catchments.

Baiting involves the use of toxins to poison pest animals such as rabbits, foxes and feral cats and are used under strict conditions.

Ripping & fumigation uses mechanical machinery to rip apart rabbit warrens or foxes dens then followed by fumigation using carbon monoxide gas.

Noise involves using a variety of acoustic devices to create sound to disturb or scare away the pest.

Exclusion fencing involves constructing a fence around an area to exclude the pest such as rabbits, foxes, feral cats and deer. The fence typically has wire netting some of which is partly buried and in the case of deer, is 2m high.

Trapping involves the capture of the pest such as rabbits, foxes and feral cats in a cage or a leg hold trap.

The following information and references were used to compile information about the intervention and to support the assessment of the effectiveness and appropriateness of the different intervention techniques currently used in the region.

Bennett, A (2020). A Review of knowledge on the effectiveness of non-lethal deer impact mitigation strategies. Report to Melbourne Water. Waterway Ecosystem Research Group, The University of Melbourne.

Bennett, A, Fedrigo M., and Greet, J (2021) Are current deer control programs effectively reducing deer densities and impacts on native vegetation. Final Report June 2021. Report to the Department of Environment, Land, Water and Planning. Waterway Ecosystem Research Group, The University of Melbourne.

Centre for Invasive Species Solutions (n.d.) Pest Smart https://pestsmart.org.au/

Department of Jobs, Precincts and Regions (2018). Directions for the Use of 1080 and PAPP Pest Animal Bait Products in Victoria, Agriculture Victoria.

McKendrick, S., Greet, J and Ede, F. (2020) Deer Impacts on three year old revegetation following fence removal. Melbourne Waterway Research Practice Partnership Technical Report 20.11. The University of Melbourne.

Melbourne Waterways Research Partnership Practice (2022) Draft Research Project Summaries: MWRPP Project D2: Managing the impacts of deer on riparian vegetation and water quality.

Johnston, M (2020). Effectiveness of feral cat eradication on French Island 2010 – 2019. Report to the Port Phillip and Westernport Catchment Management Authority. https://www.researchgate.net/publication/341817556_Effectiveness_of_feral_cat_management_on_French_Island_2010-2019/

Pest animal control	
General Information	
Conceptual model management lever	Pest animal and abundant wildlife management
Intervention group	Pest animal control
Assets intervention group relates to	Rivers, wetlands and estuaries
Conditions intervention potentially supports	Vegetation quality, vegetation extent, wetland buffer condition
Key values intervention potentially supports	Birds, Vegetation
Application of use	
Who is currently using the intervention group	Melbourne Water, Parks Victoria, Local government, DEECA
General use of intervention group in the region	Is extensively used by HWS partners and is part of business as usual
On-ground intervention techniques	Biological control, lethal control, baiting, ripping, noise and exclusion fencing
Relevant administrative interventions	Legislation: *Wildlife Act 1975, Catchment and Land Protection Act 1994, Agricultural and Veterinary Chemicals (Control of Use) Act 1992, Prevention of Cruelty to Animals Act 1986, Environment Protection and Biodiversity Conservation Act 1999, Flora and Fauna Guarantee Act 1988* Policy/Strategy: Victorian Deer Control Strategy, Protecting Victoria's Environment Biodiversity 2037, Victorian Waterway Management Strategy 2013, Healthy Waterways Strategy 2018, Port Phillip and Westernport Regional Catchment Strategy 2023, Victorian Planning Provisions (Protection of Biodiversity, Protection of Agricultural land, River and riparian corridors, waterways, lakes, wetlands and billabongs).

	Plan: Peri-urban Deer Control Plan 2021–26 Guidelines: European rabbit management toolkit, European fox management toolkit, Melbourne Water 2021 Pest plant, animal and pathogen guideline.
Maturity of techniques used in region	Biological control: High in terms of rabbits with the calicivirus Lethal control: Moderate to High only used in specific locations, particularly aerial shooting. Baiting: High has been used extensively over many years for foxes, rabbits and feral cats and now comes with strict controls for use Ripping & fumigation: High tends to be default intervention type used for rabbits and fox dens and is used regularly by Parks Victoria Noise: Low only used in specific locations as part of trials Exclusion fencing: Low only used in specific locations Trapping: High has been used for many years with foxes, rabbits and feral cats although the type that can be used is strictly regulated.
Current application barriers	On-ground Some of the main barriers to use are related to potential impacts to other flora and fauna, health and safety issues in urban areas regarding lethal control and baiting, having sufficient resources over time to ensure the breadth and frequency of the pest control program is effective. Administrative Regulatory issues can limit the use of some techniques in some locations.
Maintenance requirements	Maintenance requirements are related to exclusion fencing to ensure the fencing remains secure and maintaining effort in implementing the intervention over time, depending on the objective.
Potential outcomes	
Potential beneficial outcomes	Improved survival rates for vegetation and birds Reduced competition for resources for other values Improved conditions such as soil stability and water quality
Potential adverse outcomes	Impacts on other animals such as dogs that consume baits Disturbance of other values during lethal control
Learning	
Relevant research project(s) or monitoring programs in region	Managing impacts of deer on riparian vegetation (2018 – 2022) Deer impacts on three year old revegetation following removal (2020)
Lessons learned in application	Lessons from impacts of deer program (summarised from Deer fact sheet): • Predictions from deer density/impact models highlight that water supply reservoirs and forest-agriculture interfaces should be priority areas for deer impact mitigation efforts. Deer and their impacts are most abundant in the vicinity of large waterbodies due the availability of lush forage and water, and they prefer locations with access to both open and forested habitats. • A review of scientific literature to assess the effectiveness of different deer impact mitigation strategies found that most non-lethal strategies are only effective over the short-term (weeks) and those that are effective, generally reduce impacts but do not mitigate them entirely. Exclusion fencing remains the most effective non-lethal method to prevent impacts by deer, but it is costly and thus usually limited to small and medium-sized projects. Lethal control using

	ground-shooting can effectively reduce deer densities and impacts only if sufficiently resourced. • An assessment of effectiveness of deer control programs at Yellingbo and Warramate Hills NCRs in reducing impacts to native vegetation found that these programs were not successful, there was no difference in deer abundance before and after the control program, and although there was evidence of a short-term effect of ground shooting, this was not maintained over time. • Surveys of fenced exclosures within the Yarra Ranges National Park clearly demonstrated the impact of deer on wet forest vegetation composition and structure. Impact to individual plants was dramatically reduced, particularly for tree ferns, inside exclosures. Comparisons between the partial and full exclosures indicate that deer are largely responsible for impacts on tree ferns, as well as the reduced cover of climbers, while both deer and native fauna contribute to impacts on understorey trees and shrubs. Combined, deer impacts reduce vegetation cover between 1–2 m by ~20% in the study area with likely adverse consequences for forest biodiversity and ecosystem function. • Surveys of 3 year old revegetation areas after fence removal found highly negative impacts on vegetation through broken stems and reduced biomass reducing plant growth and densities. Lessons from Melbourne Water capital works monitoring program: • Several revegetation sites are impacted by deer, limiting natural recruitment and damaging vegetation. The impacts have increased over the monitoring period. Lessons from the feral cat eradication from French island: • A total of 1115 cats were removed from French Island between 2010 and 2019. Capture success has been variable over the program (annual range 45 - 385) and is thought to be due to changing resource availability associated with environmental variables such as prey abundance as well as trapper effort and the number of traps available. • Female feral cats maintain smaller home ranges compared to males. 'Long distance' ranging by males appears to be common. • Capture success for feral cats using cage traps and a food lure in warmer months was reported to be very low likely due to the increased abundance of preferred food, i.e. wildlife.
Effectiveness and appropriateness	
Level of effectiveness of intervention technique	Biological control: High for rabbits Lethal control: Moderate for deer, rabbits and foxes as programs have had mixed results typically due to insufficient proportion of population being removed so population reductions are short term. Baiting: Moderate for foxes and rabbits as depends on time of the year and they are typically individuals who are bait shy so typically another intervention is used in conjunction. Ripping & fumigation: Moderate for rabbits as is most effective when numbers are already low or at a time when rabbits are not usually breeding Noise: Low for deer as trials and research have shown low effectiveness that reduces over time as animals become more accustomed to the noise. Exclusion fencing: High providing fences are constructed according to deer exclusion specifications (i.e. be a minimum of 2m high) and are regularly maintained and checked for incursions.

	Trapping: Moderate as programs have had mixed results typically due to insufficient proportion of population being removed so population reductions are short term.
Level of appropriateness of intervention technique	Biological control: Moderate due to potential impacts to other species Lethal control: Moderate due to only being suitable in certain locations where potential health and safety risks to community are low. Baiting: Low due to the potential impacts to other species or domestic animals that may consume the baits and that it should not be used within 20m (ground placement) – 100m (aerial placement) of permanent or flowing waterbodies. Ripping & fumigation: Low as is not suitable along river banks or steep slopes due to risk of soil erosion or bank instability. However, ripping can be a cost effective and long lasting solution when used in large scale operations in fields. Noise: Moderate due to potential disturbance to native animals. It is a technique that is low cost, easy to install and can be used over a range of conditions. Exclusion fencing: Moderate due to installation and maintenance costs. It is most appropriate for small to medium scale areas and as a temporary solution while plants become established. Trapping: Moderate as the potential for trapping native species needs to be carefully considered.
Combination of techniques	The effectiveness of all the individual techniques increases when they are used in combination and regularly applied.
Emerging techniques or the potential to use an intervention technique more broadly	A wireless deer fence (pole with scent lure connected to electrode that provides an electric shock when touched) has been recently trialled by Parks Victoria around sambar wallows Yarra National Park. The trial indicated reduced visitation to the wallows by deer but it did transfer impacts elsewhere. While there is the potential to increase the use of lethal control for deer, this may only be suitable in specific locations such as closed catchments.

Waterway structures and operation

There are two intervention groups within this management lever, instream barrier management and physical modification.

Instream barrier management

Instream barrier management involves modifying a barrier such as dam, weir or culvert to improve longitudinal connectivity for fish, platypus, sediment and organic matter. There are three broad techniques of the intervention used for HWS implementation; constructed barrier removal, fish ladders or fishways and change of operation of barrier (Box 4).

Box 4. Description of different instream barrier management techniques

		
Barrier removal involves demolishing or partly removing the weir, dam or road crossing so it no longer pools water, sediment or organic matter behind it, effectively returning the natural hydraulics to the reach.	Fish ladders or fishways are structures installed over or next to weirs or dams that provide a passage for fish to swim upstream, bypassing the barrier. There are many different designs ranging from rock ramps and slotted fishways to automatic trap and lift structures. Platypus can also use fish ladders to bypass dams and weirs if the design is suitable.	Changing the operation of the barrier can involve opening scour valves at the bottom of weirs during high flows to initiate movement of sediment and organic matter downstream.

The following information and references were used to compile information about the intervention and to support the assessment of the effectiveness and appropriateness of the different intervention techniques currently used in the region.

Bioink, C and Coates, B., 2021. Assessment of MacKenzie Flat and Cobbledicks Ford fish barriers in the Werribee Catchment. Report by Ecology Australia for Melbourne Water.

Coats, B., Halliday, B and Bioink C. 2021. Pillars Crossing Fishway upgrade – Fish Monitoring. Report by Ecology Australia for Melbourne Water.

O'Connor, J., Stuart, I. and Jones, M. (2017). Guidelines for the design, approval and construction of fishways. Arthur Rylah Institute for Environmental Research. Technical Report Series No. 274. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

GHD 2020. Werribee River Diversion Weir Fishway Feasibility Report and Concept Design. Report for Melbourne Water.

Melbourne Water 2021. Improving Fish passage in Dandenong Creek – case study for the HWS Annual Report. https://healthywaterways.com.au/case-studies/2021/improving-fish-passage-in-dandenong-creek

Instream barrier management	
General Information	
Conceptual model management lever	Waterway structures and operation
Intervention group	Instream barrier management
Assets intervention group relates to	Rivers and estuaries
Conditions intervention potentially supports	Instream connectivity, physical form
Key values intervention potentially supports	Fish, platypus
Application of use	
Who is currently using the intervention in region	Melbourne Water

General use of intervention group in the region	Part of business as usual in the region
On-ground intervention techniques applied	Barrier removal, fishways, change of barrier operation
Relevant administrative interventions	Legislation: Water Act 1989, the Conservation, Forests and Lands Act 1987, Flora and Fauna Guarantee Act 1988, Catchment and Land Protection Act 1994, Environment Protection and Biodiversity Conservation Act 1999, Heritage Rivers Act 1992 Policy/Strategy: Victorian Waterway Management Strategy 2013, 2013, Healthy Waterways Strategy 2018, Port Phillip and Westernport Regional Catchment Strategy 2023, Guidelines: Guidelines for the design, approval and construction of fishways. 2017, Community Environment Public Health Assessment (SEPHA) checklist, Technical Guidelines for Waterway Management 2007, Why do Fish need to cross the road? Fish passage requirements for Waterway crossings (2003).
Maturity of techniques used in region	Barrier removal: Low very few examples of large barriers being removed in the region, some examples of road crossing culverts being replaced for fish passage. Fishways: Moderate to High due to some designs being early adoption (i.e. cone fishway) compared to others used more often (i.e. rock ramps). Barrier operation change: Low has been trialled on one barrier in the region but more planned in future
Current application barriers	On-ground The main barrier for fishways is the costs and resources involved in constructing a fishways. Another barrier is the presence of exotic species downstream of a barrier that could populate reaches upstream. A barrier to changing the operations of a weir is the mechanical and physical limitations of the structure to change how it is operated. Administrative Changing the operation of barriers requires significant administrative paperwork to update protocols.
Maintenance requirements	Fishways need to be maintained regularly to ensure debris does not block parts of the structure or alter the hydraulic conditions.
Potential outcomes	
Potential beneficial outcomes	Increased range for native fish species and platypus Increased breeding opportunity for fish species Improved organic matter distribution and sediment transfer downstream
Potential adverse outcomes	May allow exotic species to colonise the waterway upstream Deoxygenation of water due to sediment release from barrier Bed and bank instability following barrier removal as waterway adjusts to changes hydraulic and sediment dynamics
Learning	
Relevant research project(s) or monitoring programs in region	Assessment of MacKenzie Flat and Cobbledicks Ford fish barriers in the Werribee Catchment (2021) Dights Falls fishway surveys – summer 2020 Pillars Crossing Fishway upgrade – Fish monitoring 21/22
Lessons learned in application	Lessons from MacKenzie Flat fish passage: • The construction of a new fish friendly culvert on Lerderderg River at MacKenzies Flat has proved to be successful with pre and post construction monitoring demonstrating that common galaxias, ornate galaxias and Australian smelt were able to navigate through the culvert to move upstream. The

	culvert is now passing the full range of species of multiple size classes under a range of flows. Lessons from Pillars Crossing fishway: • Pillars Crossing Fishway was constructed in 2021 after it was identified that the old rock ramp fishway constructed in 2006/07 was of low effectiveness. The new design is a cone fishway supplemented with a rock ramp immediately downstream of the cone fishway entrance. • Pre fishway completion surveys were undertaken outside of the optimal timing of spring/early summer, an upstream migratory period for juveniles of most diadromous species including common galaxias. • It was still considered worthwhile to collect pre fishway data in Autumn 2021 and initial results from Spring 2022 (post fishway completion) show promising signs with common galaxias dominating the fish catch especially upstream, which is a great sign for the fishway with lamprey passing through as well (Bryce Halliday pers comm). • There were many challenges to overcome at Pillars Crossing, including a deeply incised straightened river channel, a work site that was highly flood prone and marrying the rock and cone fishways into one integrated fish passage solution. These challenges were resolved by pre-casting many of the concrete fishway components to speed up the construction process and basing the fishway design on the local hydrology and fish ecology. Lessons from Dights Fall Weir upgrade: • In 1993 a rock fishway was installed at Dights Falls Weir, Yarra River to better facilitate upstream movement of fish. The fishway was in operation for many years, but monitoring suggested effectiveness could be improved, so it was upgraded to a vertical slot fishway in 2012. Continued monitoring indicated that the fishway was only operating effectively under base flow conditions and not during floods. • In response, the fishway was again upgraded in 2020. Monitoring of the fishway has indicated that it is effective and now being used by Common galaxias and other species under most flow conditions. • However, the Dights Weir fishway does demonstrate the importance of fish surveys to monitor the effectiveness of fishways over time to identify the need for potential upgrades or enhancements to maximise effectiveness for a range of fish species over variable flow conditions, particularly with climate change forecasted impacts. Lessons learned from Starvation Creek Weir change of operation: • An ecological investigation was conducted at Starvation Creek Weir (no date supplied) as part of assessing the viability of changing the operation of the barrier by opening the scour valves at the bottom of the modest sized offtakes during high flow events to see it could initiate movement of sediment material out of the weir pools and into downstream reaches along with the associated organic matter. • Multiple benefits were desired 1) increasing sediment/POM supply to downstream reaches and 2) delaying the frequency (and therefore cost) of mechanically desilting the weir pools when they sedimented up.

	• Some macroinvertebrate, physical and geomorphic surveys were conducted, and results indicated that while macroinvertebrates improved, there was a substantial risk of deoxygenation (due to release of water from river bed, oxygen demand of sediment and other material (Al Danger pers. com)). • Note that the ecological survey report was not sighted at time of writing this report but the standard operating procedure for Starvation Creek Weir to include a scour and desilting procedure was updated in 2020 so that the scour valves could be opened during periods of high flows.
Effectiveness and appropriateness	
Level of effectiveness of intervention technique	Barrier removal: High in the immediate area due to the complete removal of barrier thereby enabling fish migration and sediment transfer to occur. The level of effectiveness more broadly depends on the distance to another barrier. Fishway: Moderate depending on the fishway design and the size and species of fish that can navigate to upstream of barrier under a range of flow conditions. Several fishways installed in region over a decade ago are now being upgraded or replaced to improve effectiveness for more fish species to travel upstream under a higher range of flow conditions. Barrier operation change: Unable to assess as one trial has been undertaken on Starvation Creek many years ago but little information is available about the outcomes, only anecdotal recollections from Melbourne Water staff that macroinvertebrates improved but there was a substantial risk of deoxygenating the water. No studies in Australia were found that documented the effectiveness of barrier operation to meet environmental condition or value objectives.
Level of appropriateness of intervention technique	Barrier removal: Moderate as tends to be more appropriate for road crossing culverts compared with large weir structures in the region that can be expensive and pose environmental risks to remove. Fishway: High due to the variety of designs that can accommodate a range of conditions and that many have negligible negative impacts for other environmental values. Barrier operation change: Unable to assess due to limited information although the potential risk of deoxygenation and toxicants through the release of sediment and water in some barrier operation changes is an important consideration.
Emerging techniques or the potential to use an intervention technique more broadly	The potential for barrier operation change to improve transfer of organic matter and sediments is an area that is currently being explored to see if this technique could be used more broadly in the region. Evaluation of the effectiveness of Starvation Creek standard operating procedure would assist with this. The use of cone fishways is a new fishway design used in Queensland that starting to be applied in region and there is opportunity to use it more broadly in the future.

Channel modification

Channel modification involves the physical modification of the shape or form of a waterway or instream features to improve water quality, habitat refuge, sediment dynamics, amenity and reduce erosion. There are five broad techniques of the intervention used for HWS implementation; bank protection, grade control, large woody debris reintroduction, daylighting and artificial estuary opening (Box 5).

Box 5. Description of different channel modification management techniques

Bank protection involves protecting the bank from erosion by armouring it using rock, strengthening it through revegetation or battering it to reduce the bank angle.

Grade control typically involves the installation of a rock structure to control the bed gradient of a waterway. The technique is used to manage bed incision processes.

Large woody debris reintroduction comprises the installation and management of single or multiple pieces of timber into the waterway to create flow diversity and provide habitat for fish, platypus and macroinvertebrates.

Daylighting / Naturalisation consists of replacing a pipe or a trapezoidal channel by construction of a more natural channel with instream features and a sinuous low flow channel.

An artificial estuary opening involves creating an opening through the sand berm (between the estuary and the ocean). Earth moving equipment is often used to create this opening.

The following information and references were used to compile information about the intervention and to support the assessment of the effectiveness and appropriateness of the different intervention techniques currently used in the region.

Coleman, R.A. (2006) *Ecological and physical responses to large woody debris reintroduction in the Little Yarra River, Victoria, Australia*. M.Sc Thesis. School of Biological Sciences, Monash University, Clayton Campus.

Coleman, R.A. (2017) Reintroduction of Wood Habitat in the Little Yarra River -Healthy Waterways Strategy Management Activity Case Study.

Melbourne Water (n.d). Reimaging your creek. https://www.melbournewater.com.au/building-and-works/projects/reimagining-your-creek-project Accessed 6 November 2022

McGuckin, J (2012). Hoddles Creek fish survey after LWD re-introduction. Report prepared for Melbourne Water by Streamline Research.

Water Technology (2015). Capital Works Sites Monitoring Program 2015. Linked PDF Summary Tool prepared for Melbourne Water.

Water Technology (2020). Capital Works Sites Conditions Monitoring – Spring 2019. Report prepared for Melbourne Water.

Channel modification	
General Information	
Conceptual model management lever	Waterway structures and operation
Intervention group	Channel modification
Assets intervention group relates to	Rivers and estuaries
Conditions intervention potentially supports	Instream connectivity, physical form, water quality, vegetation extent
Key values intervention potentially supports	Fish, platypus, macroinvertebrates, vegetation and amenity
Relevant administrative interventions	Legislation: *Water Act 1989, Land Act 1958, Marine Safety Act 2010. the Conservation, Forests and Lands Act 1987, Flora and Fauna Guarantee Act 1988, Environment Protection Act 2017, Yarra River Protection (Wilip-gin Birrarung murron) Act 2017* Policy/Strategy: Victorian Waterway Management Strategy , Guidelines: Estuary Entrance Management Support System, Technical Guidelines for Waterway Management 2007
Application of use	
Who is currently using the intervention in region	Melbourne Water, Parks Victoria, Local Government, DEECA
General use of intervention group in the region	Is part of business as usual for Melbourne Water
On-ground intervention techniques applied	Bank protection, bed protection, large woody debris (LWD) reintroduction, daylighting, artificial estuary opening
Relevant administrative interventions	Legislation: *Water Act 1989, Land Act 1958, Marine Safety Act 2010. the Conservation, Forests and Lands Act 1987, Flora and Fauna Guarantee Act 1988, Environment Protection Act 2017, Yarra River Protection (Wilip-gin Birrarung murron) Act 2017* Policy/Strategy: Victorian Waterway Management Strategy 2013, 2013, Healthy Waterways Strategy 2018. Guidelines: Estuary Entrance Management Support System, Technical Guidelines for Waterway Management 2007
Maturity of techniques used in region	Bank protection: High used broadly across region, various different design types applied and part of BAU Bed protection: High used broadly across region and part of BAU LWD reintroduction: Low has been used as part of pilot projects, most recently delivered as 'fish hotels' in the Maribyrnong River. Daylighting/ Naturalisation: Low due to technique being used through the Reimagine Your Creek program with several projects delivered in past 4 years. Artificial estuary opening: Low is only used at a few locations in the region on a very limited basis.
Current application barriers	<u>On-ground</u> Main barrier for daylighting/naturalisation is the cost of removing or remediating contaminated soil in urban areas. Another barrier is sourcing of the LWD that is appropriate for installation. <u>Administrative</u> One LWD reintroduction barrier is the reluctance of landholders to permit this intervention to occur due to concerns about flooding

	or erosion. There is also concerns about potential liability if it is perceived that LWD reintroduction has caused damage.
Maintenance requirements	All channel modifications need some form of maintenance to ensure the structure or technique is operating as intended. The frequency of maintenance depends on the technique used but often involves removal of debris build up or weed control.
Potential outcomes	
Potential beneficial outcomes	Stabilise eroding processes in waterways thereby improving water quality and vegetation establishment Improvement in habitat, geomorphic processes, flow diversity and water quality Improvement in amenity values related to daylighting and bank protection.
Potential adverse outcomes	High level of disturbance and removal of vegetation can see short term increases in sediment loads Scour associated with LWD may cause localised bank erosion Daylighting or naturalisation of stream may result in more litter being observed in the space leading to increased maintenance
Learning	
Relevant research project(s) or monitoring programs in region	Melbourne Water Capital works monitoring program (2011 -2021) Hoddles Creek Fish Survey after LWD reintroduction 2012 Little Yarra River LWD reintroduction 2006 Maribyrnong River Fish Hotels 2021
Lessons learned in application	Lessons learned from Capital Works Monitoring Program: • The effectiveness of bank and bed control interventions have been monitored at a few locations such as Bunyip River, Merricks Creek, Pauls Creek, Ruffeys Creek, Salt Creek and Yarra River (@ Coldstream) as part of the Melbourne Water Capital Work Monitoring Program from 2008 to 2019 using the Index of Stream Condition (ISC) Physical Score. • The limitations of the ISC Physical Score to capture the subtle changes in bed and bank conditions have been partly offset through observations recorded by the surveyor. The monitoring results indicate an increase in Physical Scores following the bank protection works at Pauls Creek and Ruffeys Creek and the stabilisation of head cuts for Bunyip River, Merricks Creek and Salt Creek. • Observations recorded tend to assess if the integrity of the structure is sound and identify if any maintenance is required. The observations for Yarra River @ Coldstream - which was used as a demonstration site for trialling pile fields and bend away weirs to prevent a possible meander cut off – highlighted that while the structure was sound, outflanking of some of the pile fields was a concern in 2012. However, by 2019 this was stabilised through natural colonisation of vegetation. • One issue raised in the observations is the challenges in retaining the control sites as these have eventually become the focus of works, particularly ones that have unstable bed conditions. Lessons learned from LWD project on Hoddles Creek: • Fish surveys conducted in 2012, two years after LWD reintroduction in Hoddles Creek, found no substantial change to the fish fauna, this includes River Blackfish. • The quantity of wood reintroduced and anchored into the river was small and consisted of single trunk with no branches and were not positioned in a way that promoted debris capture or scouring of the creek bed.

	• However, the capture of three platypus near the LWD structures indicated that the structures may be providing favourable habitat for them.
	• Future surveys were recommended 10 years after installation to allow time for the LWD to develop as habitat for river blackfish but at the time of writing, this does not appear to have been undertaken.
	
	Lessons learned from LWD project Little Yarra River:
	• To determine the outcomes of LWD reintroduction in the Little Yarra River in 2002, a range of biological and physical surveys were conducted before works commenced and up to 16 months after.
	• Survey results indicated post LWD reintroduction an increase in the presence of pools, colonisation of wood by macroinvertebrates and changes in platypus foraging behaviour.
	• The response of fish, particularly river blackfish was weak and this was hypothesised to be due to a number of factors including that wood may not be the main factor impacting fish population. Further monitoring was recommended for the future to continue to track the effectiveness of the wood reintroduction but it is unclear at the time of writing if this was done.
	
	Lessons learned from Reimagine your creek program:
	• The Reimagining Your Creek (RYC) led by Melbourne Water seeks to restore engineered drainage assets such as channels and pipes back to more natural spaces for community enjoyment and well-being. To date, several projects have been delivered with others on the way:
	    • Daylighting of a 650 m section of Blind Creek in Boronia in 2020
	    • A 1.4 kilometre section of Arnolds Creek in Melton West was naturalised in 2021. The project included removing the concrete channel and existing stormwater pipe to create a natural waterway, and planting native plants.
	    • Daylighting and enhancement of a 500 m section of Tarralla Creek in Croydon in 2022
	• While there have been lots of learnings about the delivery of the projects, at the time of writing, results for monitoring the effectiveness of the project in terms of improving water quality, habitat creation and were not available. Videos of the projects do show a visual improvement in potential habitat and flow diversity compared to the pre daylighting / naturalisation.
	
	Lessons from Merrick Creek:
	• Historically, the mouth of Merricks Creek, which is the only Intermittently Closed and Open Coastal Lake and Lagoon (ICOLL) on Western Port, had opened and closed periodically. In the mid 1970's the mouth of the creek was fixed into its current position by the installation of a timber training wall that included a number of baffles.
	• By 2012 the wall had deteriorated and was replaced by a rock wall without any baffles. This resulted in the creek being permanently open and allowed large quantities of seagrass to be deposited along the length of the estuary to Balnarring. The decomposition of this seagrass caused significant odour problems.

	• An investigation recommended that baffles be installed along the wall. Three baffles were installed in 2017 following which the creek resumed its natural opening and closing cycles. The 2021/22 draft Annual report indicates that Merricks Estuary has been artificially opened 4 times since 2018. No further information about why and lessons learned were available at the time of writing this report.
Effectiveness and appropriateness	
Level of effectiveness of intervention technique	Bank protection: Moderate as application of different techniques can have mixed results depending on the bank stability issue. Bed protection: High assuming the grade control structure was adequately designed and constructed. LWD reintroduction: Moderate depending on the objectives, typically moderately effective for providing benefits to macroinvertebrates and platypus and low for fish due to survey results however these were undertaken only a short period after construction and surveys completed 10 year post works may allow a more realistic evaluation. Daylighting/ Naturalisation: Moderate based on outcomes from projects in the UK, yet to see measurable outcomes for region. Artificial estuary opening: Unable to assess despite Merricks Estuary being artificially opened 4 times since 2018 and several artificial openings occurring across Victoria. It is assumed that as estuary openings are often driven by socio-political reasons rather than environmental reasons, very limited assessment of effectiveness of intervention for meeting environmental objectives is available.
Level of appropriateness of intervention technique	Bank protection: High a variety of materials can be used for the different bank protection techniques for most settings and bank stability issues. Bed protection: High intervention has been used across the region for the appropriate river form. LWD reintroduction: Moderate can only be used under certain conditions due to issues relating to access and potential flood risk. Daylighting/ Naturalisation: Moderate can only be used certain locations that meet a range of physical, social and economic criteria. Potential contamination of soil is a significant factor influencing appropriateness. Artificial estuary opening: Moderate artificial opening of estuaries can have some negative impacts on fish, aquatic vegetation and invertebrates due to such changes in water quality and a risk assessment should be undertaken before proceeding.
Emerging techniques or the potential to use an intervention technique more broadly	The reintroduction of LWD is a technique used regularly in other regions in Victoria but has only been used in a small number of locations in the Melbourne region, many of which were undertaken over 15 -20 years ago. There is the opportunity resurvey these sites to evaluate their effectiveness after a long period post installation, particularly regarding benefits to fish. It would also be beneficial to review the methods in the 2000s and 2010s and update knowledge of new potential approaches for future LWD reintroductions.

Waterway licence and entitlement management

There are two intervention groups within this management lever, instream flow management and floodplain / wetland flow management

Instream flow management

Instream flow management involves managing flows to improve flow conditions, water quality and sediment processes for environmental values such as fish, platypus, vegetation and provide benefits for social and cultural values. There are two broad techniques of the intervention used for HWS implementation: environmental flow release and water metering (Box 6).

Box 6. Description of different instream flow management techniques

Environmental flow release involves the provision, allocation and release of water at particular times of the year to provide a flow regime that benefits environmental, social and cultural values.

Metering controls the extraction of water for consumptive use and ensures sufficient retention of flows for environmental and social values.

The following information and references were used to compile information about the intervention and to support the assessment of the effectiveness and appropriateness of the different intervention techniques currently used in the region.

Greet, J (2022) Billabongs of the lower Birrarung: native vegetation responses to watering 20/21. Technical report 20.2 Melbourne Waterway Research Practice Partnership. The University of Melbourne.

Greet, J. and Narrap Unit Rangers (2021) Billabongs of the lower Birrarung: native vegetation responses to watering 20/21. Technical report 21.4 Melbourne Waterway Research Practice Partnership. The University of Melbourne.

Goodman, B (2021) Lower Yarra Billabong frog surveys, Report to Melbourne Water, Ecology Australia Pty Ltd, Fairfield Victoria

Halliday, B.T., Bloink, C., Robinson, W and Campbell, A. (2022). Jacksons & Riddells Creeks Fish Monitoring 2015-2021. Report to Melbourne Water, Ecology Australia Pty Ltd, Fairfield Victoria

Koster, W (2022) Movement of diadromous fishes in the Bunyip and Tarago Rivers – Summary of results 2022. Report to Melbourne Water

Instream flow management	
General Information	
Conceptual model management lever	Waterway licence and entitlement
Intervention group	Instream flow management
Assets intervention group relates to	Rivers and estuaries

Conditions intervention potentially supports	Water for the environment, Instream connectivity, physical form, water quality and vegetation extent.
Key values intervention potentially supports	Fish, platypus, macroinvertebrates, vegetation and amenity

Application of use	
Who is currently using the intervention in region	Melbourne Water, Victorian Environmental Water Holder
General use of intervention group in the region	Is part of business as usual for Melbourne Water for regulated catchments
On-ground intervention techniques applied	Environmental flow release and water metering
Relevant administrative interventions	Legislation: *Water Act 1989, the Conservation, Forests and Lands Act 1987, Heritage Rivers Act 1992, Flora and Fauna Guarantee Act 1988, Environmental Protection Act 2017, Yarra River Protection (Willip-gin Birrarung murron) Act 2017, Climate Change Act 2017* Policy/Strategy: Victorian Waterway Management Strategy 2013, Water for Victoria 2016, Victorian Groundwater Management SRWS Framework 2012, Victorian Climate Change Strategy 2020, Protecting Victoria's Environment – Biodiversity 2037, Healthy Waterways Strategy 2018, Central and Gippsland Region Sustainable Water Strategy 2022 Plans: IWM Plans, Guidelines: Estuary Entrance Management Support System, Technical Guidelines for Waterway Management 2007, Groundwater Dependent Ecosystem Ministerial Guidelines, Stream flow management Plans, Take and Use Ministerial Guidelines Other: Rosters and bans, minimum passing flows
Maturity of techniques used in region	Environmental flow release: Moderate used broadly across region, in regulated catchments and part of BAU Metering: High used broadly across region and part of BAU
Current application barriers	On-ground Environmental flow releases only applicable for regulated systems. Water recovery targets for environmental flows are challenging to achieve due to climate change reducing the volume of flows available Administrative Bans and restrictions are not enforced consistently across the Melbourne region Water recovery targets for environmental flows are challenging to achieve due to the long timeframes for legal processes and development of infrastructure projects.
Maintenance requirements	Meters require some maintenance to ensure working effectively
Potential outcomes	
Potential beneficial outcomes	Watering of riparian vegetation Provision of flows to support fish migration and spawning Improved water quality and flow diversity Provision of improved geomorphic processes and sediment dynamics Provision of instream habitat Provision of flows to support cultural practices Provision of flows to support social outcomes
Potential adverse outcomes	Flows support can support lifecycles of exotic species if applied inappropriately

Learning	
Relevant research project(s) or monitoring programs in region	Melbourne Water has a monitoring evaluation reporting and improvement (MERI) program for environmental flows. Below is a selection of some of the projects in the program: Jacksons and Riddells Creek fish monitoring 2015 -2021 Billabongs of the lower Birrarung vegetation monitoring 2020 - 2023 Frog monitoring of lower Yarra Billabongs 2021 -2021 Monitoring of diadromous fishes in the Bunyip and Tarago Rivers 2019 -2022
Lessons learned in application	Lessons from Jacksons and Riddells Creek fish monitoring 2015 - 2021 • Monitored three reaches, included a reference reach • Reference reach had higher native fish scores compared with intervention reaches • Presence of brown trout in intervention reaches is thought to be impacting native fish • Recommended that summer/autumn freshes only be used in dry years and that winter flow releases be prioritised over summer/autumn freshes to benefit native species Lessons from Billabongs of the lower Birrarung vegetation responses to watering • Seven priority billabongs were selected with varying levels of connectivity to the Birrarung both with and without planned environmental watering events to monitor changes in vegetation in partnership with Wurundjeri’s Narrap Unit • Natural flooding or environmental watering events (even of short duration) were found to have clear benefits for billabong vegetation. • At billabongs that flood more regularly and for longer durations there is greater cover of native wetland plant species, and the cover of exotic terrestrial weeds is lower • Aim to achieve flooding of these billabongs in at least 2 out of every 3 years to promote native wetland vegetation and the condition and reproductive output of River Red Gums • Longer duration flooding (up to 8 months) is preferable because it further increases the condition of River Red Gums and suppresses the cover of terrestrial weeds. Lessons from frog monitoring of lower Yarra Billabongs following environmental watering: • Frog surveys detected nine species • Species diversity was associated with presence of water in billabongs • Billabongs with a water depth > 0.5 m had higher diversity compared with shallower areas • Frog calling response to watering was rapid but the hydroperiod was too short to enable successful frog reproduction • A combination of insufficient hydroperiod, presence of predatory fish and potentially poor water quality may be impacting the successful recruitment of frogs across the billabongs. Lessons from monitoring of diadromous fishes in the Bunyip and Tarago Rivers • Examined the migrations of telemetry tagged diadromous fishes (Australian Grayling, Common Galaxias, Tupong, and Short-finned eel

	• Long distance downstream migrations in all four species were found to coincide with elevated discharge. • Results suggest that timing of flow releases differ for the 4 different species. For example Grayling found to spawn for 2 weeks in April/May so timing is critical whereas migration for short-finned eels was found to occur throughout most months of the year.
Effectiveness and appropriateness	
Level of effectiveness of intervention technique	Environmental flow release: Moderate as application of environmental flows has mixed results depending on the timing and external environmental factors. A single application of environmental water will create immediate change in floodplain ecosystems, but that change may only be temporary, and the nature of the change will differ substantially in systems with previous watering histories (and a range of other variables). Metering: Unable to assess as no studies to assess effectiveness could be identified as the time of writing this report. General information presented in academia and government reports suggest that metering can reduce the volume of illegal take of water but no evidence is presented to support this.
Level of appropriateness of intervention technique	Environmental flow release: Moderate as can only be used for regulated systems and at certain periods where there is sufficient water for flow releases. Metering: Moderate as requires installation of infrastructure for water licence holders and not all locations are suitable.
Emerging techniques or the potential to use an intervention technique more broadly	Achieving desired outcomes like improvements in the health of floodplain ecosystems requires a plan to shift the watering regime over time, not just the application of individual watering events. As such, the 'intervention' is actually about long-term regime change and assessing effectiveness through monitoring and research needs to be done by assessing the consequences of that regime change, not the effects of individual watering events.

Floodplain / wetland flow management

Floodplain/wetland flow management involves managing flows to improve flow conditions, water quality and sediment processes for environmental values such as frogs, vegetation, birds and also provide benefits for social and cultural values. There are three broad techniques of the intervention used for HWS implementation: pumping, levee modification and structural inflow intervention (Box 7).

Box 7. Description of different floodplain / wetland management techniques

Pumping flow from the river into Billabongs or wetlands provides a temporary intervention to watering wetlands.

Levee modification involves either the partial or full removal of levees to allow water to ingress onto the floodplain. Partial removal typically involves either lowering the levee or removing a section of the levee (i.e. a formal levee break).

Structural inflow interventions (diversion weirs and pipes) are installed to increase frequency of water ingress into disconnected floodplains and billabongs

The following information and references were used to compile information about the intervention and to support the assessment of the effectiveness and appropriateness of the different intervention techniques currently used in the region.

Boon, P and Treadwell, S. (2021). Cockatoo Swamp hydrology improvement project - Independent technical review. Report by Jacobs prepared for Melbourne Water.

Greet, J., Fischer, S. and Fedrigo, M. (2020) Cockatoo Swamp Monitoring Program 2015–2020: vegetation response to hydrology works. Technical report 20.8. Melbourne Waterway Research Practice Partnership. The University of Melbourne.

Greet, J, Russell, K. and Fischer S.(2021) Cockatoo Swamp Monitoring Program 2015–2021: Vegetation response to hydrology works. The Waterway Ecosystem Research Group. Technical Report 21.2.The University of Melbourne.

Greet, J. and Narrap Rangers (2021) Billabongs of the lower Birrarung: native wetland vegetation responses to watering 2020/21. Technical Report 21.4. Melbourne Waterway Research Practice Partnership. The University of Melbourne.

MWRPP (2022) Draft Research Project Summaries: MWRPP Project A2: Birrarung's billabongs, vegetation response to environmental watering.

MWRPP (2022) Draft Research Project Summaries: MWRPP Project D4: Yellingbo hydrology works MERI program.

Floodplain / wetland flow management	
General Information	
Conceptual model management lever	Waterway licence and entitlement
Intervention group	Floodplain / wetland management
Assets intervention group relates to	Rivers and wetlands
Conditions intervention potentially supports	Water for the environment, Instream connectivity, physical form, water quality and vegetation extent.
Key values intervention potentially supports	Frogs, fish, macroinvertebrates, vegetation and amenity
Application of use	
Who is currently using the intervention in region	Melbourne Water
General use of intervention group in the region	Used intermittently across the region
On-ground intervention techniques applied	Pumping, levee modification and structural flow intervention (weirs and pipes).
Relevant administrative interventions	Legislation: *Water Act 1989, the Conservation, Forests and Lands Act 1987, Heritage Rivers Act 1992, Flora and Fauna Guarantee Act 1988, Environmental Protection Act 2017, Yarra River Protection (Wilip-gin Birrarung murron) Act 2017, Climate Change Act 2017* Policy/Strategy: Victorian Waterway Management Strategy 2013, Water for Victoria 2016, Victorian Groundwater Management Framework 2012, Victorian Climate Change Strategy 2020, Protecting Victoria's Environment – Biodiversity 2037, Healthy Waterways Strategy 2018, Central and Gippsland Region Sustainable Water Strategy 2022 Guidelines: Estuary Entrance Management Support System, Technical Guidelines for Waterway Management 2007, Groundwater Dependent Ecosystem Ministerial Guidelines, Stream flow management Plans, Take and Use Ministerial Guidelines
Maturity of techniques used in region	Pumping: High used broadly across region, typically as a temporary measure Levee modification: Low used in specific locations as part of research and monitoring programs Structural flow intervention: Low used in specific locations as part of research and monitoring programs
Current application barriers	On-ground Barriers include landholders willingness to allow floodplain reconnection, costs associated with intervention and geomorphic form (e.g. incised waterway). Noise from pump for nearby landholders. Material of levee may not be appropriate for partial removal. Administrative May also need environmental entitlements for pumping in certain locations
Maintenance requirements	Pumps require regular maintenance to maintain efficiency. Structural flow interventions also require maintenance to remove any debris.
Potential outcomes	
Potential beneficial outcomes	Watering of floodplain and wetland vegetation Provision of flows to support fish migration and spawning Improved water quality and flow diversity (for wetlands) Provision of improved geomorphic processes and sediment dynamics Provision of wetland habitat for frogs and birds

	Provision of flows to support cultural practices
Potential adverse outcomes	Flows support can support lifecycles of exotic species if applied inappropriately
Learning	
Relevant research project(s) or monitoring programs in region	Birrarung's billabongs: vegetation response to environmental watering Yellingbo hydrology works MERI program 2015 - 2021
Lessons learned in application	Lessons from Birrarung billabong program: • Seven priority billabongs (Annulus, Banyule, Bolin Bolin, Burke Rd, Horseshoe, Montpellier, and Willsmere billabongs) were selected with varying levels of connectivity to the Birrarung both with and without planned environmental watering events for Narrap Ranges and researchers to monitor responses of vegetation and fauna to changes in water regime. • Environmental watering was achieved through pumping of water from the Yarra River. • Monitoring has found that Natural flooding or environmental watering events (even of short duration) have clear benefits for billabong vegetation. At billabongs that flood more regularly and for longer durations there is greater cover of native wetland plant species and the cover of exotic terrestrial weeds is lower. • However, in the absence of flooding, terrestrial vegetation may recover rapidly and become dominant within two years. Repeated flooding/watering events are necessary to substantially reduce the weed seed loads at urban billabong sites that now flood infrequently. • As flooding duration increases, so does the condition of River Red Gums, while flooding (irrespective of duration) dramatically increases the subsequent flowering of the River Red Gums and thus nectar availability for fauna. • Joint undertaking of vegetation surveys at several billabongs along the lower Birrarung by Waterway Ecosystem Research Group researchers and Narrap Unit Rangers increases Traditional Owners expertise in contemporary land and waterway management and science. This project offers a great example of effective collaborative research with TOs. Lessons from Yellingbo hydrology works MERI program: • The effectiveness of pumping and levee partial removal in meeting the objectives to improve the condition of the wetland forest was limited due to other factors relating to weather conditions, channel form and sediment dynamics. The extensive monitoring program in place highlights the complexity of the Cockatoo swamp system and provides a strong foundation for assessing future interventions. • Undertaking a pumping trial rather than installing a permanent pipeline provided a cheaper and effective way to assess that the intervention is not a long-term solution. The prevailing weather conditions (dry 2019 and wet 2020) and small pumping capacity hampered attempts to drawdown levels in Cockatoo Swamp during the pumping trial. • Temporary instream structures (weirs) and resulting flooding had multiple vegetation benefits including increased growth of extant trees and planted seedlings, germination of seedlings and seedfall. • However, vegetation monitoring has indicated that permanently waterlogged sections of Cockatoo Swamp have

	a very deficient seed bank of E. comphoro seeds indicating that recruitment in these areas will take a long time. • In the longer term, instream structures also have the potential to reduce sediment loads flowing into dieback-affected areas of the Cockatoo Swamp and facilitate the recovery of critical swamp forests therein.
Effectiveness and appropriateness	
Level of effectiveness of intervention technique	Pumping: Moderate – the judgement of effectiveness in this case is broad based on the outcomes for two very different applications. In the case of Yellingbo where pumping was used to dewater a part of the swamp, it was not effective due to the small pumping capacity and weather conditions hampering attempts to drawdown levels. In the case of using pumps to water Birrarung Billabongs, this was found to be effective for the use. Levee modification: Low – the use of this intervention has not been effective to date but has had good results in other regions. The main constraint appears to be incised nature of waterways limiting the frequency of flow overtopping banks and through the levee breaks. Structural flow intervention: Moderate – due to the early results of ingress of water onto the floodplain in the case of Yellingbo, further monitoring required to see if meets objectives.
Level of appropriateness of intervention technique	Pumping: Moderate – Pumping appears to be appropriate in certain situations and has merit as a temporary intervention before more expensive and permanent interventions are constructed. The costs of diesel and maintenance along with noise are some of the constraints and hence may only be appropriate in particular locations. Levee modification: Moderate –this intervention is only appropriate in certain circumstances and is not appropriate for incised waterways or areas where flood risk to neighbouring property is high. It becomes a more appropriate intervention if used in conjunction with other interventions such as structural flow intervention in areas where flood risk to nearby properties can be managed. Structural flow intervention: - Moderate –as can only be used under a specific range of conditions and will require maintenance to sustain effectiveness.
Emerging techniques or the potential to use an intervention technique more broadly	All the techniques used in floodplain / wetland flow management could be used in other locations in the region under the right circumstances. The results from the monitoring and research programs in the region indicate that the intervention techniques are more effective if used in combination.

Urban stormwater and pollution management

There are six intervention groups within this management lever, Stormwater infiltrate, Stormwater harvest, Industrial pollution management, Litter management, Sediment control and Wastewater management.

Stormwater infiltrate

Stormwater infiltration involves constructing water sensitive urban design (WSUD) assets to promote infiltration of stormwater runoff generated from impervious surfaces into the ground which in turn replenishes groundwater and protects baseflows within waterways. There are three broad techniques of this intervention group including lot scale WSUD (e.g. raingardens, leaky rainwater tanks, permeable paving and green roofs), streetscape scale WSUD systems (e.g. permeable paving, swales, raingardens and street trees) and regional scale WSUD assets (e.g. leaky wetlands, riparian sponges and networked tanks and small storages) (Box 8). It should be noted that designing systems to meet infiltration objectives also typically meets current best practice water quality objectives for Total Nitrogen (TN), Total Phosphorus (TP) and Total Suspended Solids (TSS).

Box 8. Description of different stormwater infiltration systems

Raingardens are specially designed garden beds that filter stormwater runoff from surrounding areas using soil and plants to work together to naturally filter the water and remove pollutants. They are also referred to as bioretention systems.

Swales are linear, shallow channels that collect and transfer stormwater. They are often lined with grass or densely vegetated.

Leaky tanks are tanks with a mechanism (e.g. dripper hose) that allows slow, passive release of water from the tank up to a certain volume into an adjacent garden or lawn area. This passively irrigates the landscape and also ensures there is storage volume in the tank each time it rains.

Infiltration wetlands are designed to infiltrate stormwater. This means not using the clay lining and allow infiltration to occur depending on the underlining soil. The wetlands can be ephemeral which means tend to dry out.

Passively watered street trees are designed to intercept and filter stormwater before it goes into the drain. They are typically planted into a tree pit set into the kerb that contains layers of substrate, mulch and rock that works with the tree root system to filter the water before excess water enters a pipe to go into the stormwater system.

Pervious paving allows water to pass through it and filter back into drains or groundwater. There are two types of previous paving, porous and permeable. The porous pavement material enables rainwater to infiltrate across its surface. The permeable pavements have impervious surfaces, but the material is laid on the underlying media with some void space, so the water can infiltrate through the joints or voids between the material.

Smart tanks can be remotely controlled to release water and help improve broader stream health.

Riparian sponges also known as bio-sponges store water along a riparian zone through vegetated depressions that temporarily hold the water on the floodplain and then slowly soak in to form baseflow on the stream.

A green roof is a multi-layered composition on the roof main structure with a planted upper surface. Vegetation is planted in a specialised soil substrate where some of the rainwater is retained and used by plants and the rest can either be stored or diverted to the stormwater system. Green roofs can be classified as extensive and intensive types. Extensive green roofs are composed of a thin substrate layer (<150 mm) with grasses and herbs. Intensive vegetated roofs have deeper topsoil layers (>150 mm) and more choices of plant species.

The following information and references were used to compile information about the intervention and to support the assessment of the effectiveness and appropriateness of the different intervention techniques currently used in the region.

Alim, M., Rahman, A., Tao, Z., Garner, B., Griffith, R., Liebman, M., (2022)
Green roof as an effective tool for sustainable urban development: An Australian perspective in relation to stormwater and building energy management,
Journal of Cleaner Production, 362, 132561,ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2022.132561.

Dagenais, D., Brisson, J., Fletcher, T., (2018) The role of plants in bioretention systems; does the science underpin current guidance?, Ecological Engineering, 120, Pages 532-545.

Davis, A., Hunt, W., Traver, R., Clar, M., (2009) Bioretention Technology: Overview of Current Practice and Future Needs J. Environ. Eng., 135, pp. 109-117,

Ekka, S., Rujner, H., Leonhardt, G., Blecken, G., Viklander, M., Hunt, W., (2021) Next generation swale design for stormwater runoff treatment: A comprehensive approach, Journal of Environmental Management, 279, 111756.

Kõiv-Vainik, M., Kill, K., Espenberg, M., Uuemaa, E., Teemusk, A., Maddison, M., Palta, M., Török, L., Mander, U., Scholz, M., Kasak, K., (2022) Urban stormwater retention capacity of nature-based solutions at different climatic conditions, Nature-Based Solutions,
2, 100038.

Merri-bek City Council (nd), Passively Irrigated Street Trees Best practice guidelines / tech notes, https://www.merri-bek.vic.gov.au/globalassets/website-merri-bek/areas/living-merri-bek/environment/water/esd---wsud---street-tree-passive-irrigation-best-practice-guidelines-tech-notes-for-web.pdf Accessed 14/4/2023.

MWRPP (2022) Draft Research Project Summaries - Project C1: How can retention, use and treatment of urban stormwater protect or provide natural flow regimes for waterway health? Sunbury sub-project.

MWRPP (2022) Draft Research Project Summaries - Project B3: Optimizing constructed wetland design, management and performance prediction.

MWRPP (2022) Draft Research Project Summaries - Project A1.2: Indicators and approaches to monitor the performance of stormwater wetlands.

MWRPP (2022) Draft Research Project Summaries - Project C5: Re-designing streetscapes for managing stormwater and increasing tree canopy cover.

Thom, J.K., Fletcher, T.D., Livesley, S.J., Grey, V. and Szota, C., (2022). Supporting growth and transpiration of newly planted street trees with passive irrigation systems. Water Resources Research, 58(1)

Thom, J.K., Livesley, S.J., Fletcher, T.D., Farrell, C., Arndt, S.K., Konarska, J. and Szota, C., (2022). Selecting tree species with high transpiration and drought avoidance to optimise runoff reduction in passive irrigation systems. Science of The Total Environment, 812, p.151466

Thom, J. K., Livesley, S. J., Fletcher, T. D., Farrell, C., Arndt, S. K., Konarska, J., & Szota, C. (2021). Selecting tree species with high transpiration and drought avoidance to optimise runoff reduction in passive irrigation systems. Science of The Total Environment, 151466

Thom, J. K., Szota, C., Coutts, A. M., Fletcher, T. D., & Livesley, S. J. (2020). Transpiration by established trees could increase the efficiency of stormwater control measures. Water Research, 115597.

Rujner, H., Leonhardt, G., Marsalek, J., Perttu, A., Viklander M., (2018), The effects of initial soil moisture conditions on swale flow hydrographs
Hydrol. Process., 32, pp. 644-654.

Szota, C., Coutts, A. M., Thom, J. K., Virahsawmy, H. K., Fletcher, T. D., & Livesley, S. J. (2019). Street tree stormwater control measures can reduce runoff but may not benefit established trees. Landscape and Urban Planning, 182, 144-155.

Payne, E. G. I., T. D. Fletcher, A. Danger and D. Carew (2015), “Constructed stormwater wetlands literature review, MUSIC uncertainty assessment and study of Melbourne Water's guidelines and procedures”, Report to Melbourne Water.

Walaszek, M., Bois P. Laurent, J., Lenormand, E., Wanko, A., (2018) Urban stormwater treatment by a constructed wetland: Seasonality impacts on hydraulic efficiency, physico-chemical behavior and heavy metal occurrence, Science of The Total Environment, 637–638, pp 443-454,

Walsh, C., Booth, D., Burns, M., Fletcher, T., (2022) Restoring the health of urban streams through stormwater management: A synthesis of the Little Stringybark and Dobsons Creek research projects, Draft Report by Water Ecosystem Research Group, University of Melbourne, Melbourne 52p.

Yousef, Y., Hvitved-Jacobsen, T., Wanielista, M., Harper, H., (1987) Removal of contaminants in highway runoff flowing through swales, Science of The Total Environment, 59, p 391-399.

Stormwater infiltrate	
General Information	
Conceptual model management lever	Urban stormwater and pollution management
Intervention group	Stormwater Infiltrate
Assets intervention group relates to	Rivers, wetlands and estuaries
Conditions intervention potentially supports	Water regime, Water Quality
Key values intervention potentially supports	Fish, platypus, macroinvertebrates, frogs, amenity

Application of use	
Who is currently using the intervention in region	Melbourne Water, Local government, Vic Roads, residents
General use of intervention group in the region	Despite the General Environment Duty (GED) and new flow guidance the requirement to meet these targets is patchy across the region and Melbourne Waters developer services schemes still only require water quality objectives to be met. Some systems are still being trialled and guidance still in development.
On-ground intervention techniques applied	Raingardens, swales, leaky tanks, leaky wetlands, passively watered street trees, pervious paving, smart tanks, riparian sponges.
Relevant administrative interventions	Legislation: Water Act 1989, EPA Act General Environmental Duty – Environmental Protection Act 2017, Planning and Environment Act 1987, Planning provisions in Clause 53.18 Stormwater Management in Urban development Strategy: Victorian Waterway Management Strategy 2013, Healthy Waterways Strategy 2018, Central and Gippsland Region Sustainable Water Strategy 2022 Plans: Integrated Water Management Framework, Guidance: EPA Urban Stormwater Best Practice Environmental Management Guidelines (BPEM), EPA Urban Stormwater Management Guidance (1739:1), Melbourne Water Biofiltration guidelines for Development Services Schemes, Stormwater Victoria WSUD Audit Guidelines, Clearwater Tool for Water Sensitive Urban Design Guidelines (2018), Local council Stormwater Management Plans Education: Awareness raising and behaviour change campaigns
Maturity of techniques used in region	Raingardens: Moderate often installed by councils but designs typically focused on removing toxicants/sediment/encouraging nutrient uptake by plants rather than maximising infiltration of stormwater into the ground. Swales: Moderate often installed by councils but designs typically focused on encouraging nutrient uptake by plants rather than maximising infiltration of stormwater into the ground. Leaky tanks: Low as tend to be installed in certain areas of the region (e.g. Dobsons Creek sub-catchment). Infiltration wetlands: Moderate as typically designed to treat nutrients and toxicants and infiltration is not part of the design. Passively watered street trees: Moderate as mainly designed for improving water quality rather than maximising infiltration. Pervious paving: Moderate but increasingly being used by councils to reduce extent of rainfall runoff. Smart tanks: Low as part of a research program to test applicability. Riparian sponges: Low as applied to one location in region (e.g. Gum Scrub Creek). Green roofs: Low limited uptake across the region.
Current application barriers	On-ground Uncertainty of feasibility to retrofit existing assets to improve infiltration. Maintenance requirements to ensure infiltration efficiency is maintained Administrative Lack of clarity around application of the GED and new EPA stormwater management guidance for infiltration. Appetite from developers to go beyond BAU. Lack of guidance for modelling and design to maximise infiltration for some systems. Developer Services Schemes process is considered by practioners as too rigid for enabling new assets and interventions needed to achieve HWS stormwater targets.

Maintenance requirements	Many of interventions require regular (3-6 months) maintenance, particularly in the first 1 – 2 years of construction while plants are being established. Tanks need to be regularly checked (e.g. annually) and maintained to retain operation efficiency.
Potential outcomes	
Potential beneficial outcomes	Preservation of baseflows and groundwater Reduction in nutrients and toxicants delivered to waterways from runoff Amenity benefits from some interventions such as raingardens and green roofs
Potential adverse outcomes	Contamination of groundwater from pollutants
Learning	
Relevant research project(s) or monitoring programs in region	MWRPP Project C1: How can retention, use and treatment of urban stormwater protect or provide natural flow regimes for waterway health? Sunbury sub-project (2019 - 2023). Restoring the health of urban streams through stormwater management: A synthesis of the Little Stringybark and Dobsons Creek research projects (2009 – 2022). MWRPP Project B3: Optimizing constructed wetland design, management and performance prediction (2019 – 2023). MWRPP Project A1.2: Indicators and approaches to monitor the performance of stormwater wetlands (2019 – 2023). MWRPP Project C5: Re-designing streetscapes for managing stormwater and increasing tree canopy cover (2019 – 2023) plus other passively watered street trees research projects in the region (see lessons learned below).
Lessons learned in application	Lessons learned from MWRPP Project B3: Optimizing constructed wetland design, management and performance prediction: • The analysis of vegetation and water level data from developer wetlands in the south east of Melbourne showed that online wetlands consistently fail to meet the current minimum performance objectives for water quality treatment systems. • Water quality monitoring at 17 wetland sites in the South found that total nitrogen removal decreased with vegetation cover, while total phosphorus removal was related to median water levels in wetlands. • Several systems showed high vegetation cover, but stormwater flows frequently bypassed wetlands. If flows are bypassing, treatment will be minimal, therefore using vegetation cover alone as a proxy for treatment performance risks over-estimating nitrogen removal. • Research project developed a new method and decision support tool ('State of the Wetlands') for prioritising major capital works on wetlands. This used existing datasets supported by a new prioritisation framework incorporating considerations of treatment performance, conservation values, importance of the asset in the network in terms of the expected level of pollutant reduction, risk of asset failure and an estimation of how difficult the asset would be to fix. This tool has greatly improved confidence in planning and delivery of the major capital works program for 2022/23. Lessons learned from MWRPP Project A1.2: Indicators and approaches to monitor the performance of stormwater wetlands:

	• Indicators that can be used to determine wetland performance in terms of reducing nutrients and toxicants include:
	  ○ Direct measurement of water and sediment concentrations of TSS, TN, TP and toxicants
	  ○ Particle size distribution
	  ○ Algal growth and toxicity
	  ○ Macrophyte composition and biomass
	  ○ Microbial community composition and function (periphyton biomass, biofilms)
	  ○ Biomarkers of aquatic organism health
	• Using some of these indicators, sampling conducted at 26 wetlands in region found toxicants detected in:
	  ○ surface water: metals – Cd, Cr, Cu, Pb, Mn, Ni, Zn, B, Hg
	  ○ sediments: metals – Cd, Cr, Cu, Pb, Ni, Zn, Hg – all exceed sediment quality (ecological) guidelines for at least one site, and total petroleum hydrocarbons (TPH) exceed sediment quality (ecological) guidelines at some sites
	  ○ Some pesticides including bifenthrin, permethrin, tebuconazole and piperonyl butoxide were detected, although no ecological guidelines are available.
	  ○ Concentrations of some metals (Cd, Cu, Ni, Zn) at some sites exceed 'clean fill' waste disposal guidelines and are thus considered 'priority waste' contaminants with additional costs associated with disposal.
	  ○ Concentrations of all pesticides measured are below 'clean fill' waste disposal guidelines and therefore not problematic for disposal.
	• This information of toxicant concentrations in constructed wetlands can be used to inform stormwater reuse and recycling schemes.
	
	Lessons learned from MWRPP Project C5: Re-designing streetscapes for managing stormwater and increasing tree canopy cover and other passively watered street trees research projects in the region:
	• Streetscapes fitted with tree-based stormwater control measures such as infiltration trenches, increase the volumetric reduction of stormwater runoff by increasing the proportion of evapotranspiration in the water balance (Thom et al 2020).
	• Access to stormwater may double the growth of street trees compared to traditional street tree planting techniques during the establishment period. However, if not carefully managed, passive irrigation with stormwater may lead to reduced tree growth or even death due to waterlogging. Installation of an underdrain or use of soils with higher exfiltration rates was found to reduce the incidence of waterlogging (Grey et al 2018).
	• In a streetscape experiment to quantify runoff retention of tree pits in a heavy clay soil with low-rates of exfiltration it was found that it is possible to achieve a 90% reduction in annual runoff and to reduce days of runoff to just 15 days per year. However, to achieve this, tree pits need to be sized between 2.5% and 8% of the impervious catchment area, depending on pit exfiltration rates. In practice, achieving these tree pit to catchment area ratios for a dense urban streetscape will require consideration in the planning stages of development works and is expected to be most feasible through implementation of tree pits alongside a suite of other complementary SCMs. (Grey et al 2018).
	• To maximise the stormwater treatment or runoff reduction, the tree pit area needs to be sized according to the exfiltration rate of the native soil. For example, for a soil exfiltration rate of 10

	mm hr-1 the tree pit should be sized to be at least 4 % of the catchment area (Merri-bek City Council, nd.) • Glasshouse experiment assessed 13 commonly planted urban tree species in Melbourne, Australia against three metrics representing crop factor, avoidance of drought stress between rainfall events and high recovery following rainfall. The species *Tristaniopsis laurina* was the species that showed the greatest potential to reduce runoff from passive irrigated systems while avoiding drought stress (Thom et al 2022). Lessons learned from Dobsons Creek research project: • Stormwater controls measures such as leaky tanks, and raingardens, positively influenced the stormflow hydrology of the catchment by reducing quickflow volume and peak flow for small-to-moderate storm events (2-8 mm). The reduction in quickflow volume is consistent with the runoff retention capacity of the SCMs, while decreased peak flows are likely a result of both the detention and retention behaviour of the SCMs. The changes observed are biologically meaningful since small-to-moderate storm events dominate wet-weather conditions. However, SCM-induced changes to the flow regime diminished for large storm events (> 20 mm).
Effectiveness and appropriateness	
Level of effectiveness of intervention technique	Raingardens: Moderate many trials have been undertaken on water use by raingardens and largely varies with the types of vegetation with root traits being identified as important predictors of performance (Davis et al 2019, Dagenais et al 2018). Swales: Moderate as the fraction of stormwater runoff that can be infiltrated by a grassed swale depends on many variables including rainfall intensity and total runoff volume, swale soil type, the maintenance history of the swale, vegetative cover in the swale, and swale slope. Studies (e.g. Yousef et al. 1987, Rujner 2018) have found that swales infiltrated between 9% and 100% of the runoff with significant variability. Check dams in swales increase surface storage capacity allowing greater opportunity for infiltration and subsequent evapotranspiration (Ekka et al 2021). Leaky tanks: Moderate as depends on the amount of storage volume available in tank and time between rainfall events. Empirical evaluation by Walsh et al 2022 suggests that while leaky tanks in conjunction with harvesting can contribute to reducing runoff (known as quickflow) in small to moderate flow events, the resulting ecological benefit has been difficult to detect. Infiltration wetlands: Moderate to due to ability to attenuate peak flows and therefore increase potential for infiltration but limited information available about effectiveness for infiltration (Walaszek et al 2018, Kõiv-Vainik et al 2022) Passively watered street trees: Moderate as research suggests large, deep rooted mature trees use a lot of water however designs are still evolving and being optimised (Szota et al 2019, Western et al 2021). Pervious paving: Moderate due to variability reported in literature (30 – 100%) to attenuate runoff (Kõiv-Vainik et al 2022). Riparian sponges: Unable to assess as no studies to assess effectiveness could be identified as the time of writing this report and no monitoring results of the riparian sponges on Gum Scrub Creek could be found. Green roofs: Moderate as summarised in Kõiv-Vainik et al (2022) when rainfall intensity is low and the roof substrate is dry, there is almost no runoff and the retention rate (and therefore infiltration) is consequently 100%. When rainfall is intensive and the substrate is already saturated with water – runoff will be instantaneous, and the runoff retention rate will be therefore very small.

	Smart tanks: Unable to assess due to insufficient information available from trials at the time of writing this report.
Level of appropriateness of intervention technique	Raingardens: High based on versatility of application in greenfield as well as brownfield developments and the different space saving designs now available. Swales: High based on versatility of application in urban areas at a lot and street scale. Leaky tanks: High based on versatility of application in greenfield as well as brownfield developments and the different space saving designs now available. Infiltration wetlands: Moderate due to only being suitable in locations with space for wetland and suitable soil type. Passively watered street trees: High due to the versality of the technique under different conditions and benefits to environmental and social values Pervious paving: High due to the versality of interventions and different designs available depending on level of infiltration desired. They should be avoided if there is a high risk of clogging by silt loads. Riparian sponges: Moderate as requires specific environmental conditions and space to be implemented. Smart tanks: Moderate due to the specific conditions required to operate the tanks. Green roofs: Moderate as depends on style of roof and the type of vegetation that can used to maximise infiltration.
Emerging techniques or the potential to use an intervention technique more broadly	Smart wetlands is a concept in early stages of being tested in Troups Creek West wetland with real-time monitoring and control of water levels which is expected to improve treatment performance, while providing additional benefits e.g. for water reuse or environmental flows. It is also possible that 'Smart WSUD' could contribute to infiltration targets by directly augmenting base flows. Smart tanks is a concept being tested as part of the Monbulk Creek smart water network project. The objective is to demonstrate the potential for real time monitoring and control of rainwater tanks on private property, council stormwater harvesting systems and urban lakes to deliver multiple outcomes such as household water supply, flood mitigation and environmental flows.

Stormwater harvest

Stormwater harvesting systems collect stormwater runoff, typically from stormwater drains, for subsequent reuse. Stormwater harvesting is becoming an increasingly important component of stormwater management with the benefits of both reducing potable water use and reducing the volumes of runoff and pollutants entering the downstream waterways. The types of approaches to achieve this can range from large scale stormwater to potable reuse schemes to lot scale rainwater tanks for non-potable needs. Losing water to the atmosphere through evapotranspiration is also another way in which stormwater volumes can be reduced. The different techniques for achieving stormwater harvesting are similar to stormwater infiltration assets and often the one asset can achieve both outcomes (Box 9). It should be noted that designing systems to meet harvesting and infiltration objectives also typically meet current best practice water quality objectives for TN, TP and TSS.

Box 9. Description of different stormwater harvesting systems

Harvest wetland systems often include a sediment basin and constructed wetland to capture and treat stormwater and may also have an underground storage tank, a distribution tank and UV treatment to enable use for irrigation purposes in parks and sports fields.

Tanks collect stormwater run-off from impervious surfaces such as roofs or overflow from other stormwater treatment systems.

Raingardens or biofiltration gardens can be used as part of stormwater harvesting systems to treat nutrients before

Passively watered street trees are designed to intercept and filter stormwater and can be connected to an underground harvesting system.

A green roof is a multi-layered composition on the roof main structure with a planted upper surface. Vegetation is planted in a specialised soil substrate where some of the rainwater is retained and used by plants and the rest can either be stored or diverted to the stormwater system

The following information and references were used to compile information about the intervention and to support the assessment of the effectiveness and appropriateness of the different intervention techniques currently used in the region.

Dagenais, D., Brisson, J., Fletcher, T., (2018) The role of plants in bioretention systems; does the science underpin current guidance?, Ecological Engineering, 120, Pages 532-545.

Dietz, M.E., 2007. Low impact development practices: A review of current research and recommendations for future directions. Water, Air, and Soil Pollution, 186(1-4), pp.351-363.

MWRPP (2022) Draft Research Project Summaries - MWRPP Project C1: How can retention, use and treatment of urban stormwater protect or provide natural flow regimes for waterway health? Sunbury sub-project.

MWRPP (2022) Draft Research Project Summaries- MWRPP Project C5: Re-designing streetscapes for managing stormwater and increasing tree canopy cover.

MWRPP (2022) Draft Research Project Summaries - MWRPP Project C6: Optimising real-time monitoring and control of networked stormwater harvesting systems to augment household water supply, reduce nuisance flooding and provide environmental flows to streams.

Szota, C., Coutts, A. M., Thom, J. K., Virahsawmy, H. K., Fletcher, T. D., & Livesley, S. J. (2019). Street tree stormwater control measures can reduce runoff but may not benefit established trees. Landscape and Urban Planning, 182, 144-155.

Walsh, C., Booth, D., Burns, M., Fletcher, T., Hale, R., Hoang, L., Livingstone, G,. Rippy, M., Roy, A., Scoggins, M. & Wallace, A. (2016). Principles for urban stormwater management to protect stream ecosystems. Freshwater Science, 35, 398–411.

Walsh, C., Booth, D., Burns, M., Fletcher, T., (2022) Restoring the health of urban streams through stormwater management: A synthesis of the Little Stringybark and Dobsons Creek research projects, Draft Report by Water Ecosystem Research Group, University of Melbourne, Melbourne 52p.

Western, A., Arora, M., Burns, M., Bonneau, J., Thom, J., Yong, C., James, R., Poelsma, P., & Fletcher, T., (2021) Impacts of stormwater infiltration on downslope soil moisture and tree water use. Environmental Research Letters, 16, 104014.

Yuan, J., Dunnett N., & Stovin, V., (2017) The influence of vegetation on rain garden hydrological performance, Urban Water Journal, 14:10, 1083-1089.

Stormwater harvest	
General Information	
Conceptual model management lever	Urban stormwater and pollution management
Intervention group	Stormwater harvest
Assets intervention group relates to	Rivers, wetlands and estuaries
Conditions intervention potentially supports	Water regime, Water Quality, Physical Form
Key values intervention potentially supports	Fish, platypus, macroinvertebrates, frogs
Application of use	
Who is currently using the intervention in region	Melbourne Water, Local government, water retailers, residents
General use of intervention group in the region	Implementation of systems is growing although some new technologies are still being trialled and guidance still in development
On-ground intervention techniques applied	Harvest wetlands, rainwater tanks, raingardens, passively watered street trees, green roofs.
Relevant administrative interventions	Legislation: Water Act 1989, EPA Act General Environmental Duty – Environmental Protection Act, Planning Policy Framework (19.03-3S for Integrated Water Management) Strategy & Policy: Victorian Waterway Management Strategy 2013, Healthy Waterways Strategy 2018, Central and Gippsland Region Sustainable Water Strategy 2022, Victoria Planning Provisions (Clause 56, 53.18) Guidelines: EPA Urban stormwater management guideance_1739.1 Australian Guidelines for Stormwater Harvesting and Reuse, Melbourne Water Stormwater Harvesting guidelines, Guidelines for Stormwater Harvesting on Melbourne Water drainage assets
Maturity of techniques used in region	Harvest wetlands: Moderate local government have been constructing these systems for some years. Melbourne Water's current stormwater assets and planned future assets in growth areas are not designed for harvesting. Rainwater tanks: Moderate rainwater tanks plumbed to toilets became common in new developments when 5 star regulations came into effect. Raingardens: Moderate often used in developments for meet Clause 56 requirements under the VPP.

	Passively watered street trees: Moderate often used in developments for meet Clause 56 requirements under the VPP Green roofs: Low limited uptake across the region.
Current application barriers	<u>On-ground</u> Competing demands for water from recycled and potable water Storage and demand issues as precinct demands are often insufficient to use the volume of stormwater needing to be harvested. Where existing storage e.g. existing ornamental lake is not available the costs for installing storage can be high <u>Administrative</u> Lack of clarity around application of the GED and new EPA stormwater management guidance. Appetite from developers to go beyond BAU Lack of guidance for modelling and design for harvest wetlands and passively watered street trees. Developer Services Schemes process is considered by practioners as too rigid for enabling new assets and interventions needed to achieve HWS stormwater targets.
Maintenance requirements	Large and small stormwater harvesting schemes require regular maintenance to retain operational efficiency.
Potential outcomes	
Potential beneficial outcomes	Preservation of pre-urban stream flow regimes which supports all instream values. Improvement of social values through amenity benefits provided through irrigation sourced from stormwater harvesting.
Potential adverse outcomes	Risk of algal blooms and pathogens if water is not adequately treated (e.g. using UV treatment).
Learning	
Relevant research project(s) or monitoring programs in region	MWRPP Project C1: How can retention, use and treatment of urban stormwater protect or provide natural flow regimes for waterway health? Sunbury sub-project (2019 - 2023). MWRPP C5: Re-designing streetscapes for managing stormwater and increasing tree canopy cover (2019 – 2023). Restoring the health of urban streams through stormwater management: A synthesis of the Little Stringybark and Dobsons Creek research projects (2009 – 2022). MWRPP Project C6: Optimising real-time monitoring and control of networked stormwater harvesting systems to augment household water supply, reduce nuisance flooding and provide environmental flows to streams (2021 -2025).
Lessons learned in application	Lessons from MWRPP Project C1: How can retention, use and treatment of urban stormwater protect or provide natural flow regimes for waterway health? Sunbury sub-project: • Project aims to test in the Sunbury Growth area the HWS assumption that stream protection and potentially restoration is possible through catchment-based stormwater control measures. • A baseline consisting of 5 years of ecological data is currently being collected in different catchments before the two different stormwater control approaches (integrated water management vs business-as-usual approach) are operational in 2023/24. Monitoring will continue after this date to assess the effectiveness of the two different stormwater control approaches

- The baseline data has highlighted the importance of urban development incorporating appropriately designed stormwater control measures which act to mimic the natural flow, water quality regimes and reach-catchment connectivity observed in the baseline.

Lessons from MWRPP Project C6: optimising real-time monitoring and control of networked stormwater harvesting systems to augment household water supply, reduce nuisance flooding and provide environmental flows to streams:

- This project is testing the technical and social feasibility of operating distributed stormwater control measures, through a major experimental intervention in the catchment of Monbulk Creek to protect threatened platypus under a changing climate as well providing additional benefits by augmenting household water use, contributing towards urban stormwater management targets and reducing the risk of localised flooding. It will test this through three complementary research questions:
    1. Flow regime: Can networked Stormwater Control Measures and Real Time Control technology improve flow regimes in Monbulk Creek?
    2. Social sustainability: In what ways do household water practices support or challenge the social sustainability of networked rainwater tanks being co-managed for private and public good?
    3. 3. In-stream response: Do the increased base flows and reduced stormflows increase platypus foraging habitat?
- No results were available at the time of writing this report but this project will be an important input into understanding the effectiveness of distributed stormwater harvesting systems.

Lessons from MWRPP C5: Re-designing streetscapes for managing stormwater and increasing tree canopy cover:

- Creating large storage for runoff near street trees requires a significant change in current practice. However, there is likely no new radical technology which will transform our streetscapes. More likely, solutions can be found by combining design elements proven to work in stormwater control measures; e.g. simple inlets and large storage, coupled with technologies used to support vegetation, e.g. porous asphalt and structural soils.
- This project is employing these design elements to identify alternative streetscapes which specifically target volumetric reduction in stormwater runoff and support rapid canopy development.
- Two projects have been installed and are currently being monitored, results are expected in 2023/24.

Lessons from Dobsons and Stringybark projects:

- Achieving both reduction in uncontrolled runoff frequency and restored filtered flow regime depends on demand for harvested stormwater (Walsh et al., 2016a), as well as maximizing opportunities for evapotranspiration.
- Maximizing the amount of demand requires end-uses which are regular (e.g. indoor uses) rather than seasonal (e.g. irrigation). Without these regular demands, rainwater and stormwater harvesting storages will remain full for much of the year (Mitchell et al., 2007), leading to frequent discharge of unmitigated runoff.
- SCMs should therefore be positioned to permit distribution of water from them to meet demands. This is typically done by

	locating rainwater tanks at the land parcel scale. Larger scale, more centralized application (i.e. central storage with reticulation back to demands) will be difficult to achieve in existing urban areas, but may be possible where redevelopment or new development is being proposed. • Harvesting (and infiltrating) stormwater lead to improvements to phosphorous and nitrogen concentrations and water temperatures were reduced. Peak flows and volumes were reduced for small events. These changes in condition lead to an increase in some moderately sensitive taxa and improvements to diatom abundances. • Important aspects of stream ecosystem structure and function degraded by urban stormwater can be restored. • Harvesting is critical as infiltration systems alone cannot improve stream health. • Should not rely entirely on large end-of-pipe systems as upstream systems reduce the hydraulic loading of downstream systems and downstream systems act as insurance for upstream systems that may fail.
Effectiveness and appropriateness	
Level of effectiveness of intervention technique	Harvest wetlands: Moderate while there are examples of many systems operating in the region, research indicates they are not at the scale required to protect stream health (Walsh et al 2016, Walsh et al 2022). The Sunbury intervention monitoring project will help to improve how harvest wetlands can play a more effective role as part of an integrated stormwater control system. Rainwater tanks: Moderate due to the technique being a as proven technology at the lot scale however a 'repair lag' (Walsh et al 2022) in maintaining tanks can result in a reduction in effectiveness when tanks are non-operational. Raingardens: Moderate to High many trials have been undertaken on water use and nutrient uptake by raingardens and results in terms of quality of treated stormwater for harvesting largely varies with the types of vegetation and growing media (e.g. Dietz 2007, Yuan et al 2017, Dagenais et al 2018). Passively watered street trees: Moderate as research suggests large, deep rooted mature trees use a lot of water however designs are still evolving and being optimised (Szota et al 2019, Western et al 2021). Green roofs: Unable to assess limited evidence available for harvesting, tend to be used more for infiltration purposes.
Level of appropriateness of intervention technique	Harvest wetlands: Moderate due to only being suitable in locations with space for sufficient storage and treatment of stormwater before re-use. Rainwater tanks: High based on versatility of application in greenfield as well as brownfield developments and the different space saving designs now available. Raingardens: Moderate due to applicability in certain circumstances for a harvesting objective. Passively watered street trees: Moderate due to applicability in certain circumstances for a harvesting objective. Green roofs: Moderate as depends on style of roof and the space available for storage of harvested stormwater.
Emerging techniques or the potential to use an intervention technique more broadly	Smart tank and networked storage technology including the use of new 'real-time monitoring and control' technologies is a potential solution to private asset maintenance, with the potential to enhance the owner's awareness about when and what maintenance is required, or facilitate remote monitoring, that will allow for a centralised support program.

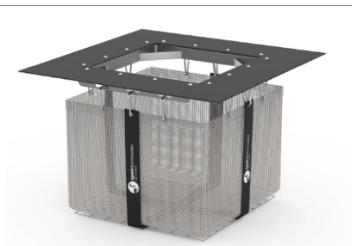
Industrial pollution management

Industrial pollution management requires a more nuanced treatment approach than general urban land uses due to the additional pollutant load generated from industrial sites, including contaminants such as nutrients, heavy metals, hydrocarbons, insecticides and surfactants. Regulation, prevention, and reduction of pollution within industrial estates can be costly and challenging. The types of systems used in industrial areas include lot and streetscape swales and raingardens, property contain measures, precinct scale toxicant traps, stormwater treatment wetlands and diversion to sewer (Box 10).

Box 10. Description of different industrial pollution management

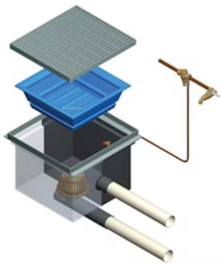
Lot and street-scale swale and raingardens operate by filtering runoff through dense vegetation followed by vertical filtration through soil.

Property containment measures include enclosing or roofing active work areas, sealing ground surfaces, installing cut out drains, bunds, sumps and waste enclosures to allow pollutants to be contained with the site area to be treated and then removed.



Precinct toxicant traps are designed to trap sediment and pollutants and prevent them from entering the stormwater system. They are typically installed in drains near the source of the pollution.

Stormwater treatment wetlands are shallow waterbodies designed to hold stormwater runoff, filter out pollutants and slowly release water after rainfall events.



Diversion to sewer involves diverting stormwater from industrial estates to sewer during baseflow conditions which captures pollutants during dry weather conditions and in first flush of storms.

The following information and references were used to compile information about the intervention and to support the assessment of the effectiveness and appropriateness of the different intervention techniques currently used in the region.

Ainley Projects (2007), Investigation of the Application of Structural Isolation for Reducing Stormwater Pollution from Industrial Premises, Report for City of Kingston.

Kellar, C., MacMahon, D., Townsend, K., Long, S., Myers, J., Hassell, K., Tillet, B., Allinson, M., & Pettigrove, V., (2018), Enhancing Our Dandenong Creek Catchment Study: Pollution Prevention Program: Overview of sourcing and management of pollution in the Upper Dandenong Creek Catchment 2010-2018. Aquatic Pollution Prevention Partnership, Overview, RMIT University, Victoria, Australia.

Kellar, C., Miranda, A., Hassel K., Tewman., M., Pettigrove, V., (2020), Identification of effective and affordable opportunities for addressing pollutants from industrial catchments, Aquatic Pollution Prevention Partnership, Technical Report No. 18, RMIT University, Victoria, Australia.

Melbourne Water (2020). Enhancing Our Dandenong Creek: Monitoring and reducing pollution. Summary report. Melbourne Water, Victoria, Docklands.

Industrial Pollution Management	
General Information	
Conceptual model management lever	Urban stormwater and pollution management
Intervention group	Industrial Pollution Management
Assets intervention group relates to	Rivers, wetlands and estuaries
Conditions intervention potentially supports	Water Quality
Key values intervention potentially supports	Fish, platypus, macroinvertebrates, frogs, amenity
Application of use	
Who is currently using the intervention in region	Melbourne Water, Local Government, industrial businesses
General use of intervention group in the region	Implementation of systems is patchy. Some are still being trialled and guidance still in development.
On-ground intervention techniques applied	lot and streetscape swales and raingardens, property containment measures, precinct scale toxicant traps, stormwater treatment wetlands and diversion to sewer
Relevant administrative interventions	EPA Act General Environmental Duty – Environmental Protection Act 2017, Planning provisions in Clause 53.18 Stormwater Management in Urban development includes industrial subdivisions. Local Government Laws (e.g. Management of stormwater – Kingston Council). Environment Protection (Industrial Waste Resource) Regulations 2009, Strategy: Victorian Waterway Management Strategy 2013, Healthy Waterways Strategy 2018, Central and Gippsland Region Sustainable Water Strategy 2022 Guidance: Urban Stormwater Best Practice Environmental Management Guidelines (BPEM), Urban Stormwater Management Guidance (1739:1), EPA Liquid Storage and Handling Guidelines (1698), Industrial Stormwater Code of Practice -Hume City Council. Education: Awareness raising and behaviour change campaigns Enforcement and compliance: penalties and enforcement by Officers for the Protection of the Local Environment (OPLEs). Monitoring dry weather discharges with sensor technology
Maturity of techniques used in region	Lot and streetscape swales and raingardens: Low there is limited uptake of these systems in industrial areas as was not mandatory. Property containment measures: \ Moderate as small business tends to not install these measures whereas it is more common for large businesses. Precinct toxicant traps: Low still in trial phase. Stormwater treatment wetlands: Moderate there are several Melbourne Water wetlands downstream of industrial areas. Diversion to sewer: Low this approach was considered by DELWP (now DEECA), EPA and water retailers several years ago but has not been adopted regularly except during pollution incidents.
Current application barriers	On-ground Toxicant traps are still in trial phase Cost of maintenance of lot and street-scale swales and raingardens High costs associated with diverting water to sewer and challenges in obtaining approval from Water Corporation. Administrative

	Lack of regulation to require lot and street-scale swales and raingardens Limited funding for compliance and enforcement measures Behaviour change programs can be limited by high turnover of tenants and business willingness to participate
Maintenance requirements	Prescribed waste requirements for some the maintenance of some property containment measures Prescribed waste requirements for maintenance of wetlands Maintenance requirements of toxicant traps are still being developed
Potential outcomes	
Potential beneficial outcomes	Protection of water quality Improved amenity in industrial area
Potential adverse outcomes	Constructed (and natural) wetlands receiving industrial runoff are becoming compromised due to the type of pollutants discharged to them. Constructed wetlands can become ecological traps for some species. High pollutant loads in industrial areas mean that it can be toxic for some flora and fauna.
Learning	
Relevant research project(s) or monitoring programs in region	A3P Project A1.5: Identification of cost-effective opportunities for addressing pollutants from industrial catchments Enhancing our Dandenong Creek: Pollution Detection and Prevention Program
Lessons learned in application	Lessons from Identification of cost-effective opportunities for addressing pollutants from industrial catchments (Part A – literature review): • There needs to have continued inspections, evaluations to maintain change. Priority should be given to small and medium businesses. • While property containment measures can be effective, without compliance and enforcement, incentives and education, many businesses, particularly small to medium ones fail to install these. These measures should be incorporated when designing new industrial estates. • Laboratory trials indicate maintenance of media in a toxicant trap could be annual. The most cost-effective materials are sand, aggregate gravel and blue metal. • Many of the bioretention and biofilter techniques are most suitable for 'light' industrial areas (e.g. don't use or store chemicals) • There is an opportunity to treat dry weather pollution events through filter material which capture pollutants at the end of catchment (bottom of the industrial estate). • The review confirmed that the best management practice and the most successful for industrial estates should be a multi-faceted approach that combines a mix of enforcement, non-structural and structural stormwater strategies, and that this approach is not a "one size fits all" but needs to be tailored to the area. Lessons from Identification of cost-effective opportunities for addressing pollutants from industrial catchments (Part B – laboratory trials): • Laboratory trials assessed different media potential to adsorb pollutants. Seven different materials (bluestone, sand, clay pebbles, premium horticulture pumice, agricultural charcoal,

	vermiculite, pinebark) were tested in the experiment for zinc concentrations and physico-chem parameters and the trial ran for 40 days. • The results showed that all the materials effectively absorbed zinc for 40 days, except for pine bark mulch. The laboratory trials indicate maintenance of these media in a treatment facility could be annual. The most cost-effective materials are sand, aggregate gravel and blue metal. Lessons from Identification of cost-effective opportunities for addressing pollutants from industrial catchments (Part C – industrial estate water sampling): • Water samples were collected weekly during June-August 2020 and March-May 2021 across 13 sites below Industrial Estates and analysed for metals and ammonia. • Across all sites, copper and zinc were nearly always above the ANZG values (ANZG 2018) and at levels toxic to the non-biting midge *Chironomus tepperi*, an indicator of aquatic toxicity (except at West Eltham Main Drain). • The most polluted industrial areas include West Eltham Main Drain, Bell Street Main Drain, Burgess Street Main Drain, Fairbairn Drain, Ainslie Road and Barry Road indicating where to focus intervention efforts. Lessons from Enhancing our Dandenong Creek: Monitoring and reducing pollution: • Research and monitoring of the Dandenong catchment indicated that numerous sediment contaminants including petroleum hydrocarbons, pesticides and metals were coming largely from industrial areas of the catchment and were impairing aquatic fauna and insects. • A series of passive sample surveys were conducted at targeted locations to identify the potential source of specific contaminants. This led to a number of businesses identified as potentially being sources and they became the focus of EPA investigations which was followed by a series of minor works pollution abatement notices and installation of property containment measures. . • A behaviour change program was conducted in the Old Joes Creek industrial program alongside a water sampling program. The results of the water sampling program indicated that while the behaviour change program may have reduced some metals such as lead, cadmium and zinc, overall there was little change in the concentration of metals. It was concluded several factors such as turnover of tenants, reluctance to participant and some businesses already undertaking best practice within their property limited the effectiveness of the behaviour change program. • A number of low cost water quality sensors were installed in stormwater pipes in the Old Joes creek sub-catchment to detect possible illegal dry weather discharges. Between 2019 – 2020, an average of 123 dry weather events were detected. Approximately 61% of these occurred during daylight hours of 6am – 6pm with a higher probability of discharge events on Friday afternoons. Sampling results indicated that higher commercial or industrial land users had more frequent dry weather discharges compared with areas that are largely residential. Additional sensors have been installed to identify the source of the dry weather discharges but no information about the findings of these additional sensors were available at the time of writing this report.

Effectiveness and appropriateness	
Level of effectiveness of intervention technique	Lot and streetscape swales and raingardens: Moderate contaminate loading from some sites will be too high for vegetated systems. Tends to be more suitable for 'light' industrial areas. Property containment measures: Moderate: can prevent pollutants from entering the system, however it is dependent on the appropriate disposal of pollutants once they have been contained and collected. Precinct toxicant traps: High Dry weather flow and first flush pollutants directed to treatment systems which absorb pollutants. Stormwater treatment wetlands: Moderate as depends on the design and the age of the treatment wetland. Effectiveness will reduce over time if wetland not maintained. Diversion to sewer: High as is very effective at preventing hydrocarbons, metals, nutrients from entering waterways.
Level of appropriateness of intervention technique	Lot and streetscape swales and raingardens: High as can be integrated at low cost within the landscape of an industrial site. Property containment measures: High as can be implemented at a relatively low cost for small business. Precinct toxicant traps: Moderate as without compliance and enforcement, many businesses fail to maintain the traps. Stormwater treatment wetlands: Moderate level of contamination is an issue for longevity of systems and can be costly to maintain. Diversion to sewer: Low there is not yet industry agreement on the broadscale adoption of this intervention.
Emerging techniques or the potential to use an intervention technique more broadly	Optimisation of in-field online treatments (Barry Road), to understand maintenance schedule and costs, reuse and recycling options for online treatment facilities. Materials such as coconut husks, diatomite and clay minerals show promise in laboratory trials to remove heavy metals, particularly when the material has been treated to target specific metals. Testing in the field has been limited to date in other countries.

Litter management

Litter management involves preventing or removing litter from entering waterways and can occur at different scales within a catchment and include a range of intervention types including: litter traps and racks, street sweeping, gross pollution traps, litter vacuum as well as source control and other general litter management such as rubbish collection, litter clean ups and waste recycling (Box 11).

Box 11. Description of different litter management techniques

Street sweeping is a mechanical device that sweeps litter and debris from roadside kerbs into a collection device for removal.

Gross Pollution Traps (GPTs) are structures that use physical processes to trap solid waste such as litter and coarse sediment from stormwater.

Floating litter traps and booms are devices that trap and capture litter that is transported on the surface in waterways. They can be installed as a fixed element of infrastructure or can be floating on top of the surface of water.

Litter Vacuum is a device used to suck litter from hard to reach areas such as along river banks or reed beds. Smaller units are also used by Councils to remove litter from road verges.

General litter management involves rubbish collection, litter clean ups and waste and recycling services.

The following information and references were used to compile information about the intervention and to support the assessment of the effectiveness and appropriateness of the different intervention techniques currently used in the region.

Lange, K., Österlund, H., Viklander, M., Blecken, G., (2022) Occurrence and concentration of 20–100 µm sized microplastic in highway runoff and its removal in a gross pollutant trap – Bioretention and sand filter stormwater treatment train, Science of The Total Environment, 809, 151151, https://doi.org/10.1016/j.scitotenv.2021.151151.

Lariyah, M. (2014). A study on the effectiveness and performance of gross pollutant traps for stormwater quality control for River of Life project. Conference Proceedings for the 13th International Conference on Urban Drainage, Sarawak, Malaysia, 7-12 September 2014.

Myers, JH., Richardson, K., Long, S., Tewman, M. and Pettigrove, V. (2020), Year 1 Summary Report: Melbourne Water business purposes for the monitoring and assessment of litter, Aquatic Pollution Prevention Partnership, Technical Report No. 27, RMIT University, Victoria, Australia.

Myers, J., Mondschein, G., Clark, M., & Pettigrove, V (2021), Aquatic Pollution Prevention Partnership Project: Stony Creek whole of system litter investigation & management prioritisation Target Litter Survey Summary Report, Aquatic Environmental Stress Research Group, Technical Report No. 56, RMIT University, Victoria, Australia.

Oceancrusaders (2018), Yarra River Blitz, accessed 20/4/23 https://oceancrusaders.org/yarra-river-blitz/

Queanbeyan Palerang Regional Council (2017), Gross Pollutant Trap Effectiveness, accessed 20/4/23 https://lgnsw.org.au/common/Uploaded%20files/PDF/GPT_effectiveness_Queanbeyan.pdf

Richardson, K., Myers, J.H., Long, S., and Pettigrove, V. (2020), A framework for litter monitoring and assessment: A comparison of existing riverine and litter trap litter survey and monitoring methods, Aquatic Pollution Prevention Partnership, Technical Report No. 30, RMIT University, Victoria, Australia.

RMIT University. (n.d.). Litter Trackers 'Burbs" to the Bay, accessed 20/4/23, https://www.rmit.edu.au/about/schools-colleges/science/research/research-centres-groups/aquatic-environmental-stress/litter-trackers

Sartor, J., Gaboury, D., 1984, Street sweeping as a water pollution control measure: Lessons learned over the past ten years, Science of The Total Environment, Volume 33, 171-183, https://doi.org/10.1016/0048-9697(84)90391-7.

Sidek, L., Basri, H., Lee, L., & Foo K, (2016) The performance of gross pollutant trap for water quality preservation: a real practical application at the Klang Valley, Malaysia, Desalination and Water Treatment, 57:52, 24733-24741, DOI: 10.1080/19443994.2016.1145599

Trestrail, C, Myers, J, MacMahon, D & Pettigrove, V (2020), Aquatic Pollution Prevention Partnership Project: Stony Creek whole of system litter investigation & management prioritisation Catchment background report, Aquatic Environmental Stress Research Group, Technical Report No. 31, RMIT University, Victoria, Australia.

Walker, T., and Wong, T., 1999, Effectiveness of street sweeping for stormwater pollution control, Technical Report 99/8, Cooperative Research Centre for Catchment Hydrology, 43p, https://www.ewater.org.au/archive/crcch/archive/pubs/pdfs/technical199908.pdf

Willis, K., Hardesty, B., Vince, J., and Wilcox, C., (2022) Local waste management successfully reduces coastal plastic pollution, One Earth,5, Issue 6, p 666-676, https://doi.org/10.1016/j.oneear.2022.05.008.

Litter Management	
General Information	
Conceptual model management lever	Urban stormwater and pollution management
Intervention group	Litter management
Assets intervention group relates to	Rivers, wetlands and estuaries
Conditions intervention potentially supports	Litter, Water Quality
Key values intervention potentially supports	Platypus, community connection, recreation, amenity
Application of use	
Who is currently using the intervention in region	Melbourne Water, Local government, EPA, Parks Victoria Sustainability Victoria VicRoads, community and volunteer groups
General use of intervention group in the region	Councils and Melbourne Water have many different litter management programs in place although there are concerns by community there is not enough co-ordinated effort.
On-ground intervention techniques applied	Street sweeping, gross pollution traps, floating litter traps and booms, litter vacuum, general litter management.

Relevant administrative interventions	Legislation: Environment Protection Act 2017, Marine and Coastal Act 2018, Water Act 1989, Statewide bans on lightweight plastic shopping bags (2019) and single use plastics (2023) Strategy: Victorian Waterway Management Strategy 2013, Healthy Waterways Strategy 2018, Protecting Victoria's Environment Biodiversity 2037 Plans: Port Phillip and Westernport Environmental Management Plan 2017, Victorian Litter Plan 2018, Metropolitan Melbourne Litter Plan 2020 Education: Litter Hotspot program, Litter Action Project, Litter Prevention Program Kit 2013, Council litter education programs, Litter Tracker project Compliance & Enforcement: fines by EPA and enforcement by Officer for the Protection of the Local Environment (OPLE)
Maturity of techniques used in region	Street sweeping: High as majority of local councils have a regular street sweeping program that can also be deployed before significant rainfall is anticipated. Gross pollution traps: High is regularly used for removing litter and debris from stormwater before it is discharge to river and creeks. The designs of gross pollutant traps (GPTs) have evolved over the years to increase trapping efficiency and improve removal of litter from traps. Floating litter traps and booms: Moderate tends to be used in major waterways such as Yarra and Maribyrnong Rivers. Litter vacuum: Low has been used as a trial on the Lower Yarra River along reedy river edges General litter management: High as all councils have a rubbish removal program and waste and recycling program. The Beach patrol and Love your street volunteer group program regularly collect rubbish once a month across the majority of council areas in the region.
Current application barriers	On-ground Maintenance requirements for GPTs and litter traps can provide a barrier to installation and ensuring effectiveness is maintained. Finding locations for the installation of litter traps can be barrier, particularly when considering requirement for equipment to remove the litter from the trap. Administrative Distributed responsibility across multiple agencies and associated difficulties coordinating, aligning priorities, and collaborating on projects. The absence of agreed quantifiable aesthetic and ecological targets for litter or a clear understanding of the amount and impact of litter Uncoordinated and variable approaches to litter measurement and tracking and limited opportunities to evaluate reduction activities on specific waterways or reaches.
Maintenance requirements	Gross Pollutant Traps typically require emptying twice a year and may require more regular maintenance during La Nina periods. Floating traps and booms typically require frequent litter removal on a monthly basis.
Potential outcomes	
Potential beneficial outcomes	Improvement and protection of social values such as amenity Protection of environmental values from litter entanglement Improvement of water quality
Potential adverse outcomes	nil
Learning	

Relevant research project(s) or monitoring programs in region	A3P F5.1 Understand the impact of litter, including microplastics, on the social and ecological values of waterways and bays (Aquatic Environmental Stress Research Group – Litter Tracker Project (2019 – 2020) Note that there are a number of litter monitoring programs and reports available but very few provide information about the different litter interventions.
Lessons learned in application	Lessons learned from research program – understand the impact of litter, including microplastics, on the social and ecological values of waterways and bays: • A program for monitoring litter was designed to meet Melbourne Water needs. The program standardises quantitative monitoring of litter along Melbourne waterways and qualitatively assessing litter condition. This was trialled at sites in the Litter for Amenity program and subsequently refined. • It was also used to identify the principal types, sources and quantities of litter entering waterway from 6 sub-catchments. Preliminary results from quantitative surveys show that Dandenong Creek and Moonee Ponds Creek have consistently higher litter loads, while Werribee River has the lowest. Key litter types contributing to litter loads include food related packaging, expanded polystyrene and soft plastics, while at select sites cigarettes, hard plastics and paper items are also significant contributors. • A strategic litter investigation of the Stony Creek catchment was also undertaken to identify the types and sources of litter to help identify and prioritise recommendations for management of litter. The monitoring program is currently being implemented to also help assess the effectiveness of litter management. Lessons learned from the Litter Tracker project: • The Litter Trackers project involved launching GPS tracked bottles into Melbourne's waterways to demonstrate how and where litter travels in our waterways. The project aims to reduce littering and educate communities about the environmental effects of litter on our waterways to empower individuals with the knowledge to make informed choices about preventable litter pollution. • GPS tracked bottles were launched into Balcombe, Dandenong, Darebin, Elster, Gardiners, Jackson, Kananook, Kororoit, Merri, Moonee Ponds, Olinda, Skeleton creeks and Yarra, Plenty, Maribyrnong and Werribee rivers. Although some GPS bottles were captured in litter traps, the majority were found trapped in vegetation or backwash areas a short distance from where they were released. Some were found on beaches in Port Phillip Bay having travelled 53km downstream and into the Bay. The data and program has been used to develop education programs for schools.
Effectiveness and appropriateness	
Level of effectiveness of intervention technique	Street sweeping: Moderate as studies (e.g. Satour & Gadbury 1984, Walker & Wong, 1999) have found the technique to have limited effectiveness in reducing gross pollutant loads due to limitations with sweeper access to source areas (mainly due to street design and car parking), sweeping mechanisms used and operator skills. Gross pollution traps: Moderate due to variable results in effectiveness of gross pollutant traps typically associated with age (and therefore maintenance needs), design and frequency of

	removal of trapped litter (e.g. Lariyah 2014, Sidek et al 2016, Queanbeyan Palerang Regional Council, 2017). The effectiveness of gross pollutant traps in trapping microplastics is less compared to larger litter items due microplastics staying suspended in the water column and being diverted into overflow mechanisms in large storm events (Lange et al 2022). Floating litter traps & booms: Moderate due to the frequency the litter traps in Yarra are emptied and that the 2019 litter tracking trial found that 8 out of 10 GPS tracked bottles placed in the Yarra and Gardiners Creek were captured in the litter traps, However two bottles captured in Elster Creek were able to become free again due to tidal movement (RMIT University, 2023). Litter vacuum: High in removing litter that is difficult to extract via traditional litter picking (e.g. polystyrene and microplastics). An example from 2018/19 highlighted that 5.2 tonnes of litter was removed from the Yarra River in 5 days (with 4 people assisting operation), this compares to 476 kg collected by 276 volunteers over two days by hand (Oceancrusaders, 2018). General litter management: Moderate due to variable results as summarised in Willis et al 2022.
Level of appropriateness of intervention technique	Street sweeping: Moderate as can be used regularly in urban areas to collect litter at source in specific areas. Gross pollution traps: High as can be used in a broad range of conditions and locations to treat stormwater based on different designs. Floating litter traps & booms: Moderate as the technique needs to be installed in a waterway or lake that has sufficient space (width and depth) to house the trap and for equipment such as truck to aid in the removal of the litter. Litter vacuum: High due to the use of the technique in hard-to-reach areas along river banks and in reed beds to remove litter such as polystyrene and microplastics. General litter management: High due to applicability across the region
Emerging techniques or the potential to use an intervention technique more broadly	Artificial Intelligence (AI) approaches to monitor litter in waterways (e.g., litter counts and broad characterisation of litter types) are currently being trialled by Melbourne Water and Aquatic Pollution Prevention Partnership. Bubble barriers (used in Amsterdam) create a bubble curtain by blowing air through a perforated tube placed on the bottom of the river bed. This generates a screen of bubbles that blocks plastics and directs suspended plastics to the surface. The diagonal placement of the bubble curtain in the waterway guides plastic waste to the side and into a litter trap.

Sediment control

Controlling sediment from construction sites is important for preventing excess sediment and associated pollutants from entering waterways. On-ground interventions are often required at a range of scales from the construction site to the downstream stormwater system. Onsite controls include measures to minimise soil erosion, clearance of vegetation, scheduling of ground disturbance activities to avoid rainfall, managing vehicle movement around the site and dust suppression. Treatment trains are often used e.g. Primary treatment for physical screening of sediment (e.g. sediment fences and basins). Secondary treatment involves treatment of fine particle sedimentation and filtration in swales, infiltration trenches and filter bags. Tertiary treatment includes the removal of nutrients and dissolved heavy metals in wetlands and bio-retention systems. The accumulated sediment in some systems requires desilting and removal of material which may be classified as prescribed waste due the accumulated toxins present **(**Box 12**).**

Box 12. Description of different sediment control techniques

Primary treatments include screening of coarse sediment and debris using techniques such as sediment fences, sediment basins and portable sedimentation tanks.

Secondary treatments include treatment fine sediment in swales, infiltration trenches and filter bags.

Tertiary treatments include the removal of nutrients and dissolved heavy metals attached to sediment particles in wetlands and bio-retention systems.

Desilting can be undertaken at a lot scale such as at a wetland or precinct scale such as a reach of waterway or drain. It involves the removal and disposal of accumulated sediment material.

The following information and references were used to compile information about the intervention and to support the assessment of the effectiveness and appropriateness of the different intervention techniques currently used in the region.

Bugg RA, Donald W, Zech W, Perez M. (2017), Performance Evaluations of Three Silt Fence Practices Using a Full-Scale Testing Apparatus. *Water*. 9(7):502. https://doi.org/10.3390/w9070502

Livingston, E. H. (1995, April). Infiltration practices: the good, the bad, and the ugly. In *1EPA Seminar Publication* (p. 352).

Osouli, Abdolreza, Azadeh Akhavan Bloorchian, Sina Nassiri, and Scott L. Marlow.(2017), Effect of Sediment Accumulation on Best Management Practice (BMP) Stormwater Runoff Volume Reduction Performance for Roadway, *Water* 9, no. 12: 980. https://doi.org/10.3390/w9120980

Pitt, R., Clark, S. E., & Lake, D. W. (2007). *Construction site erosion and sediment controls: Planning, design and performance*. DEStech Publications, Inc.

Robotham J, Old G, Rameshwaran P, Sear D, Gasca-Tucker D, Bishop J, Old J, McKnight D. (2021) Sediment and Nutrient Retention in Ponds on an Agricultural Stream: Evaluating Effectiveness for Diffuse Pollution Mitigation. *Water*. 13(12):1640. https://doi.org/10.3390/w13121640

Russell, K. and Vietz, G. (2019) Sediment budgets: major sources and fate of sediments in streams, wetlands, estuaries and bays to inform management opportunities. June 2019. Melbourne Waterway Research-Practice Partnership Interim Report 19.1.

Chapman, J., Proulx, C., Veilleux, M., Levert, c., Bliss, S., André, M., Lapointe, N., Cooke, S., (2014), Clear as mud: A meta-analysis on the effects of sedimentation on freshwater fish and the effectiveness of sediment-control measures, Water Research, 56: 190-202.

Sediment control	
General Information	
Conceptual model management lever	Urban stormwater and pollution management
Intervention group	Sediment control
Assets intervention group relates to	Rivers, wetlands and estuaries
Conditions intervention potentially supports	Water quality, physical form, amenity, recreation
Key values intervention potentially supports	Macroinvertebrates, fish, platypus, frogs
Application of use	
Who is currently using the intervention in region	Melbourne Water, Local government, EPA, Vic Roads
General use of intervention group in the region	While there are industry wide guidelines, codes of practice and some enforcement efforts, use of the intervention can be piecemeal for infill developments.
On-ground intervention techniques applied	Primary treatments, secondary treatments, tertiary treatments and desilting waterways.
Relevant administrative interventions	Legislation: *EPA Act General Environmental Duty – Environmental Protection Act 2017, Water Act 1989, Planning and Environment Act 1987,* Sediment load target for Westernport in the Environmental Reference Standards Strategy: Victorian Waterway Management Strategy 2013, Protecting Victoria's Environment Biodiversity 2037, Healthy Waterways Strategy 2018, Port Phillip and Westernport Regional Catchment Strategy 2023 Plans: Port Phillip and Westernport Environmental Management Plan 2017, Guidance: EPA Civil construction, building and demolition guide_1834, EPA Urban stormwater management guidance_1739.1, Do it Right Clean site factsheets, Council Construction Management Guidelines (e.g. City of Melbourne) Compliance & enforcement: fines by EPA and enforcement by Officer for the Protection of the Local Environment (OPLE)

Maturity of techniques used in region	Primary treatments: High are regularly used across region due to legislative requirements. Secondary treatments: High are regularly used across region due to legislative requirements. Tertiary treatments: High are regularly used across region due to legislative requirements. Desilting: High is used broadly across the region although costs of disposal mean this is applied less frequently compared to the other treatments.
Current application barriers	Compliance and enforcement at lot scale, particularly for infill development is a significant barrier. Maintenance of constructed assets can limit the number installed. Disposal of stored sediment can be costly to remove due to level of toxins in sediment.
Maintenance requirements	Varies depending on technique used but required for all techniques to maintain effectiveness. Maintenance of vegetation particularly important for swales and bioretention treatments.
Potential outcomes	
Potential beneficial outcomes	Prevention of sediment and associated contaminants entering waterways from building and construction sites. Protects instream habitats from smothering from sediment Manages impacts to amenity values (e. swimming in bay)
Potential adverse outcomes	nil
Learning	
Relevant research project(s) or monitoring programs in region	A3P Project: Impacts of sediment from urban and rural stormwater on stream health MWRPP Project B2: Major sources and fate of sediments in streams, wetlands, estuaries and bays to inform management opportunities (2019 – 2023)
Lessons learned in application	Lessons learned from impacts of sediment from urban and rural stormwater on stream health (Fact sheet): • Since November 2019, stormwater wetlands and associated receiving waters in Officer have been monitored for sediment-bound pollutants and water pollutants during different phases of housing construction. • The monitoring showed low levels of metals present across all wetlands, but bifenthrin, an insecticide used for termite control, was detected at all wetlands (except for the most recently built one) at concentrations likely to cause toxic effects to invertebrates. • Bifenthrin was also found in Quirks Creek downstream of the estate, indicating that flooding of wetlands during high rainfall events has contributed to this pollutant being found in the creek. Additionally, high concentrations of bifenthrin were found on power boxes within the estate, suggesting that it enters waterways through surface runoff and dust particles. • The research recommends developing industry best practice guidelines for the pest control industry, educating residents about termite controls, and preferring physical barrier treatments over chemical barrier treatments. The use of an alternative chemical to reduce the risk to the environment and human health and education of managers/industry regarding pollution pathway- i.e., stormwater and airborne/dust route is also advised. Lessons learned from Indicators and approaches to monitor the performance of stormwater wetlands: • Long term sediment quality monitoring in streams, wetlands and estuaries in the Melbourne region indicate that zinc, nickel,

	copper and lead are widespread and commonly exceeded ecological guideline values, whilst mercury, arsenic and cadmium tended to be more localised to specific sites within some catchments. Total petroleum hydrocarbons occur in high concentrations whilst other toxicants that have been measured include pesticides such as bifenthrin. • Concentrations of some metals (Cd, Cu, Ni, Zn) exceed 'clean fill' waste disposal guidelines and are thus considered 'priority waste' contaminants with additional costs associated with disposal. • Concentrations of all pesticides measured are below 'clean fill' waste disposal guidelines and therefore not problematic for disposal. • Concentrations of TPH exceed 'clean fill' waste disposal guidelines, and at some sites approach concentrations close to the Category C upper limit guideline value of 10,000 mg/kg, with additional costs associated with disposal. • Outcomes from monitoring indicate the benefits of flexible maintenance regimes for wetlands, so the maintenance schedules can be tailored to avoid sediment loads exceeding priority waste categories. This could be achieved through a wetland toxicant monitoring program, with triggers based on EPA priority waste categories or other relevant guideline values. Lessons learned from B2: Major sources and fate of sediments in streams, wetlands, estuaries and bays to inform management opportunities: • A conceptual model of construction stages and their effect on sediment supply potential showed that potential sediment supply peaks with bare soil cover, but then remains high during subsequent road and house construction as imperviousness and drainage connection increase. • Sampling on Quirks Creek in Officer has revealed that at this late stage of urbanisation (when most construction in the catchment has already been completed), increased sediment loads downstream of the urbanising area driven by increased flow rather than increased sediment concentration. • The natural wetlands which receive runoff from the development appear to accumulate sediment at some times of year and generate sediment at others (potentially due to seasonal vegetation changes or disturbance of the corridor by weed management).
Effectiveness and appropriateness	
Level of effectiveness of intervention technique	Primary treatments: Moderate due to the various techniques meeting intended objectives of trapping coarse sediment but results from studies (Pitt et al 2007; Chapman, 2014; Bugg et al 2017) indicate that this can be inconsistent due to installation errors leading to structural failure (e.g. silt fences) or maintenance needed to maintain effectiveness (e.g. sediment basins). Secondary treatments: Moderate due to some studies indicating that effectiveness can be variable due to age of intervention (e.g. Osouli et al 2017) or ineffective design of primary treatment train leading to secondary treatments becoming clogged with coarse sediment (e.g. Livingstone 1995). Tertiary treatments: Moderate due to some studies (e.g. Robotham, 2021) showing reduced effectiveness in large storm events, particularly for online wetlands. Desilting: High due to the physical removal of sediment from the system.

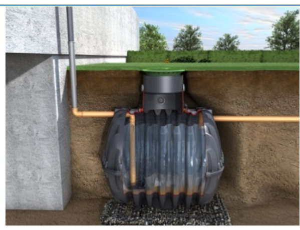
Level of appropriateness of intervention technique	Primary treatments: High as can be used across a broad range of locations and conditions, including greenfield and brownfield development sites. Secondary treatments: High as can be used across a broad range of locations and conditions, including greenfield and brownfield development sites. Tertiary treatments: Moderate due to toxicant levels in some wetlands in Melbourne being above Australian and New Zealand Fresh and Marine Water Quality guideline values and impacting on invertebrate species and macrophytes (e.g. duckweed). Desilting: Low due to potential impacts to plants and invertebrates during the desilting operation, the special permit required for H&S risks and that the technique can only be used in specific circumstances.
Emerging techniques or the potential to use an intervention technique more broadly	None identified.

Wastewater management

Wastewater management involves treating sewerage and is a highly regulated activity. Most sewage in our region is treated via large sewage treatment plants and a relatively small proportion of on-site septic systems used in peri-urban and rural areas. The different management techniques described here include wastewater treatment plants, septics and sewerage network management **(**Box 13**).**

Box 13. Description of different wastewater management techniques

A wastewater treatment plant is a facility which uses a combination of physical, chemical and biological processes to treat effluent so that it is suitable to discharge to the surrounding environment or for an intended re-use application.



A septic tank is an underground chamber made of concrete, fiberglass, or plastic through which domestic wastewater flows for basic local sewage treatment.

Sewerage network management involves the maintenance of existing assets such as pipes and pumps. It also involves the community sewerage program where areas of septic tanks that are converted to the sewerage network.

The following information and references were used to compile information about the intervention and to support the assessment of the effectiveness and appropriateness of the different intervention techniques currently used in the region.

A3P (2022) Draft Research Project Summaries: A3P Project B1.2: Understanding the ecological impacts of treated and untreated sewage inputs to waterways.

Wastewater Management	
General Information	
Conceptual model management lever	Urban stormwater and pollution management
Intervention group	Wastewater management
Assets intervention group relates to	Rivers, wetlands and estuaries
Conditions intervention potentially supports	Water Quality, Water regime
Key values intervention potentially supports	Platypus, macroinvertebrates, fish, frogs, recreation
Application of use	
Who is currently using the intervention in region	Melbourne Water, Local government, water retailers, EPA, landowners
General use of intervention group in the region	The management of sewerage is regulated by the EPA and managed by various agencies.
On-ground intervention techniques applied	Treatment plants, Septics, Sewerage network management
Relevant administrative interventions	EPA Act General Environmental Duty – Environmental Protection Act. Under the *Environment Protection Act 2017* an on-site wastewater treatment plant must meet the appropriate standard set by EPA. 'Appropriate standard' is defined in regulation 4 of the Environmental Protection Regulations 2021.

	Guidelines: Australian guidelines for water recycling (2006), Victorian Guideline for Water Recycling (2021), Guidelines for validating treatment processes for pathogen reduction: supporting Class A recycled water schemes in Victoria (*2013*), Guide for the completion of a recycled water quality management plan: for Class A water recycling schemes (*2008*). New guidelines being drafted for how recycled water can be considered a benefit to the environment (part of the Central Gippsland Sustainable Water Strategy – Action 8-22).
Maturity of techniques used in region	Treatment plants: High the Western Treatment Plant has been operating since 1837 and Eastern Treatment plant since 1975. Both plants have had a series of upgrades to improve standard of treatment. Septics: High as have been used in rural areas outside of the sewer network. Sewerage network management: High due to regular maintenance and the roll out of community sewerage programs in the region in the past 20 years.
Current application barriers	Landowner uptake of community sewering programs due to the increase cost of water bills and connection to the sewerage.
Maintenance requirements	Treatment plants have significant maintenance requirements to ensure continual and efficient operation. Septics can be problematic to maintain and best practice is to pump the tank every 3 to 5 years.
Potential outcomes	
Potential beneficial outcomes	Improvement and protection of water quality for social values (e.g. pathogens) as well as environmental values (e.g. nutrients and other chemicals of concern e.g. pharmaceuticals) Contribution towards environmental water through flow releases from treatment plants.
Potential adverse outcomes	Flow releases not in line with ecological flow objectives and possible risks from water quality.
Learning	
Relevant research project(s) or monitoring programs in region	Sewage Quality Risk Assessment Toolbox B1.2 Understanding the ecological impacts of treated and untreated sewage inputs
Lessons learned in application	Lessons learned from Sewage Quality Risk Assessment Toolbox: • Melbourne Water, City West Water, South East Water, and Yarra Valley Water work together to manage the quality of Melbourne's sewage. A key part of this work is assessing the risk from expected changes in the raw sewage entering our sewers, which typically come as industrial trade waste discharge. As existing methodologies are challenging to use, a more streamlined, collaborative process was developed to determine sewage quality risk more effectively. • The Sewage Quality Risk Assessment Toolbox (SQRAT) is a centralised 'single source of truth' digital platform for assessing sewage quality risk. The platform, developed collaboratively between the four water businesses, contains a set of tools that can be used to streamline the risk assessment processes. • The SQRAT is not a static system. Rather, it is modular, allowing updates or replacement of existing methods as better ones become available. This ensures that all decisions about managing the quality of sewage are supported by the best available data and knowledge.

	Lessons learned from understanding the ecological impacts of treated and untreated sewage inputs: • Data from the Melbourne Water Sewage Transfer Monitoring Plan (Water Quality Monitoring) was collated for the period of 2000-2019. This dataset included more than 7300 records for chemicals measured in sewage. The most frequently detected chemicals included metals such as Zn, Cu, Cr, Ni, Pb, Ca, volatile organic compounds such as formaldehyde and BTEX (benzene, toluene, xylene, ethylbenzene), phenols, surfactants, hydrocarbons and several pesticides. • Median concentrations were generally in the low mg/L range for most chemicals, with occasional spikes at much higher concentrations for some. • Data provided from South East Water on trace organic chemicals measured in sewage from 2016-2019 showed several pharmaceuticals and personal care products, plasticisers, industrial chemicals and endocrine disrupting chemicals (EDCs) detected in all samples (100% detection). • Based on findings from extensive field sampling, a list of priority chemicals that may be suitable indicators of sewage pollution were identified as; Roxithromycin, Sulfamethoxazole, Venlafaxine (for treated and untreated sewage), Trimethoprim (for treated sewage only), Diflufenican, Ketoprofen, Diphenylamine, Methabenziazuron and Piperonyl butoxide (for untreated sewage only). • Ecotoxicological testing is planned of identified priority chemicals to establish threshold levels to calculate the relative risk of each chemical and impact assessments using fish, invertebrates or other biota in identified priority areas to contribute to understanding the risks of sewage pollution in waterways.
Effectiveness and appropriateness	
Level of effectiveness of intervention technique	Wastewater treatment plants: High for water quality treatment of effluent which can then be discharged to receiving environment or reused. Moderate for environmental flow management due to water quality risk concerns. Septics: Moderate there are many factors (e.g. size and maintenance) which lead to mixed success across the region (ego Mullum Mullum Creek there is a high number of septics and there is evidence that they are not working effectively (T Grant pers comm). Sewerage network management: Moderate for maintenance of sewerage network and High for community programs.
Level of appropriateness of intervention technique	Wastewater treatment plants: Moderate due to the limited areas where wastewater treatment plants can be built and operate. Septics: Moderate odour and maintenance issues limit appropriateness so are used in areas where no sewerage network is available. Sewerage network management: High asset management approaches are mature e.g. upgrades of emergency relief structures when required and conversion of septics to the sewerage network has many positive benefits to the environment.
Emerging techniques or the potential to use an intervention technique more broadly	The Western and Eastern treatment plants have a planned series of improvement and upgrades over the next few years that will help to remove more nutrients from effluent as well as installing less energy intensive treatment processes.

Agriculture and runoff management

There are 2 intervention groups within this management lever; rural land management and forestry runoff management.

Rural land management

Water quality and other impacts from agriculture can be managed through a range of best practice management techniques on farms which can range from structural measures through to practice changes. There are numerous options which suit different farming practices and sites. These can include, headwater stream protection, riparian buffer or swales, fencing, off-stream stock watering, track management, erosion control measures, farm dam management, fertilizer and effluent management, constructed water quality systems, shade and shelter belts. Fencing and vegetation establishment is a key intervention for rural land so please refer to the vegetation establishment section for the assessment of this intervention.

Box 14. Description of different rural land management interventions

Riparian buffers /swales are often strips of vegetation that aim to intercept overland flow and allow denitrification before using water for irrigation or for trapping sediment.

Off-stream stock watering to limit livestock accessing the waterway and causing erosion and water quality issues.

Farm track management involves ensuring the track is a minimum of 20 m from waterways, uses crushed rock or gravel for high use tracks, drainage improvements and are shaped to shed water.

Gully Erosion control typically involves stabilising the gully and managing surface flow from the catchment.

Farm dam management involves managing erosion around the dam (i.e. from cattle or the inflow point). Also includes improving habitat of the dam if it is not needed for stock watering.

Fertilizer and effluent management involves managed use of fertilisers (timing, rate and placement) and recycling effluent in effluent ponds to be used on pastures to reduce nutrient input to waterways.

Shelterbelts are vegetative barriers that are designed to reduce wind

A feed pad is a confined yarded area that provides adequate water, space, facilities and has an effective waste removal system

speed, create shade, and reduce erosion when the soils can be bare.	to allow for the regular feeding of the whole herd. Feed pads tend to be used in dairy farms and concentrate impact in an area away from waterways and tend to be used in dairy farms.	

The following information and references were used to compile information about the intervention and to support the assessment of the effectiveness and appropriateness of the different intervention techniques currently used in the region.

DEPI (2010), Guidelines for Victorian Dairy Feedpads and Freestalls, Department of Primary Industries Victoria on behalf of the Geoffrey Gardiner Dairy Foundation, Echuca Victoria Australia. https://www.dairyingfortomorrow.com.au/wp-content/uploads/Victorian-Guidelines-feedpads-and-freestalls.pdf

Frankl, A., Nyssen, J., Vanmaercke, M., and Poesen, J. (2021) Gully prevention and control: Techniques, failures and effectiveness. *Earth Surf. Process. Landforms, 46: 220-238* https://doi.org/10.1002/esp.5033.

Julie-Ann C. Malan, Nicole Flint, Emma L. Jackson, Andrew D. Irving, Dave L. Swain, Offstream watering points for cattle: Protecting riparian ecosystems and improving water quality?, Agriculture, Ecosystems & Environment, Volume 256, 2018, Pages 144-152.

Lim, T. J. Y., Sargent, R., Henry, R., Fletcher, T. D., Coleman, R. A., McCarthy, D. T., & Lintern, A. (2022). Riparian buffers: disrupting the transport of E. coli from rural catchments to streams. *Water Research*, *222*, [118897].

MWRPP (2022) Draft Research Project Summaries: MWRPP Project C2: Effectiveness of rural land interventions to improve stream flows and water quality.

River of Carbon, Fogarty, P., Bolton, A (nd), Guide improving farm roads and tracks to withstand erosion, 2023, April 7,https://riversofcarbon.org.au/improving-farm-roads-and-tracks-to-withstand-erosion.

Sargent R, Fletcher T., McCarthy, D., (2021) Stream buffer performance and design for water quality. Research Note 21.2, Melbourne Water Research Practice Partnership, Melbourne University, Melbourne.

Sharpley., A, (2016), Managing agricultural phosphorus to minimize water quality impacts. Scientia Agricola, Volume 73, p1-8.

Sustainable Farms (2022), Managing natural assets on farms: Shelterbelts, Australian National University, https://www.sustainablefarms.org.au/wp-content/uploads/2022/09/Shelterbelts-Management-Guide_online.pdf

Witheridge.G, (2022), Gully Erosion Field Guide Part 3 – Gully Bank Stabilisation and Land Management Practices. Catchments and Creeks Pty Ltd., Bargara, Queensland.

Rural Land Management	
General Information	
Conceptual model management lever	Agriculture and run-off management
Intervention group	Rural land management
Assets intervention group relates to	Rivers, wetlands and estuaries
Conditions intervention potentially supports	Water regime, Water Quality, Vegetation Extent, Physical form

Key values intervention potentially supports	Fish, platypus, macroinvertebrates, frogs, birds
Application of use	
Who is currently using the intervention in region	Melbourne Water, landowners, Landcare, Westernport Biosphere. Agriculture Victoria
General use of intervention group in the region	Implementation of Melbourne Water program (also incorporating the CMA program) is mature and focused on priority areas. Delivery shared with partner organisations such as Agriculture Victoria and Landcare.
On-ground intervention techniques applied	Riparian buffer /swales, Fencing (multi-purpose), Off-stream stock water, Tracks, Erosion control Farm dam management, Fertilizer management, Effluent management, Constructed WQ systems and Shade and shelter belts
Relevant administrative interventions	Legislation: *Catchment and Land Protection Act 1994, Water Act 1989, Environment Protection Act 2017, Environment Protection and Biodiversity Conservation Act 1999, Flora and Fauna Guarantee Act 1988* Strategy: Victorian Waterway Management Strategy 2013, Protecting Victoria's Environment – Biodiversity 2037, Healthy Waterways Strategy 2018, Central and Gippsland Region Sustainable Water Strategy 2022, Port Phillip and Westernport Regional Catchment Strategy 2023 Guidelines: Agriculture – Guide to preventing harm to people and environment: EPA 1891, Guidelines for Victorian Dairy Feedpads and Freestalls, Melbourne Water Rural Land guide for reducing the impact of runoff to waterways Education: Awareness raising and behaviour change campaigns and support in developing Property management plans, Farm planning session, Integrated pest management plan. Enforcement and compliance: penalties and enforcement by EPA.
Maturity of techniques used in region	Riparian buffer /swales: High regularly used across the region to improve water quality. Off-stream stock watering: High regularly used across the region to improve water quality. Farm track management: High regularly used across the region to improve water quality. Gully erosion control: Moderate used across the region but recent research has identify how techniques need to improved. Farm dam management: Low as tends to be used by farmers with bigger landholdings, less so by lifestyle farms. Fertilizer management: High due to education and capacity programs in the region. Effluent management: High due to education and capacity programs in the region. Shelterbelts: Moderate to High have been used across certain parts of the region for decades. More recently, biodiversity and carbon storage have been incorporated into design considerations. Feedpads: Moderate use has been gaining momentum over the past 10 years with design improvements.
Current application barriers	Limited resources, limited funding and relies on private landholder willingness to participate.
Maintenance requirements	Mixed. Some require annual maintenance and others will only need maintenance as required.
Potential outcomes	
Potential beneficial outcomes	Preservation of baseflows and groundwater, Improvement of water quality, improved land management and erosion control, increased biodiversity on farm, increase habitat, increase vegetated buffer, increase vegetation quality

Potential adverse outcomes	Nil
Learning	
Relevant research project(s) or monitoring programs in region	Prioritisation and effectiveness of rural land runoff control interventions (2016 – 2022) C2: Effectiveness of rural land interventions to improve stream flows and water quality (2018 – 2022) Tarago (microbes)

Lessons learned in application	Lessons from: Effectiveness of rural land interventions to improve stream flows and water quality (Sargent, Fletcher & McCarthy, 2021):
	• Install fencing along gullies in rural areas to provide water quality benefits irrespective of buffer widths, by excluding cattle from the stream bed and adjacent banks.
	• Where stock exclusion is not possible, rotational grazing management can improve sediment, nutrient and microbial water quality.
	• Address concentrated surface flow pathways by changing buffer shape (making the buffer strip wider where flows converge) and diverting track drains.
	• Avoid drainage or channelization of wetland areas, to ensure flow stays diffuse.
	• Expand the buffer area to surround natural topographic depressions, avoiding concentrated flow from paddock to stream
	• Divert discharge from track drains over a broader area of enclosed buffer zone before it reaches the stream.
	• Maintain dense vegetation at the ground surface to reduce riparian erodibility and improve flow interception
	    o Maintain the greatest possible surface vegetation cover in riparian areas, through permanent stock exclusion if possible, followed by either active or passive vegetation establishment.
	    o Monitor surface vegetation density within buffers, particularly in established buffers where canopy shading may reduce surface vegetation density, or where concentrated flow is likely to occur.
	    o Consider re-planting low-density surface vegetation areas, with shade-tolerant species if under canopies.
	• Employ fit-for-purpose pollutant control methods
	    o Buffers must be sized so they have capacity for water treatment. Buffers should be wider in areas where higher flows are expected, e.g. where flows are concentrated by convergent topography
	
	Lessons learned from Prioritisation and effectiveness of rural land runoff control interventions (Vegetated swales) (MWRPP 2022):
	• Similar performances were measured for the natural and constructed swales. It may therefore be more cost-effective to preserve and enhance existing vegetated drainage lines (where possible) rather than construct treatment systems.
	• Constructed swales should be designed and built to maximise filtration of flows. This can include:
	    o Ensuring the cross-section is shaped as a trapezoid (the base is flat, not v-shape,) to maximise contact of flow with vegetation.
	    o Ensuring dense vegetation with a combination of sedges/reeds and ground-cover (grass). Sedges and reeds alone can create preferential flow paths over surrounding bare soil, undermining treatment effectiveness.
	    o Aiming for quick establishment of vegetation to avoid erosion.

	○ Ensuring frequent inspection of erosion and vegetation establishment during the first 12-24 months. Lessons learned from riparian buffer establishment on the contribution of faecal sources to waterways (Lin et al 2022, Sargent, 2022): • Catchments draining agricultural and residential land in the Tarago area had higher E. coli concentrations than predominately forested catchments. • The proportional contribution of cattle to the total faecal community in water samples was very low, with wild animals dominating waters across the study area. Notably, it was found that there was a substantial contribution to the E. coli burden from waterbirds. • Source-tracking demonstrated the value of buffer strips, with cattle faecal contributions to E. coli levels being much lower in buffered streams than those that were unbuffered. Riparian buffers appear to reduce E.coli concentrations in stream by disrupting the transport pathway. • In high relief landscapes, with narrow buffers, pollutants from groundwater are unlikely to be significantly mitigated by buffers. In these circumstances, at source methods of control including fertiliser application management should be the focus.
Effectiveness and appropriateness	
Level of effectiveness of intervention technique	Fencing (multi-purpose): High see vegetation establishment Rural revegetation: High see vegetation establishment Riparian buffer /swales: Moderate as depends on the slope of the land, can be effective in reducing E coli concentrations in waterways by disrupting the transport pathways that govern E coli movement from agricultural and residential land (Lim et al 2022). Off-stream stock watering: Moderate due to research indicating that the intervention can reduce the amount of time livestock spent in riparian corridors and waterways but the length of time can be variable and several installation factors such as distance from stream, slope to stock watering, size of paddock and shading can influence the effectiveness of this intervention (Malan, 2022). Farm track management: Moderate as can have variable outcomes depending on soil type and slope. Good track drainage is the key to keeping erosion of the track surface to a minimum (Rivers of Carbon, 2023) Gully erosion control: Moderate as has variable success due to a number of factors such as soil type, slope, size (width and depth), drainage pathways and the different techniques used to stabilise the erosion and manage the flow path (Fankl et al 2021; Witheridge, 2022) Farm dam management: High as research in North East Victoria has shown management through fencing and planting helps to lower levels of nitrogen, turbidity and coli counts and support more water bugs than unmanaged dams (Sustainable Farms, 2023) Fertilizer management: Moderate due to range of results under different conditions and particularly as nutrients such as phosphorus can be released from sediment stores as a result of legacy applications (Sharpley, 2016). Effluent management: Moderate as depends on if has been designed correctly, is maintained appropriately, and does not interact with groundwater. Shelterbelts: Moderate as depends on the location and the width. Wider shelter belts slow wind more effectively and generate greater biodiversity (Sustainable Farms, 2022).

	Feedpads: Unable to assess no information about the effectiveness was identified. Many publications highlighted benefits but did not look at effectiveness.
Level of appropriateness of intervention technique	Fencing (multi-purpose): High see vegetation establishment & maintenance for more details. Rural revegetation: High see vegetation establishment & maintenance for more details. Riparian buffer/swales: High as can be used across the region and has benefits for many environmental values. Off-stream stock watering: Moderate due to being more appropriate for farms with large stream frontage compared with farms with small stream frontage (Malan et al 2018). Farm track management: High as can be used across region with track designs altered depending on soil type and slope. Gully erosion control: High as a large variety of techniques available to stabilise gully erosion. Prevention of gully erosion is a priority followed by early intervention before gully erosion become significant. Farm dam management: High can be used for majority of farm dams. Fertilizer management: High for all land uses to use best practice measures to limit nutrient inputs (e.g. nitrogen and phosphorus) from entering waterways. Effluent management: High as dairy farmers have a legal responsibility to contain all dairy effluent within their farm boundaries. Shelterbelts: Moderate as can be used in specific locations on a property based on wind direction and provides benefits to environmental values. Planting of non-native species reduces level of appropriateness. Feed pads: Moderate as tends to be used by large dairy farms due to installation costs and may require a planning permit to install to ensure potential environment and amenity impacts are managed (DEPI, 2010).
Emerging techniques or the potential to use an intervention technique more broadly	Regenerative agriculture and broader suite of land management interventions, especially post integration with PPWCMA. Single property interventions may be too small to detect improvement or difficult to demonstrate improvement. As such site scale studies are limited, need to look at sub-catchment scale for understanding effectiveness.

Forestry runoff management

Forestry runoff management uses several best practice management techniques to mitigate the impact of runoff from forested or logging areas entering the waterways. These include best practice measures such as avoiding machinery work in wet weather, closure of haulage tracks during prolonged wet weather and the application of exclusion zones alongside waterways and large drainage lines. Physical interventions include road silt management, buffer strips and temporary drainage crossings (Box 15). Note that evaluating interventions following a forest fire were out of scope for this report.

Box 15. Description of different forestry runoff management interventions

Road silt management techniques include the use of silt curtains along the side of haul roads and geotextile filter cloth or hale bale silt traps along road drains to trap silt before it enters the waterways.

Buffer strips are areas of ground cover and vegetation located alongside drainage lines and creeks. The roughness of a vegetated area acts to slow surface flow velocities thereby encouraging sediment deposition.

Appropriate design of temporary drainage crossing points can reduce the level of disturbance and therefore amount of sediment entering the watercourse. Best practice includes crossing watercourses at right angles, on a straight section of the creek and use runoff controls and fluming so that runoff is not discharged onto any loose fill near the approaches or abutments and abutments are stabilised using rock protection, compacting, benching or revegetation.

No information could be found about the projects investigating the effectiveness of forestry runoff interventions within the HWS region. A recent review on the effectiveness of some interventions for the NSW Natural Resources Commission was used as a basis for the evaluation:

Alluvium (2020) Review of the current state of knowledge for the monitoring of forestry impacts on waterway health in NSW coastal forests. Report for the Natural Resources Commission. pp 1-33. December 2020.

Forestry runoff Management	
General Information	
Conceptual model management lever	Forestry run-off management
Intervention group	Rural land management
Assets intervention group relates to	Rivers, wetlands and estuaries
Conditions intervention potentially supports	Water regime, Water Quality, Vegetation Extent, Physical form
Key values intervention potentially supports	Fish, platypus, macroinvertebrates, frogs, birds
Application of use	
Who is currently using the intervention in region	Vic Forests, Private forestry operations
General use of intervention group in the region	Part of legislative requirements for logging in catchments

On-ground intervention techniques applied	Road silt management techniques such as silt curtains, hay bales and geotextile filter cloths, vegetated buffer strips and drainage crossing points
Relevant administrative interventions	Legislation: *Forests Act 1958, Conservation, Forests and Lands Act 1987, Flora and Fauna Guarantee Act 1988, Water Act 1989, Catchment and Land Protection Act 1994, Environment Protection and Biodiversity Conservation Act 1999, Environment Protection Act, 2017* Strategy: Guidelines: Code of Practice for Timber Production 2014, Management Guidelines for private native forests and plantations Compliance: Office of Conservation Regulator, Forest Audit Program and Investigations,
Maturity of techniques used in region	Road silt management techniques such as silt curtains, hay bales and geotextile filter cloths: High used regularly in logging areas Vegetated buffer strips: High used regularly in logging areas Temporary drainage crossing points: High as guidelines have helped to improve design in logging areas over the past 10 years.
Current application barriers	Onground Barriers for use for onground intervention techniques relate to landscape characteristics such as slope and soil type. These can be overcome through consideration of how and when logging practices are undertaken and identifying the most appropriate location for a technique. Administrative A barrier for administrative interventions is the compliance and enforcement of the Timber Code of Practice
Maintenance requirements	Mixed. Some require annual maintenance and others will only need maintenance as required as they are temporary measures during the logging operation.
Potential outcomes	
Potential beneficial outcomes	Improvement of water quality and amenity
Potential adverse outcomes	Nil
Learning	
Relevant research project(s) or monitoring programs in region	No known recent programs identified for the region
Lessons learned in application	Not available
Effectiveness and appropriateness	
Level of effectiveness of intervention technique	Road silt management techniques: Moderate during low to moderate intensity rainfall events if applied correctly to trap sediment and limit drainage connectivity from disturbed areas to waterways and drainage lines. Less effective in high intensity rainfall. Vegetated buffer strips: Moderate if the vegetated buffer is undisturbed and the width is between 5– 50 m depending on the size of the receiving waterway. Effectiveness varies depending on slope of buffer strip. Temporary drainage crossing points: Moderate depending on the design and the extent disturbed surfaces with 20 m of the crossing are rehabilitated and stablished.

Level of appropriateness of intervention technique	Road silt management techniques: High as has limited health and safety risks in application and can be used across a broad range of landscapes due to the range of techniques and products available. Vegetated buffer strips: High as retains natural vegetation structure and can be applied across a broad range of landscapes. Temporary drainage crossing points: Moderate as depends on the construction location and the complexity of the design.
Emerging techniques or the potential to use an intervention technique more broadly	None identified

Community facilities

There is only one intervention group that is addressed in this document within this management lever, access management.

Access Management

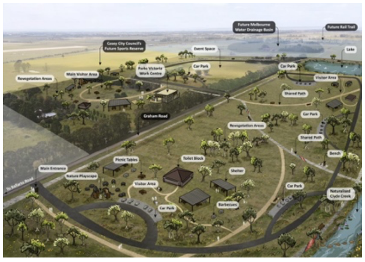
Access management involves improving access to waterways to support social values such as amenity, recreation and community connection. There are six techniques of the intervention used for HWS implementation; paths, canoe platforms, improving existing access, new open space, visitor facilities and signage (Box 16).

Box 16. Description of different access management techniques

Paths can improve access to and along waterways for recreation, amenity and commuting.

Canoe platforms enable a safe way to access on-water recreation such as canoeing, kayaking and rowing.

Improving existing access involves either upgrading or widening existing access paths, replacing stairs with ramps to provide inclusive mobility access or installing a bridge across a waterway.



New open space involves the designation of land as a public park for recreation, biodiversity and cultural objectives.

Visitor facilities such as benches, bbqs, drinking fountains, bird watching hides, outdoor gyms etc can encourage people to use the space for longer and more frequently.

Signage can encourage people to access and use the space for longer and learn about the surrounding environment or past history and to highlight particular issues or features. Creating a series of signs along a waterway creates a journey for participants to experience.

The following information was used to compile information about the intervention and to support the assessment of the effectiveness and appropriateness of the different intervention techniques currently used in the region.

Gascon, M., W. Zijlema, C. Vert, M. P. White and M. J. Nieuwenhuijsen (2017). "Outdoor blue spaces, human health and well-being: A systematic review of quantitative studies." International Journal of Hygiene and Environmental Health **220**(8): 1207-1221.

Kohlhardt, R., Honey-Rosés, J., Fernandez Lozada, S., Haider, W. & Stevens, M., (2018). Is this trail too crowded? A choice experiment to evaluate tradeoffs and preferences of park visitors in Garibaldi Park, British Columbia. *J. Environ. Plann. Manag.* **61**, 1–24.

MWRPP (2022) Draft Research Project Summaries - MWRPP Project: Community engagement with Melbourne's blue spaces before, during and after the COVID-19 pandemic

Pitt, H. What prevents people accessing urban bluespaces? (2019) A qualitative study. *Urban For. Urban Green.* **39**, 89–97.

Wilson, L., Giles-Corti, B., Burton, N., Giskes, K., Haynes, M., Turrell, G., (2011) The associated between objectively measured neighbourhood features and walking in middle aged adult. AM. J. Health Promot. 25, 2-21.

Ying, Z., Ning, L., Xin L., (2015) Relationship between built environment, physical activity, adiposity and health in adults aged 46-80 in Shanghai, China. J. Phys. Act. Health 12, 569-78.

Access Management	
General Information	
Conceptual model management lever	Community facilities
Intervention group	Access Management
Assets intervention group relates to	Rivers, wetlands and estuaries
Conditions intervention potentially supports	Access
Key values intervention potentially supports	Amenity, Recreation and Community Connection
Application of use	
Who is currently using the intervention in region	Parks Victoria, Local Government, Melbourne Water, Community volunteers
General use of intervention group in the region	Regularly used across the region with a focus in urban areas
On-ground intervention techniques applied	Paths, canoe platform, improving existing access, new open space, visitor facilities and signage
Relevant administrative interventions	Legislation: *Water Act 1989, Local Government Act 2020, Parks Victoria Act 2018* Strategy: Plan Melbourne 2020-2050, Open Space for Everyone 2021, Local government walking and cycling strategies, Local government open space strategies Plans: Victorian public health and wellbeing plan 2019-2023 Guidelines: Constructed Waterways in Urban Developments Guidelines 2009, Melbourne Water Shared Pathways Guidelines 2009
Maturity of techniques used in region	Paths: High used regularly in providing access along waterways using a variety of materials. Canoe platforms: Moderate as although have been present for many decades, new canoe platforms using different materials and designed for more inclusive use have been installed over the past 5 years.

	Improve existing access: Moderate as this is developing with greater understanding of mobility needs and modifying access for shared paths. New open space: High has been applied across the region over many year and most recently through the suburban parks program and local council open space initiatives. Visitor facilities: High with a variety of different facilities used across the region with an increasing use of recycled materials. Signage: High as often placed in locations with lots of foot traffic to communicate information and maximise education benefits.
Current application barriers	On-ground The main on-ground barriers relate to available space, cost of installation and ongoing maintenance costs and liabilities around potential health and safety risks of ageing infrastructure. Administrative Funding is common focused on constructing new access interventions, less so on their maintenance.
Maintenance requirements	Many of these interventions require regular maintenance for health and safety reasons and some like visitor facilities, paths and canoe platforms can require renewal/replacement after a long period of time due to use, impacts from being exposed to the weather and also changing community expectations.
Potential outcomes	
Potential beneficial outcomes	Improvement of social values such as amenity, recreation and community connection.
Potential adverse outcomes	Increased access can have negative impacts to biodiversity in bush settings Increased access through paths can increase the area of imperviousness if concrete is used for paths.
Learning	
Relevant research project(s) or monitoring programs in region	Community engagement with Melbourne's blue spaces before, during and after the COVID-19 pandemic (2020 – 2021)
Lessons learned in application	Lessons learned from Community engagement with Melbourne's blue spaces before, during and after the COVID-19 pandemic research project: • A combination of desktop analysis of human movement data and online questionnaires was used to identify how the COVID-19 restrictions changed community awareness of and engagement with Melbourne's waterways and other blue spaces. • The majority (80%) of survey respondents spent more time in blue and green spaces and 89% had a stronger appreciation for them due to the restrictions. However, some noted the lack or poor quality of such spaces in their local areas. Respondents also expressed concerns about litter and safety, particularly around shared pedestrian and cycling paths. • The top ways to increase the value of these spaces as suggested by survey respondents include increasing vegetation, providing information about plants, animals, and cultural values, improving enjoyment facilities, and offering community events. These suggestions align with the Healthy Waterways Strategy's performance objectives to increase vegetation cover and access to waterways and could be

	extended to strengthen connections to place through education and community facilities. • The results from this research confirm the relationship between environmental conditions and experiences in the Conceptual Models for the Social Value of Waterways. • Overall, the research highlights the importance of blue and green spaces for physical and mental health and the need to address inequities in access.
Effectiveness and appropriateness	
Level of effectiveness of intervention technique	Paths: Moderate due to variable findings in studies for inland rivers (Wilson et al 2011, Ying et al 2015, Gason et al 2017) on use of paths vs proximity to waterway but other factors such as perceptions on safety, litter and water quality can strongly influence the usage of paths (Pitt, 2019). Canoe platforms: High as installation of a canoe platform is likely to increase access to on-water recreation in a particular location. Improve existing access: Moderate as while improvements may enhance social values such as recreation and community connection, other factors such as safety and water quality can limit the extent of access (Pitt, 2019). New open space: High as enhances social values to locations where visitors have not previously been able to access. Visitor facilities: High as studies (e.g. Kohlhardt et al 2018, Pitt 2019) have found that sites with good facilities are linked to more visitors. Signage: Unable to assess as no information found in terms of effectiveness but likely related to the design and type of information provided in the sign.
Level of appropriateness of intervention technique	Paths: Moderate as sometimes particular areas are best managed for environmental values rather than social values Canoe platforms: Moderate as the location of canoe platforms needs to be carefully considered to ensure easy and safe entry and exit from the waterway and nearby facilities such as parking Improve existing access: High as several options exist to improve existing access to encourage mobility inclusive use as well as improve wellbeing experience. New open space: Moderate as opportunities are limited due to availability and cost of land. Visitor facilities: Moderate as it depends on the type and location of facilities but generally, facilities help to enhance social values for waterways. Signage: High can be used across a broad range of applications for education and awareness raising while accessing waterways
Emerging techniques or the potential to use an intervention technique more broadly	The use of QR codes on signs is gaining momentum in natural resource management as a way to provide more information to interested members of the community, encourage action to be taken (e.g. download Frog census app to monitor frogs) and to track engagement.

5. Synopsis of stocktake

Key findings

A total of 81 intervention techniques were evaluated based on maturity of application in the region and effectiveness and appropriateness of the region.

Application and maturity of intervention techniques used in the region

Intervention techniques were reviewed to ascertain the level of application across the region and maturity of their use.

Just under half (44%) of the 81 intervention techniques reviewed were assessed as high for application and maturity, meaning they have been used across the region for 10 years or longer and represent interventions that are 'tried and tested'. Many of the interventions in the Sediment control, Pest animal control, Wastewater management, Rural land management, Forestry management intervention groups fell into this category.

25% of the interventions were assessed as moderate application and maturity with their use gaining momentum over the past 10 years. Interventions in this category included those in the Stormwater infiltrate, Stormwater harvest and Industrial pollution management groups. The maturity of these interventions likely reflects an increase emphasis in the current and previous HWS on addressing stormwater flows and urban and industrial water quality.

Interventions were assessed as low maturity if they had limited application within the region, or if the intervention was still in the research and development phase (i.e. being trialled through a research or a pilot program). Twelve of the 16 intervention groups had at least one intervention technique assessed as 'low maturity', and overall 30% of intervention techniques were assessed as low maturity.

Interventions still in the research and development phase included litter vacuums, precinct toxicant traps, smart tanks, levee modification, structural flow interventions, noise (pest animal control) and thermal weed treatment.

Effectiveness of intervention techniques

The investigation into interventions originally intended to assess and provide a high-level evaluation of the effectiveness and appropriateness of HWS interventions in response to KEQ 4a. However, preliminary analysis and review of the literature revealed that interventions were more commonly reported as partially effective or having mixed results (i.e. effectiveness varied between studies or results being inconclusive or dependent on the site context or intervention design) (Figure 4).

This mirrors a similar finding to Doerr et al 2018 (who developed a knowledge bank of management effectiveness for NRM in Australia) who found that interventions were more commonly reported as partially effective. They reported it was unclear whether full effectiveness is achievable as it is often context specific meaning it can be difficult to come up with general findings for effectiveness.

Instead, as part of the foundational work we summarised the available evidence from studies conducted in the Melbourne region and where there was sufficient evidence, we identified a preliminary list of interventions for further consideration.

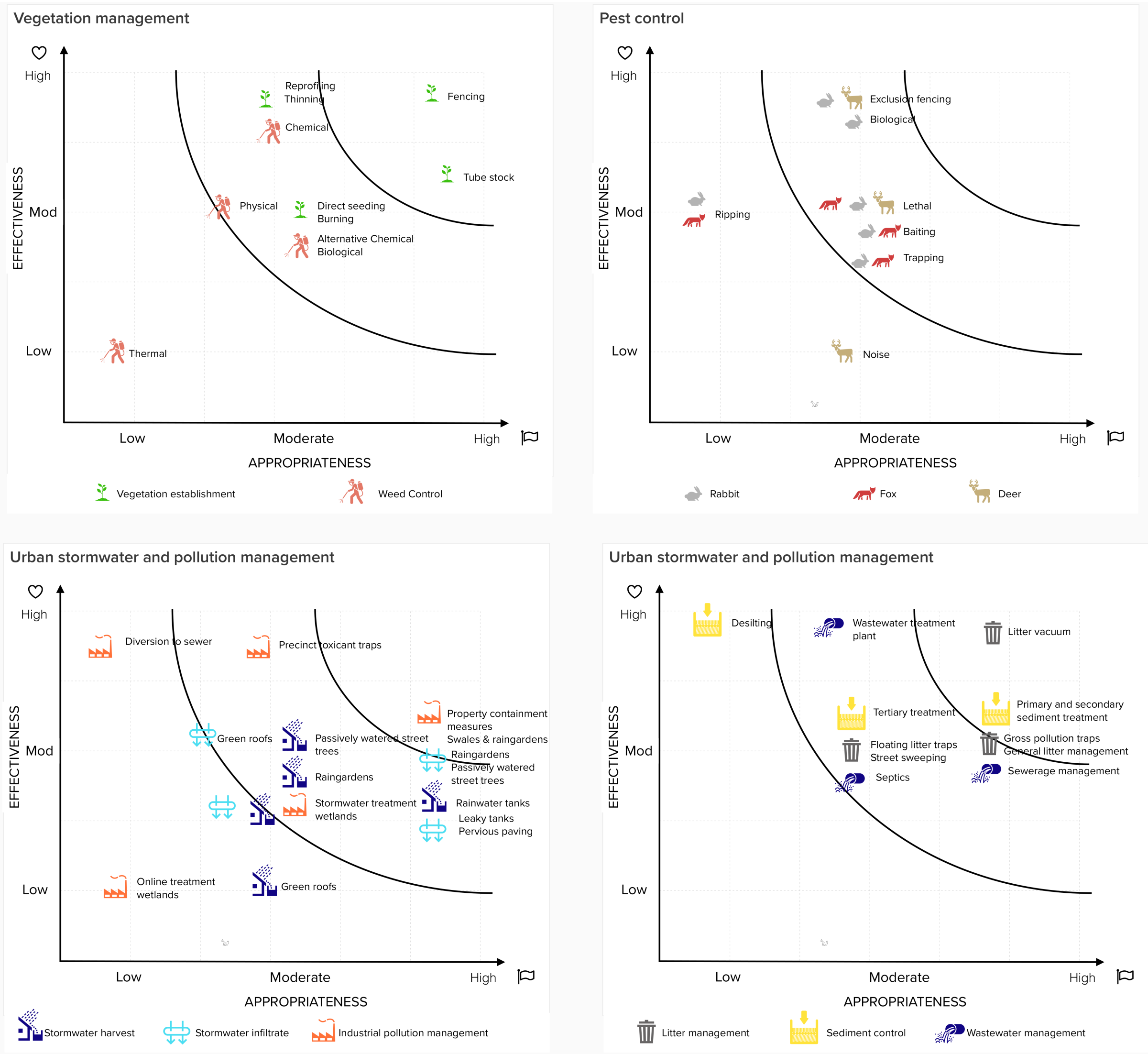


Figure 4. Summary of the evaluation results for some interventions used in the HWS region.

Based on the results from the investigation, three categories of intervention have been identified to flag through the Science Inquiry with the following characteristics (see Table 5)

1. *Interventions that could benefit from improvements to design/implementation and or maintenance.* HWS partners may want to consider how to adjust or refine techniques in response to the findings from research. Eleven interventions were included in this category.

2. *Interventions that have been tested through research and pilot programs and found to be effective, but to date have not been adopted widely.* HWS partners could consider if there are opportunities to apply these interventions more broadly. Fourteen interventions were included in this category.

3. *Interventions with evidence indicating they have limited or low effectiveness or may not be appropriate for application.* HWS partners may want to consider stopping or changing the way these interventions are applied. Only two interventions were included in this category,

however the Interventions technical report highlights a further seven interventions that may require careful consideration, subject to further review of the evidence.

Table 5. Interventions for further consideration by Melbourne Water and partners.

Intervention group	Intervention	Maturity of intervention in region	1.Potential to improve intervention	2. Tested through research/pilot programs but not widely adopted	3.Reconsider due to limited effectiveness/ appropriateness
Vegetation establishment & maintenance	Tubestock planting	High	✓		
	Direct seeding	Low		✓	
	Reprofiling (saltmarsh)	Low		✓	
Weed control	Chemical weed control	High	✓		
	Alternative chemical control	Low		✓	
Pest animal control	Ripping near waterways	High			✓
	Lethal control (deer)	Moderate		✓	
	Exclusion fencing (deer/rabbits)	Low		✓	
Instream barrier management	Fishways	High	✓		
	Barrier operation change	Low		✓	
Channel modification	Daylighting / naturalisation	Moderate	✓		
	LWD introduction / fish hotels	Low		✓	
Floodplain wetland flow management	Structural flow intervention, Partial levee removal and Pumping	Low / Moderate		✓	
Stormwater infiltrate & harvest	Smart tanks	Low		✓	
	Stormwater wetlands	Moderate	✓		
	Raingardens	Moderate	✓		
	Green roofs	Low		✓	
	Leaky tanks	Low		✓	
	Passively watered street trees	Moderate	✓		

Intervention group	Intervention	Maturity of intervention in region	1.Potential to improve intervention	2. Tested through research/pilot programs but not widely adopted	3.Reconsider due to limited effectiveness/ appropriateness
Industrial pollution management	Property containment measures	Moderate	✓		
	Precinct toxicant traps	Low		✓	
	Swales and raingardens	Low		✓	
Litter management	Litter vacuum	Low		✓	
Sediment control	Online treatment wetland (tertiary system)	High			✓
Rural land management	Riparian buffers/swales	High	✓		
	Gully erosion control	Moderate	✓		
Access management	Signage	High	✓		

The detailed findings and learnings for each intervention within the three categories are set out in Table 6, Table 7, Table 8. The remaining interventions were assessed as suitable to keep applying as needed.

In addition, the following high-level lessons learned emerged from the research and literature regarding the effectiveness of interventions.

- Interventions are likely to be more effective when used in combination with other interventions.
- Maintenance in the form of follow up activity is crucial to ensure the effectiveness of an intervention is maintained over time.
- Trials and pilot programs are an important aspect of developing new intervention techniques and can be used to understand the benefits, costs and risks in different settings prior to committing to broad scale application.

Table 6. Interventions that could benefit from improvements to design, implementation or maintenance

Intervention	Rationale
Vegetation establishment and management	
Tubestock planting	Tubestock planting tends to be the default method for revegetation in the Melbourne region. Lessons from several intervention monitoring projects in the region and across Victoria indicate that the use of complementary interventions such as weed control, tree guards and stock exclusion fencing increase effectiveness. The density of overstorey species planting could be reduced by carefully considering upfront the implications of the overstorey species outcompeting understorey and ground cover species (which has been observed after 10 years). Planning for revegetation to occur over a number of years, rather than planting all species at once, would help to mitigate this and emulate natural succession resulting in a more natural vegetation community structure. Work is already underway in the region to modify species selection for climate resilience, however the mechanisms and processes to support the sourcing of climate adjusted seed mixes will become increasingly important over the next five years.
Weed control	
Chemical weed control	Chemical control tends to be the default method and is used as part of capital establishment and maintenance revegetation works. Herbicides produce the most effective and reliable weed control outcomes when used for the target species, but environmental and human health risks vary depending on the product used. An integrated strategy that combines physical, chemical, biological and alternate chemical methods may be required in the future in order to manage environmental and public health risks.
Instream barrier management	
Fishways	Fishways have been installed across the region, however some designs are in early adoption (e.g. cone fishway) compared to others (e.g. rock ramp). Lessons from the Dights Fall Weir upgrade and Pillars Road fishway highlight the importance of undertaking fish surveys to monitor the effectiveness of fishway operation and inform upgrades or rectification works to maximise the effectiveness for a range of species over time.
Channel modification	
Daylighting / naturalisation	Daylighting and naturalisation has been applied in five locations through the Reimagining your creek program since 2018. While there are assertions that this program helps to improve environmental and amenity values, no monitoring results from the program are current available to support this. A proportion of investment in applying this intervention could include monitoring and evaluation of environmental and social conditions as part of adaptive management and learning based process.
Stormwater infiltrate & harvest	
Infiltration wetlands	Stormwater wetlands have been designed primarily to treat stormwater through infiltration and nutrient removal via vegetation. There is a need to improve the standard designs to maximise infiltration rates and harvesting opportunities to reduce the volume of stormwater entering waterways to help meet the HWS stormwater targets as well as meet best practice for nutrient removal. Harvesting is critical as research has shown that infiltration systems alone cannot improve stream health. However harvesting stormwater from existing stormwater wetlands built for primarily removing nutrients and toxicants does have a number of issues related to the potential level of toxicants. Recent toxicant surveys of wetlands in the region should be used to inform stormwater reuse and recycling schemes.
Raingardens	Raingardens have had moderate application in the region, particularly by councils. Designs typically focus on encouraging nutrient uptake by plants. There is potential to improve designs in future applications to maximise infiltration as well as removing toxicants and nutrients.
Passively watered street trees	Passively watered street trees are an intervention that has been increasingly applied by councils in the past 10 years. Research has shown that to maximise the stormwater treatment or runoff reduction, the tree pit area needs to be sized according to the exfiltration rate of the native soil. Access to stormwater

	can double the growth of street trees compared to traditional planting techniques, but if not carefully managed, passive irrigation may lead to reduced tree growth or even death due to waterlogging.
Industrial pollution management	
Property containment measures	While property containment measures can be effective, many businesses, particularly small to medium ones fail to install these. These measures should be incorporated when designing new industrial estates.
Rural land management	
Riparian buffer/swales	Riparian buffers and swales are used regularly across the region to improve water quality. Recent research indicates that setbacks should be wider in areas where higher or more concentrated flows are expected. Maintaining dense vegetation at the ground surface reduces erodibility and improves flow interception Re-planting with shade-tolerant species can be considered to improve density. In high relief landscapes, with narrow buffers, pollutants from groundwater are unlikely to be significantly mitigated by buffers. In these circumstances, at source methods of control including fertiliser application management should be the focus.
Gully erosion control	Gully erosion control involves stabilising erosion and managing surface flow from the catchment. The intervention has been applied in the Melbourne region but recent research has identified improvements to design. Installing fencing along gullies can provide water quality benefits regardless of the width by excluding cattle from the stream bed and adjacent banks. Where stock exclusion is not possible rotational grazing (managing grazing pressure) can improve sediment, nutrient and microbial water quality. Lessons regarding width and design for riparian buffers also have application for this intervention.
Access management	
Signage	The use of QR codes on signs is gaining momentum in natural resource management as a way to provide more information to interested members of the community, encourage action to be taken (e.g. download Frog census app to monitor frogs) and to track engagement.

Table 7. Interventions that have been tested through research or pilot programs but not applied widely.

Intervention	Rationale
Vegetation establishment and management	
Direct seeding	Direct seeding has had limited application in the region as it can be difficult to use in riparian areas. Direct seeding is effective for establishing overstory on large, flat, and accessible sites, but its success can be limited by weed competition. There is potential to use direct seeding more broadly where the settings are appropriate and if the primary objective is the establishment of overstorey. Supplementary planting shade tolerant understorey species using tube stock could be considered after establishment.
Reprofiling (saltmarsh)	Reprofiling has had limited application in the Melbourne region. The method can be effective if it provides the right level of inundation and water regime. Reprofiling and shaping of the western lagoon at the Western Treatment Plant has helped facilitate natural recolonisation of saltmarsh through the creation of hydraulic conditions beneficial for the community. Monitoring of Western Lagoon has demonstrated that the technique is very successful and is progressing towards a functioning ecosystem comparable to adjoining areas of remnant saltmarsh.
Weed control	
Alternative chemical weed control	Alternative chemical treatment is used by a few councils in suburban or high public use areas. It involves the use of biodegradable products such as acetic acid, pelargonic acid and manuka oil to kill weeds. A review of literature indicates they are most effective on small annuals and broadleaf species but are less effective for the control of large established perennial species or grasses.

	There is opportunity to incorporate alternative treatments in combination with other weed control techniques as part of an integrated program.
Pest animal control	
Lethal control (deer)	Both lethal control and exclusion fencing have been applied in the Melbourne region to control deer in specific locations and circumstances. A recent review of literature found that non-lethal strategies are only effective over the short-term (weeks) and those that are effective, generally reduce impacts but do not mitigate them entirely. Exclusion fencing remains the most effective non-lethal method to prevent impacts by deer provided they are constructed appropriately and are regularly check and maintained. However, the technique is costly and thus usually limited to small and medium-sized projects. Lethal control through ground-shooting can effectively reduce deer densities and impacts but requires sufficient resources over a long period of time.
Exclusion fencing (deer / rabbits)	
Channel modifications	
LWD / Fish hotels	LWD reintroduction has only been used at a small number of locations in the Melbourne region, and most were undertaken over 10 years ago. Evaluating the effectiveness of existing structures and reviewing contemporary approaches used in other regions would assist with providing new information to inform future LWD reintroductions.
Instream barrier management	
Barrier operation change	Barrier operation change has not been applied widely in the region but could be used more in the future during periods of high flows. Lessons from the Starvation Creek Weir change of operations indicate that modification to standard operating procedures can be made to enable sediment and coarse particulate organic matter (CPOM) to move through a system. While there are risks associated with potential deoxygenation, research from xx indicates that this can be minimised through timing with high flows. Intervention monitoring could be used to understand how to minimise the risks and the potential benefits to environmental values and maintenance costs.
Floodplain/wetland flow management	
Structural flow intervention	Structural flow interventions (diversion weirs, pipes and pumps) have only been trialled as part of research and pilot programs for wetlands and floodplains on the Yarra River. The mixed results indicates potential to be applied in other projects however, they do require detailed understanding and monitoring of the local environment, along with a regular maintenance regime to be effective. In particular, the approach of trialling the intervention before investing in an engineered permanent structure is recommended to enable adaptive management for complex systems.
Industrial pollution management	
Precinct toxicant traps	Precinct toxicant traps in industrial estates are still in the trial phase. They are designed to trap sediment and pollutants and prevent them from entering the stormwater system. They are most effective when used at the start of a treatment train and easy access to the removal of waste products has been factored in.
Swales and raingardens (industrial areas)	There has been limited uptake of lot and streetscape swales and raingardens in industrial areas. They tend to be more suitable for 'light' industrial areas, as the contaminate loading from sites will be too high for these vegetated systems. These treatments can be integrated at low cost within an industrial site.
Stormwater infiltrate and harvest	
Leaky tanks	Leaky tanks have only been installed in a small number of sub-catchments as part of research and trial programs. Lessons from the Dobsons Creek pilot indicate that controls such as leaky tanks and rain tanks positively influenced the stormflow hydrology of small to moderate storm events (2-8mm), however they diminished for large storm events (>20mm). They are best incorporated with other storm control measures and the potential for a 'maintenance lag' needs to be factored in.
Smart tanks	Smart tanks can be remotely controlled to release water and are being tested as part of the Monbulk Creek smart water network research project. This project is in early stages of implementation but a recent ARC grant provides a unique opportunity to build on this to explore the potential of a market-

	driven smart-grid of stormwater storages, providing consumers with nonpotable water supply, while financially rewarding them for contributions to flood mitigation and environmental flows to waterways.
Green roof	Green roof interventions have had limited application in the Melbourne region to date, despite great potential to reduce stormwater runoff. Research and monitoring of green roofs in Australia has provided important lessons in adapting designs for the climate and vegetation species. The maintenance requirements for green roofs is complex but recent publication of Australian maintenance guidelines will help to improve understanding of maintenance to ensure to ensure they continue to deliver aesthetic and environmental outcomes.
Litter management	
Litter vacuum	Litter Vacuum is a device used to suck litter from hard to reach areas such as along river banks or reed beds or road verges. A trial application has been completed in the Lower Yarra. The technique is effective at removing litter that is difficult to extract via traditional methods in hard to access areas. There is potential to use this technique more frequently along major waterways that have a wide margin of reeds that trap litter that is difficult and time consuming to remove.
Rural land management	
Farm dam management	Farm dam management has had variable application in the region and involves managing stock access and control of erosion around the dam (i.e. from cattle or the inflow point) as well as planting vegetation and installing floating islands or partly submerged logs for biodiversity outcomes. Research from North East Victoria has shown management through fencing and planting helps to lower levels of nitrogen, turbidity and e-coli counts and increase macroinvertebrate diversity as well as improving farm productivity and weight gain in stock.

Table 8. Interventions that have limited effectiveness or appropriateness.

Intervention	Rationale
Sediment control	
Online treatment wetlands [tertiary treatment]	Research indicates online wetlands consistently fail to meet minimum performance objectives for water quality treatment, with higher water levels, frequent bypassing of stormwater flows and lower vegetation cover than required.
Pest animal control	
Ripping near waterways	Ripping is not a suitable intervention along riverbanks and steep slopes due to the risk of soil erosion or bank instability. May be suitable in other contexts e.g. when used in paddocks or open spaces away from waterways.

Future research

Several intervention monitoring programs have implemented over the years to understand effectiveness and improve application for the region.

As noted in Doerr et al 2018, the effectiveness of natural resource management (NRM) programs can be improved by comparing multiple interventions that are designed to achieve the same outcome, rather than examining one intervention at a time. This approach has been used in the region (e.g. stormwater control measures, revegetation techniques) and allows for more rapid learning and can increase the cost-effectiveness of NRM investment while minimising the risk of future investment. Programs can be designed to apply two or more specific interventions intended to achieve the same outcome so that their outcomes can be compared. This approach should continue and expand to consider other intervention groups.

Doerr et al 2018 also reflected that incorporating a few sites with novel interventions into a broader program in which multiple interventions are being compared can both minimize the risk and maximize learning. This is currently underway with research testing the use of smart tanks and leaky wetlands. Programs must also be designed so that comparisons can be made with control sites to unpick the influence of interventions versus other drivers within a system, and monitoring additional control sites would identify whether the change was occurring regionally, regardless of investment.

It should be noted that not all intervention types lend themselves to being monitored with formal comparisons and controls (e.g. environmental watering), and in such cases, clear articulation of the anticipated system change that will occur through interventions over time is essential using conceptual systems models, and monitoring and learning about effectiveness should focus on testing those conceptual models.

Future research is needed to understand how the effectiveness of different intervention techniques could potentially be impacted by climate change. A good example of this is fishways which are designed based on local condition hydrology and hydraulics. A change in flow conditions could reduce the effectiveness of the fishway, a phenomenon that is already happening. There are likely to be several intervention techniques that have been previously installed that may need to be adjusted to maintain effectiveness and conversely there will be intervention techniques that need to be applied to help maintain climate resilience. Local empirical local studies on climate implications for interventions are needed to ensure current and future intervention investment is good value for money.

6. Summary and recommendations

A stocktake of management actions being undertaken as part of the HWS has documented the maturity of actions, key lessons from recent monitoring and evaluated the appropriateness and effectiveness of many specific techniques.

Overall there are 8 management levers containing 18 intervention groups and 81 techniques. The outcomes suggest that 2 intervention techniques are inappropriate and should not be continued (i.e. on-line constructed wetlands and ripping near waterways). There are a number of techniques which require careful consideration in the project design phase (such as thermal weed control and noise deterrent for deer control), a number where improvements to techniques are available (mainly for stormwater management and weed control) and others where we should start to implement actions more broadly such as instream habitat enhancements and precinct scale toxicant traps in industrial areas.

Future research is needed to understand how the effectiveness of different intervention techniques could potentially be impacted by climate change. Local empirical studies on climate implications for interventions are needed to ensure current and future intervention investment is good value for money. It is anticipated further consideration of interventions may take place as part of the response to the mid-term evaluation and through asset service planning processes.

The following recommendations are presented for consideration of inclusion in the Science Inquiry

General

A database and geodatabase be developed to adequately collect all of the management interventions undertaken across the Melbourne Water region. The database should also be able to collect and store survey information.

Improve data collection and reporting of maintenance of interventions to better understand their current level of effectiveness and if additional maintenance is required.

Climate

Explore how existing interventions could be modified to consider enhanced climate resilience. Develop suite of new interventions that will be needed in the future to help with climate resilience. Trials are suggested to determine the short and long-term effects of management interventions on climate change resilience.

Climate adjusted seed should be incorporated in a proportion of Melbourne Waters plantings to assess the effectiveness of this action on reducing the impact of extreme weather events on plantings.

Intervention specific

Due to research demonstrating that online wetlands (constructed within a main river) consistently show higher water levels and lower vegetation cover than required to meet minimum performance objectives, it is recommended that a review of planned online wetlands is conducted, and changes made where feasible. Going forward, online wetlands should not be accepted as water quality treatment systems for new schemes.

Resurvey Large Woody Debris (LWD) reintroduction sites in the region to evaluate their effectiveness after a long period (15+ years) post installation, particularly regarding benefits to fish. There is also a need to revisit the assumptions about LWD reintroduction and assess the benefits of a passive LWD recruitment program vs an active program.

An integrated strategy combining weed control intervention techniques is required to reduce reliance on herbicides due to public concerns of safety to human health and the environment.

Water supply reservoirs and forest agricultural interfaces should be the priority areas for deer impact mitigation measures. A combination of exclusion fencing and lethal control will be required to achieve deer mitigation objectives. A landscape wide approach incorporating coordinated deer control across both public and private land is required over a long time period.

7. References

These references are in addition to the ones listed under each intervention group in Section 3: Intervention Stocktake

Alluvium (2017) Healthy Waterways Strategy Waterway Science Conceptual Models. Report developed for Melbourne Water by Alluvium Consulting, Melbourne.

Department of Environment and Primary Industries (2013). *Improving our Waterways: Victorian Waterway Management Strategy*. East Melbourne.

Doerr VAJ, Davies MJ, Doerr ED, Prober S, Murphy H, McGinness H, and Hoffmann B (2017) Knowledge Bank of Management Effectiveness: Technical guide. CSIRO, Australia.

Doerr VAJ, Dickson F, Davies MJ, Doerr ED, Prober S, Murphy H, McGinness H, Hoffmann B, Turner L and Norman E (2018) Knowledge Bank of Management Effectiveness: Learning from Australia's actions to improve the environment. CSIRO, Australia.

Markiewicz, A and Patrick, I. (2016). *Developing Monitoring and Evaluation Frameworks.* Sage Publishing.

Melbourne Water. (2018). *Healthy Waterways Strategy.* Melbourne Water Corporation.

Melbourne Water. (2019). *Healthy Waterways Strategy Monitoring Evaluation Reporting Improvement framework.* Final report.

Melbourne Water (2020) *Healthy Waterways Strategy Resource Document*. Melbourne Water, Melbourne; https://mwrcstorage.blob.core.windows.net/files/2021-03/HWS-2018-Resource-Document.pdf

Melbourne Water (2023a) Science Inquiry Report: A report to inform the mid-term review of the Healthy Waterways Strategy, Melbourne Water, Docklands, Victoria, Australia.

Melbourne Water (2023b) Threats: A technical report to inform the Healthy Waterways Strategy mid-term review, Melbourne Water, Docklands, Victoria, Australia.

Melbourne Water (*in prep*) Implementation Inquiry Report: A report to inform the mid-term review of the Healthy Waterways Strategy, Melbourne Water, Docklands, Victoria, Australia.

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Healthy Waterways Strategy

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