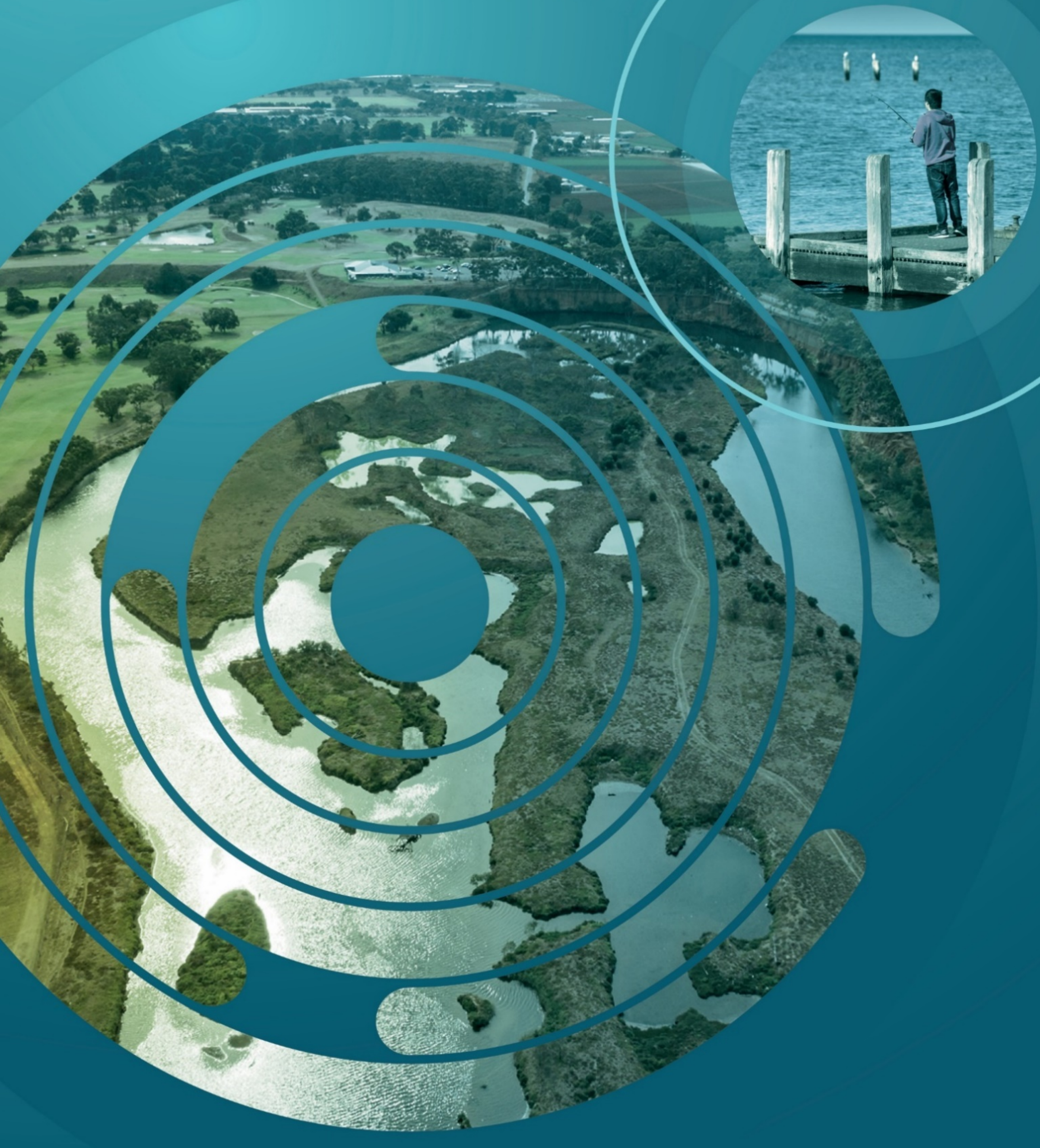
Healthy Waterways Strategy

Estuaries Monitoring and Evaluation Plan

Working together for healthy waterways



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Acknowledgement to Country

We acknowledge and respect Traditional Owners and Aboriginal communities and organisations.

We recognise the diversity of their cultures and the deep connections they have with the region's lands and waters.

We value partnerships with them for the health of people and Country.

We pay our respects to Elders past and present, and we acknowledge and recognise the primacy of Traditional Owners' obligations, rights and responsibilities.

Contributors

This Monitoring and Evaluation Plan for estuaries has been prepared in consultation with many people within Melbourne Water and other agencies. The team responsible for drafting this plan included Trish Grant (Melbourne Water) Bronwyn Gwyther, Fiona Gilbert and Simon Treadwell (Jacobs), Paul Boon (Dodo Environment) Wayne Robinson (NumbersMan) and, Matt Dell (dellbotany),

Many Melbourne Water, State government and university staff were involved in developing the scientific methods that are summarised in this document. We would like to acknowledge their key contributions. These people include Melbourne Water staff Paul Rees, Dr William Steele, Sharyn RossRakesh, Dr Rhys Coleman, Dr Al Danger, Leigh Smith, Karen White, Simone Wilkie, DELWP staff Dr Fiona Warry and Dr Paul Reich, Professor Nick Bond, Dr Michael Shackleton, Dr David Crook and Dr Alison King (Latrobe Uni) (Fish) and Monash Uni staff Dr Reid Tingley, Dr Andrew Weeks and Chung-Huey Wu (EnviroDNA).

Abbreviations and Acronyms

Abbreviation or acronym	Full description
A3P	Aquatic Pollution Prevention Partnership
ARI	Arthur Rylah Institute for Environmental Research
DELWP	Victorian Department of Environment, Land, Water and Planning
EMSS	Estuary Entrance Management Support System
HWS	2018 Healthy Waterways Strategy
MEP	Monitoring and Evaluation Plan
MERI framework	Monitoring, Evaluation, Reporting and Improvement Framework
MWRPP	Melbourne Water Research Practice Partnership; a research partnership between Melbourne Water and the Water Ecosystem Research Group of the University of Melbourne
PPWP	Port Phillip and Westernport catchment region
PPWPCMA	Port Phillip and Westernport Catchment Management Authority

Introduction

The Estuaries Monitoring and Evaluation Plan describes the monitoring indicators and reporting requirements needed to effectively track the progress towards targets and objectives set in the Healthy Waterways Strategy. It outlines how to evaluate the success of the strategy for rivers in the region.

1. Background and context

1.1 The 2018 Healthy Waterways Strategy

The 2018 *Healthy Waterways Strategy* (HWS) (Melbourne Water 2018) is the overarching planning document for the management of rivers, wetlands and estuaries in the Port Phillip and Westernport region. It is a 10-year plan that takes a 50-year outlook and aims to ensure that the values of waterways in the region are protected and improved.

The development of the HWS was led by Melbourne Water, with a stakeholder co-design approach used to determine collaboratively the goals and management actions to be undertaken in each major catchment (Yarra, Maribyrnong, Werribee, Westernport and Dandenong).
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1.2 The HWS Monitoring, Evaluation, Reporting and Improvement Framework

The HWS commits Melbourne Water to developing and implementing a Monitoring, Evaluation, Reporting and Improvement (MERI) plan to support implementation. To address this, Melbourne Water prepared a MERI Framework (Melbourne Water 2019), under which there are three Monitoring and Evaluation Plans (MEPs), one for each waterway "asset class": rivers/streams, estuaries and wetlands. In addition, there will be a separate MEP for regional performance objectives.

Key Evaluation Questions

Under the MERI Framework (Melbourne Water 2019), key evaluation questions (KEQs) were developed to ensure we measure the effectiveness, impact, efficiency, appropriateness, and legacy of the HWS (see Table 1). Accordingly, these KEQs include both *bona fide* monitoring questions regarding environmental change but also administrative and environmental survey-type questions. Monitoring requirements outlined in this MEP will contribute directly to addressing KEQs 1, 2, and 3 in the MERI Framework. KEQs 4 and 5 are not focused on estuary environmental conditions or values and these are addressed in the MERI Framework rather than the Estuaries MEP.

Table 1. Healthy Waterways Strategy key evaluation questions (from Melbourne Water 2019).

Evaluation question	When it is asked
KEQ No. 1 - To what extent have the performance objectives of the Strategy been achieved?	Annual Event-based (as needed) Mid-term (2022)
KEQ No. 2 - To what extent has progress been made towards the longer term environmental condition targets for rivers, wetlands and estuaries?	Mid-term (2022) End of Strategy (2026)
KEQ No. 3 – What is the state of waterway values?	Mid-term (2022) End of Strategy (2026)
KEQ No. 4 -To what extent have the delivery methods of the Strategy been cost effective and efficient?	Mid-term (2022) End of Strategy (2026)
KEQ No. 5 – To what extent have legacy items been identified and managed for?	End of Strategy (2026)

Reporting timeframes

Although the HWS has a temporal scope of ten years, 2018/19 – 2027/28 (inclusive), data will be needed to inform reporting midway, in 2022, and again in 2026 (to allow time for evaluation and for findings to be adopted before the preparation of a new strategy) (see Figure 2). Although reporting on wetland condition and key values will occur at mid-term and towards the end of the HWS most significant improvements – are expected to take longer than this to become evident. Therefore, reporting during the HWS will involve a mix of **output** reporting (the measurable result of management activity, such as hectares of revegetation) and **outcome** reporting (the resulting impact of these activities, such as increased area of native vegetation).

Years 1-2 of strategy implementation (i.e. 2018/19 and 2019/20) are foundation years and involve: "*finalising MEPs, refining indicators, improving systems and data management, collecting phase 1 data, testing evaluation methods and developing report templates and conducting the first annual review* (Melbourne Water 2019)." The three MEPs will be reviewed periodically, and no later than mid-term (2022) to ensure that new techniques and any safety issues are addressed.

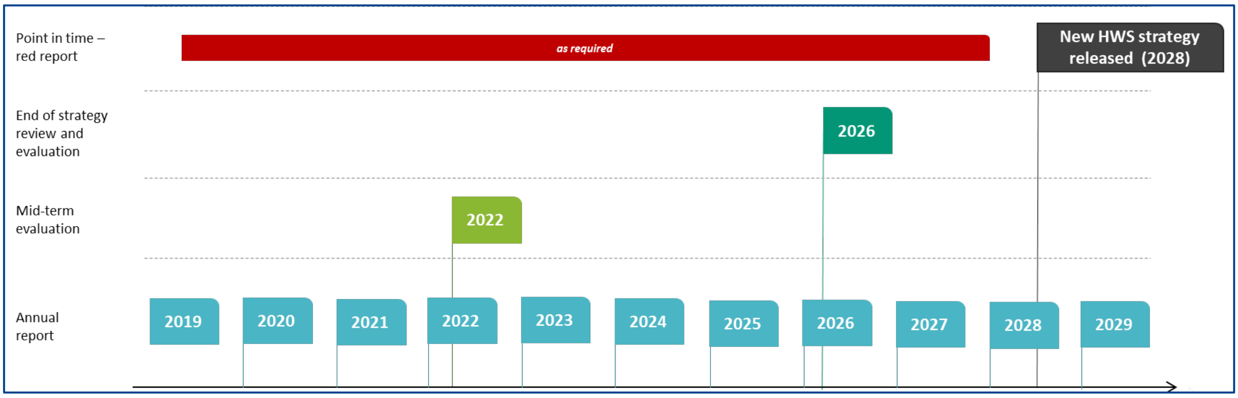

Figure 2. Reporting timeline for the 2018 Healthy Waterways Strategy (Melbourne Water 2019)

1.2 Our Estuaries Monitoring and Evaluation Plan

This plan fulfils the requirement for an Estuaries MEP and describes the requirements for key estuary values and conditions to be measured consistently for the duration of the HWS. The document will be updated over time, but particularly at mid-point of the HWS, to adopt learnings and efficiencies, such as developments in monitoring methods and analytical techniques. Similar information for the other asset classes can be found in the Wetlands MEP and Rivers MEP and information about regional targets are provided in the Regional Performance Objectives MEP.

A thorough safety review has been undertaken during the development of the MEPs which was partly initiated due to an electrofishing incident in 2019. Key initiatives resulting from this review include:

- Elimination, substitution and reduction of monitoring activities whilst confidently addressing the KEQs through safety in monitoring design approaches including maximising the adoption of eDNA and remote surveillance approaches where appropriate
- Waterway Monitoring Safety Risk Register as a Melbourne Water controlled document with commitment to review annually
- Commitment to develop standard safety operating procedures for electrofishing and high-risk monitoring activities
- Coordinated site selection and program delivery to ensure safety at monitoring site locations
- Commitment to innovation and improvement through investment in research and practices that improve safety monitoring, including working with our partners and experts
- Commitment to updating the partners Code of Practice for electrofishing.

This MEP presents a summary of planned Estuary monitoring for the HWS. It adopts and builds upon many existing monitoring programs. So, where comprehensive or contextual information is available in existing documents these are referred to, rather than repeating detailed information here.

The Estuaries MEP is for all priority estuaries in the Port Phillip and Western Port (PPWP) region. It focuses on the:

- Indicators and methods for monitoring and evaluation for HWS targets and objectives
- Accountabilities for monitoring, reporting and evaluation
- Timeframes and Reporting
- Knowledge gaps (research and intervention monitoring)

The following is an overview of the contents of this MEP so that the reader can identify the part (or type of target) that is most relevant to their work and interest.

MEP section	Title	Purpose and time frames	Key Audience
Part A	**Monitoring Implementation** *How are the estuary performance objectives tracking?*	Determining how Performance Objectives will be tracked and evaluated. How the strategy is being implemented locally *Guide on ground works* *Annual planning and prioritisation* *Sub-catchment, catchment and regional scale* *Focus is on **annual** reporting*	Implementers of the Strategy (e.g. MW, PV, local councils, IWM forums) Interested community groups and members Regional Leadership Group
Part B	**Key Values** Surveillance Monitoring *How estuary key values will be monitored*	Determining if the Values are on track to achieve long term targets. State of Environmental and Social Values *Catchment and regional scale focus* *Focus is on **end of strategy***	Long term planners Policy makers Researchers Regional Leadership Group (end of Strategy)
Part C	**Waterway Conditions** Monitoring *How estuary environmental conditions will be monitored*	Determining if waterway conditions are being maintained and improved to support the key Values *Catchment and regional scale focus* *Focus is **mid-term** and **end of strategy***	Medium term planners Regional Leadership Group (end of Strategy) Researchers
Part D	**Research and Intervention** Monitoring	Focussing effort on filling knowledge gaps to drive continuous improvement *Catchment and regional scale focus* *Focus is on **end of strategy***	Researchers MW Communities of Practise

2. About the Estuaries MEP

2.1 Estuaries in the Melbourne region

From a scientific perspective, estuaries are aquatic environments where seawater is measurably diluted by fresh water (Tagliapietra et al. 2009). In the *2018 Healthy Waterways Strategy*, estuaries are defined in pragmatic terms as: "where a river meets the sea, including the lower section of a river that experiences tidal flows where fresh water and saline (salty) water mix together. For the purposes of the HWS, an estuary must be at least one kilometre in length, or have a lagoon longer than 300 metres (Melbourne Water 2009).

Estuaries are often places of high biodiversity value and are important as habitat and nursery areas, as pollution filters and in protecting shorelines against erosion (Victorian Coastal Council 2014; Victorian Saltmarsh Study 2011). They are very important places for many fish and bird species and typically have unique vegetation types that are salt tolerant. Fish that migrate between fresh and marine waters rely on estuaries to provide important triggers for movement; other species live their entire life cycle in the estuary only, still others use estuaries as breeding areas. Birds use estuaries as places to feed and roost. High fish richness and the intertidal mudflats of estuaries provide rich food sources for foraging birds. Estuarine vegetation types, such as mangroves, saltmarsh and sea grass have specifically evolved to only occur in these unique zones.

Estuaries, especially those close to Melbourne, also provide exceptionally high social values with people enjoying them as places to fish and recreate.

Three features of estuaries in the region are relevant to the development of this MEP.

Climate

First, the region spans a section of the Victorian coast that embraces two distinct climates, known as the West Central and the East Central climatic regions (Bureau of Meteorology and Walsh 1993). Annual rainfall across the region varies significantly with the Western shores of Port Phillip Bay typically being the driest (400-600 mm). Summers are typically hot and dry, which can lead to hypersaline conditions developing over summer in the mid- to upper estuary fringe, relieved only by rainfall in the wetter seasons of winter and spring. The dry climate of the west also generates estuarine vegetation, typified by a 'dry' saltmarsh that is quite different to that which occurs around the considerably wetter western side of Western Port (Barson and Calder 1981). The difference in climate between west and east also has major implications for freshwater flow into the various estuaries, and thus for the feature that defines them.

Land use

Second, the estuaries of the region drain catchments with contrasting land uses. Some drain catchments that include large areas of intensive agriculture (e.g. the Yarra River, the Werribee River in the west and the Lang and Bunyip Rivers in the east); others discharge into the sea through land managed by Melbourne Water and mostly closed to human access (e.g. Little River in the region's west); others flow through areas long used for heavy industry (e.g. Kororoit Creek and Laverton Creek); others flow though urban areas with large residential populations (e.g. Maribyrnong River, Skeleton Creek, Patterson River). Such differences in catchment land use have major impacts on the health and value of each estuary (Harris 2001; Webster and Harris 2004; Woodland et al. 2015).

Open or intermittently closed

Third, there are two distinct types of estuaries present in the region. Australian estuaries are often classified on the basis of their geomorphology and dominant hydrological regime (e.g. Roy et al. 2001; Ryan et al. 2003). Along the south-eastern coast of Australia, most estuaries fall into either Group III (permanently open and wave-dominated systems[1]; or Group IV (intermittently closed and open lagoonal systems; see McSweeney et al. 2017). Estuaries within the region therefore include those that are permanently open to the sea (e.g. the mouths of the Werribee, Maribyrnong, Bunyip, Bass and Yarra Rivers) and those that are naturally intermittently open and closed to the sea (e.g. Balcombe and Merricks Creeks estuaries). The two types have markedly different ecological structure and function, as demonstrated in the conceptual models for various aspects of estuary function and stressors at the Ozcoasts website (https://ozcoasts.org.au/conceptual-diagrams/).

Priority estuaries

There are 133 rivers or streams in the Port Phillip and Western Port (PPW) region that flow into the sea: 36 that flow into Port Phillip Bay and 97 into Western Port. Continuing the prioritisation work of the Healthy Estuaries Strategy (Melbourne Water 2011), 29 of these 133 waterways are considered to be priority estuaries in the 2018 HWS (Table 2, Figure 2.). There are also a further 13 waterways in the region that may include an estuarine component, but which require further investigation to conclusively determine whether this is the case. This represents a knowledge gap to be filled under this MEP (see Part D). There are also waterways in the region that have been piped for some or all of their length. Those that have been piped where an estuary would have previously occurred are not included in the Strategy.

[1] see the OzCoasts website at https://ozcoasts.org.au/conceptual-diagrams/typology/estuaries/climate_regions/#sec)

Table 2. Estuaries in the PPW region included in the Strategy.

Catchment / receiving bay	**Estuaries**				
Werribee	Little River	Werribee River	Skeleton Creek	Laverton Creek	Kororoit Creek
Maribyrnong	Stony Creek (PPB)	Maribyrnong River			
Yarra	Moonee Ponds Creek*	Yarra River			
Dandenong	Elwood Canal	Mordialloc Creek	Patterson River	Kananook Creek	
Port Phillip Bay**	Balcombe Creek	Sheepwash Creek	Chinamans Creek		
Westernport Bay**	Merricks Creek	Stony Creek (WPB)	Warringine Creek	Kings Creek	Olivers Creek
	Watsons Creek	Tooradin Road Drain	Cardinia Creek	Deep Creek	Bunyip River
	Yallock Creek	Lang River	Bass River		

**Managed under the Maribyrnong Region Co-designed Catchment Program*

***Managed under the Westernport and Mornington Peninsula Region Co-designed Catchment Program.*

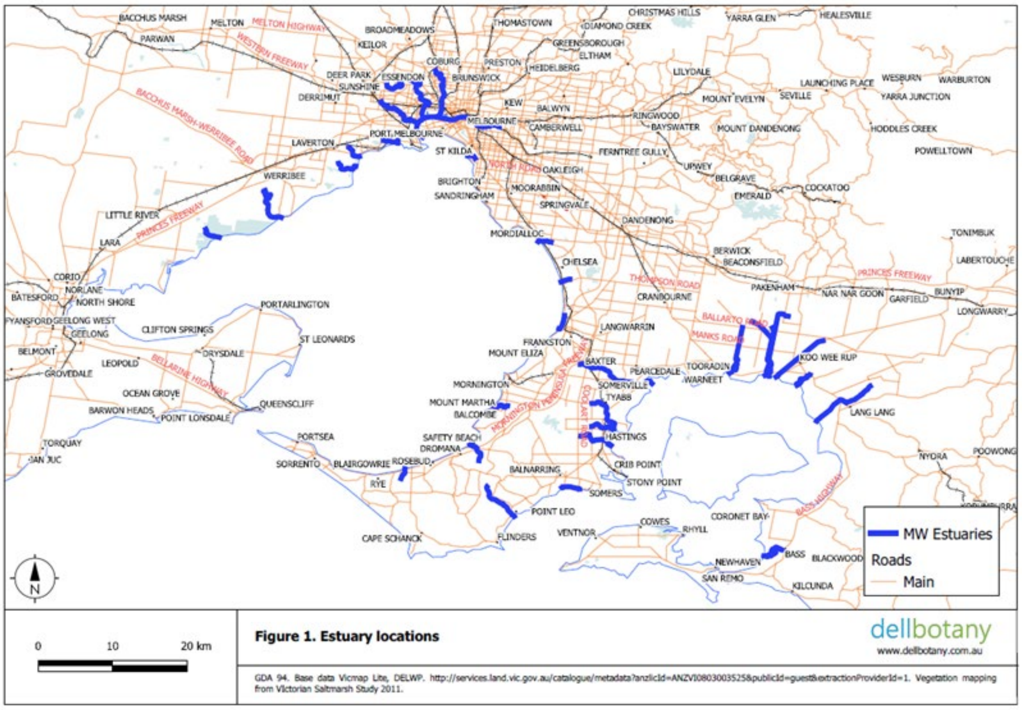

Figure 1 Map of Estuaries included in the HWS (taken from Dell, 2020b)

2.2 Estuary targets (values and conditions) and Performance Objectives

The Estuaries MEP describes the requirements so that key estuary values and conditions are monitored consistently over the life of the strategy (Parts B and C). It also describes how performance objective progress will be tracked and how these will be evaluated (Part A). Additionally, it outlines the key areas of uncertainty that exist around how best to manage estuaries and what research is required to support improvement over time (Part D)

Targets

Targets provide quantitative measures of progress towards the goals and visions of the HWS. The Estuaries MEP outlines how we will monitor, evaluate and report progress against targets and adopt learnings over time. There are three different types of targets in the HWS:

- Performance objectives
- Condition targets
- Key values targets

They have different timescales associated to them in reference to the period of time it can take for a measurable change to occur and be detected (Figure 2).

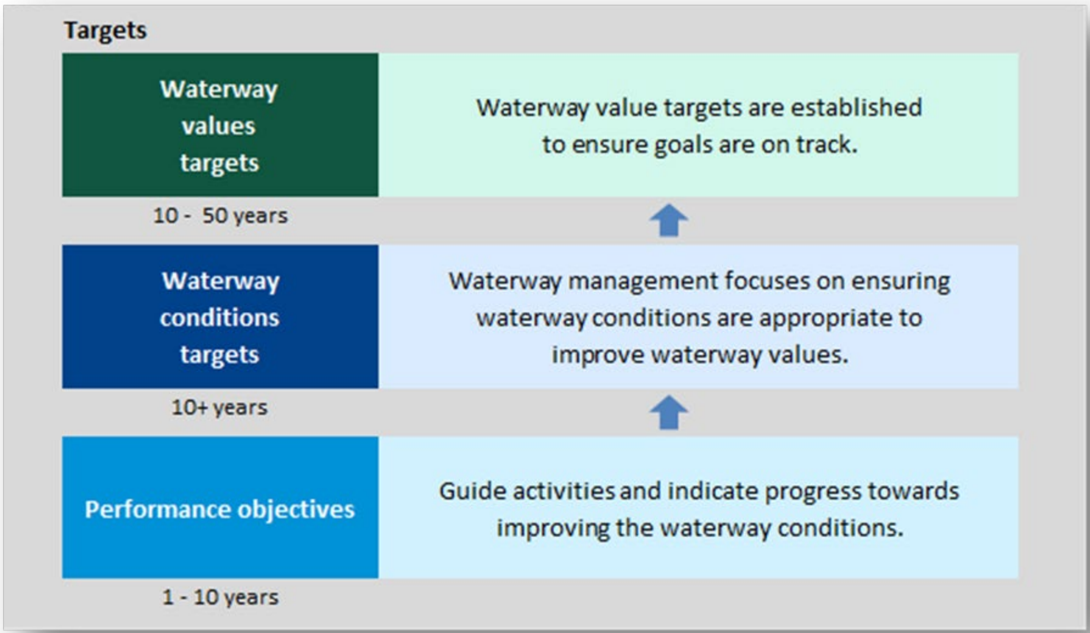

Figure 2. Hierarchy of targets in HWS

Nine **Key values** have been chosen as representatives of a broader range of social and environmental waterway values (Melbourne Water 2018a). Of the nine, six are included as estuary key values: three environmental values (birds, fish, vegetation) and three social values (amenity, community connection and recreation).

The HWS defines waterway (and hence) **estuary condition** as the overall state of the waterway and the key processes that underpin a well-functioning ecosystem (Melbourne Water 2018a). It is assumed that improvements in estuary conditions will improve estuary key values.

Estuary condition and its links to estuary key values in the HWS were developed from the HWS Conceptual Models (Melbourne Water, 2020). The seven estuary conditions identified in the HWS are:

- flow regime
- tidal exchange
- longitudinal extent
- water quality
- estuarine vegetation
- estuarine wetland connectivity
- access.

Current state and targets

The **current state** of key values and the estuary conditions (as at 2017) that support them are measured by a series of variables outlined in the HWS Resource Document (Melbourne Water, 2020); the results are reported at a high level in the Healthy Waterways Strategy. More specific detail at the estuary scale is provided in each of the Co-designed Catchment Programs.

Improving current state (or sometimes merely maintaining the state due to significant threats) of the key values and the estuary condition that supports them helps to progress against the catchment goals and vision. **Targets** have been set to quantify the amount of improvement or threat mitigation that is required to meet the catchment goals and vision within a set timeframe.

When the Strategy was being developed the level of data available to set targets was variable across values, conditions and asset types. Rivers, due to our investment over many years in data acquisition, was more developed than wetlands and estuaries. The Estuaries MEP seeks to address this by establishing a fit-for-purpose monitoring plan that will help us develop a better understanding of the values and conditions of estuaries across the region over time. As better data is gathered our development of appropriate metrics and analyses will improve. This could mean that the ‘current’ state of estuary values and conditions may change compared with what was published in the HWS. If the current state changes then the target state may also change. For many estuary values and conditions, rather than reporting against the old target we will aim at establishing the new baseline by mid-term review.

If ‘current’ condition changes (established by mid-term review in 2022) we will use a similar approach to that used during the strategy development process to set a new long-term target (Melbourne Water 2020). If the long-term target differs from what has already been published, we will take the new targets to the RLG for discussion and endorsement and changes will be communicated at catchment forums and via the Healthy Waterways Strategy website.

Performance objectives

The short term (one to ten-year quantitative steps) by which targets can be achieved are described in the HWS by **performance objectives**. Performance objectives provide short-term, tangible outcomes which indicate progress towards less tangible, long-term outcomes (i.e. change in condition or in key value).

Performance objectives may, for example, define an area of land that must be revegetated, or a number of fish barriers that need to be removed. The terminology 'performance objectives' is aligned with the requirements of the *State of Victoria Yarra River Protection (Wilip-gin Birrarung Murron) Act (2017)*.

According to the HWS, performance objectives should have the following attributes:

- are outcome-based, and not based merely on actions undertaken
- enable a partnership approach with other parties that undertake waterway management actions
- are quantitative, measurable and achievable in 10 years
- inform short-term management aims through annual planning processes
- describe where they link to environmental conditions
- are underpinned by transparent and best available information and knowledge
- are able to be assessed without needing to measure waterway values and condition outcomes on every asset.

Program logic

The Program Logic for Estuaries in Figure 3 shows the relationship between the performance objectives and how they link to changes in environmental conditions and values. It illustrates the time frames across which change is expected to be detectable. Additionally, it maps the relationship between the program logic and the parts of this Estuaries MEP.

The program logic for estuaries (Figure 3) recognises that management activities and outcomes occur over a range of timeframes. It covers:

- Aspirational long-term regional vision and catchment goals: (50+ years)
- Longer term outcomes - key values targets (~ 20+ years - addressed in this document in Part B)
- Intermediate outcomes - waterway condition targets (~10+ years – addressed in this document in Part C)
- Immediate outcomes– performance objectives (1-10 years – addressed in this document in Part A)
- Activities – on-ground actions, partnerships, governance, tracking performance (annual – in this document addressed in Part A)

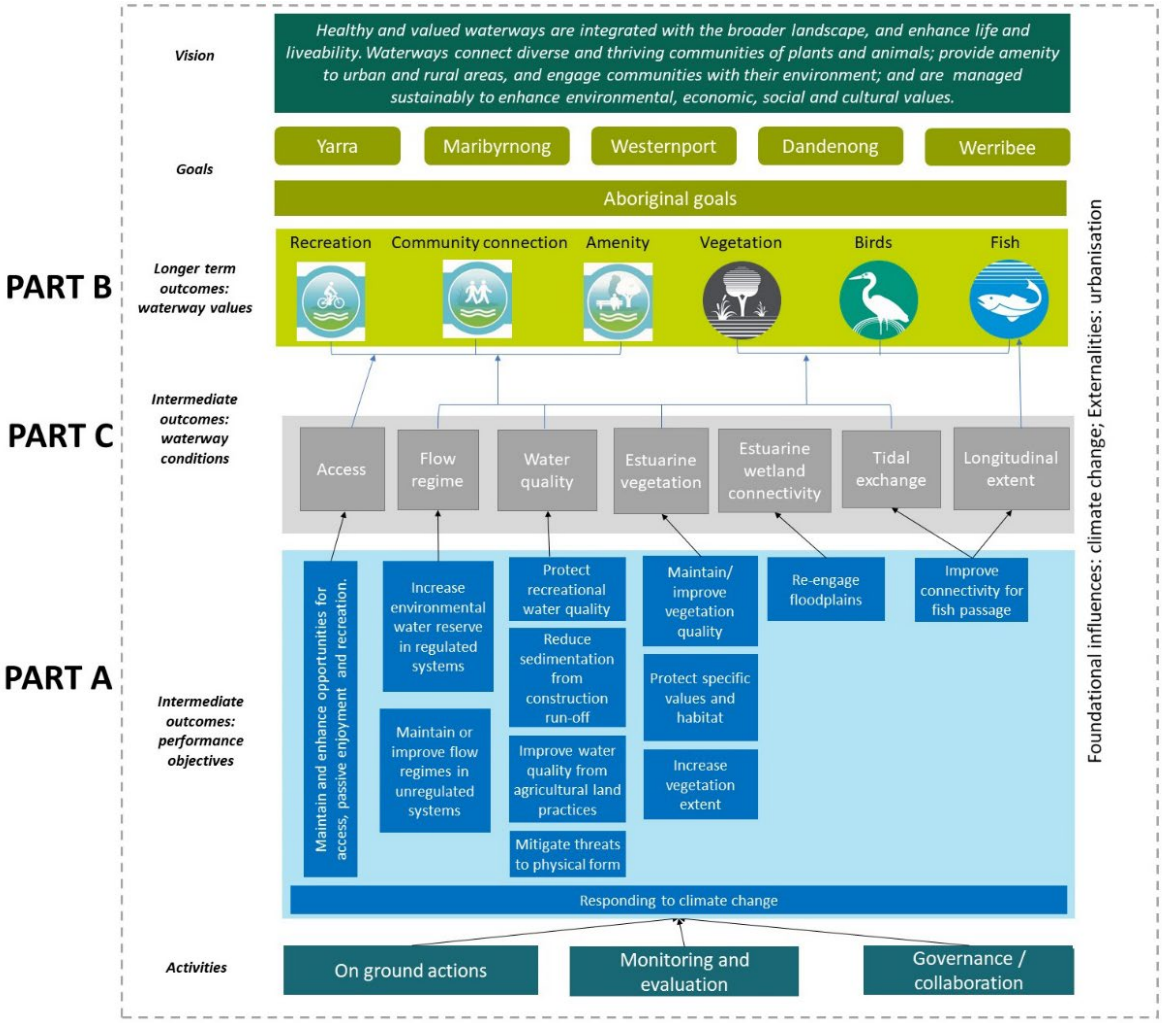

Figure 3. HWS program logic for estuaries showing the links between performance objectives, conditions and values.

2.4 Evaluation and reporting

Tracking progress towards meeting the three different types of targets, allows us to know if our actions are creating the change that is outlined in the HWS vision and goals. But tracking progress isn't enough, we also need to evaluate our efforts to understand if the actions we are doing are the best ones to create the change. It is through evaluation that we are able to learn and adapt to ensure the HWS remains effective over the 10 year period. It this reason that the Estuaries MEP will be updated over time, but particularly at mid-point of the HWS period (2021/22), to adopt learnings and efficiencies, such as developments in monitoring methods and analytical techniques.

A web-based reporting system will be used, with annual, mid-term (i.e. 2022) and end of strategy (i.e. 2028) reporting. Delivery Partners, community groups and the RLG will all utilise the evaluation results (annual, mid-term and final) to understand progress, guide annual planning and drive continuous improvement. The HWS governance processes will involve the RLG where significant findings require further deliberation and direction. These processes are in development with the RLG and will be documented in the MERI Framework. The Science Panel will also provide expert advice on evaluation and communicate recommendations to the RLG.

Our approach to evaluation and reporting is summarised below:

Annual Reporting

The focus of annual evaluation and reporting will be on the short-term indicators

Performance Objectives

KEQ No. 1 - To what extent have the performance objectives of the Strategy been achieved?	Annual Event-based (as needed) Mid-term (2022)

Progress towards the 10 year Performance Objectives will be tracked annually using output indicators (e.g. area of vegetation revegetated). It is planned that some POs will only be reported on at mid-term and end of strategy. Reporting will be collated, synthesised and communicated through the Healthy Waterways website https://healthywaterways.com.au/)

Where appropriate reporting will align with the 9 PO groupings outlined in the MERI framework (e.g. vegetation, habitat, community places - see HWS website for facts sheets on these https://healthywaterways.com.au/) Whilst each PO theme and group will be tracked at the individual estuary level, a traffic light approach will be used to determine whether a PO group is on track or off track at catchment scale only (i.e. Werribee, Maribyrnong, Yarra, Dandenong and Westernport). The main reason for this scaling is to allow for works to be implemented at different times in different estuaries based on local planning decisions and opportunities. In addition, it provides a way to synthesise how the strategy is performing at a catchment and regional scale which is valuable information for managers and the Regional Leadership Group.

Annual evaluation will only occur for POs where a rubric has been developed to define performance i.e.: On-track, Slightly Off-track and Significantly Off-track. The different types of tracking are outlined below:

Quantitative targets Where Performance Objectives have 10 year quantitative targets, the measureable indicator will be used to track progress with a rubric that defines *On-track, Slightly off-track and Significantly off-track* each year.

Status updates can be used where quantitative indicators or targets are not available. For example each PO will be assigned an annual status update of 'not started', 'in-progress', or 'complete'. Rubrics can then be used to evaluate performance (i.e. on track or not) for PO groups or themes for each major catchment.

Progress reports can be used where quantitative targets are not available or appropriate. They provide a brief update (one or two sentences only) on progress made each year. An on-track/ off track assessment will not be made for this form of reporting. Progress reports will be used at mid-term to help decide if an evaluation is required.

Case studies will highlight stories of success, or challenge, and focus on the achievements of a range of strategy partners or collaborations. These will typically be four to five paragraphs in length, be more story-based and accompanied by pictures or possibly a brief video. An on-track/ off track assessment will not be made for this form of reporting. Case studies can be used either as the main form of tracking or in addition to the approaches outlined above. If it is the only form of tracking, like Progress Reports, a decision will need to be made at mid-term whether an evaluation is required.

Values and Conditions

While most values and conditions will only be evaluated at mid-term, information on the key values and conditions can be reported annually as new data is available. This approach provides useful context both spatially and temporally about relevant indicators and metrics related to the HWS values and conditions.

Mid-term review process

A summary of the approach to the mid-term evaluation for both Performance Objectives and Values and Conditions is summarised below. More detail can be found within each of the relevant sections. The RLG will be play a key role in deciding what gets evaluated and make decisions resulting from evaluation outcomes. The science panel will also provide expert advice on the design of evaluations and critique of the findings.

Performance Objectives

Mid-term evaluation of the POs will focus on POs or groups which are significantly off-track rather than evaluating all PO's. Potential lines of enquiry which would be worth pursuing if a deeper mid-term evaluation is deemed necessary are outlined within each PO Group. The RLG decide which areas are evaluated and evaluation methods will need to then be developed.

Under this Estuary MEP, the mid-term evaluation will consider the following:

- identifying PO groups that are significantly off track, either from tracking demonstrated by the rubric or when the progress reports show little progress has been made
- reviewing performance objectives if better data is available.
- Examining performance objectives groups that progressed well and determining whether mechanisms that support progress can be transferrable.
- identification on new performance objectives that have arisen from strategy partners or community
- examining what has been collected for estuary condition and values data and undertaking some preliminary data analysis to confirm the most appropriate metrics and rubrics to use.
- flagging any major threats to estuary condition that have not been previously identified.
- re-prioritising management if required (based on this updated information) for the second half of the strategy.
- re-prioritising monitoring if required, including:
    - which estuaries and which metrics are the most relevant and useful?
    - Does monitoring need to be undertaken more/less frequently at specific estuaries to be ready for a deeper evaluation at end of strategy review?

The outcome of the mid-term evaluation of particular performance objective groups will need to be reported to the RLG with options of how to address the PO in the future. If a performance objective target needs to be altered, or is reliant on actions from partner organisations, this will need to brought to the attention of RLG to resolve and decide the way forward.

Potential lines of enquiry will be used as a means to identify underlying or institutional reasons for PO groups to lag and will help to focus on the mechanisms and arrangements required for bringing these back on track.

Values and conditions

The mid-term review phase (2022) will focus on an assessment of progress towards the long term sub-catchment scale targets. The relevant KEQs are:

KEQ No. 2 - To what extent has progress been made towards the longer term environmental condition targets for rivers, wetlands and estuaries?	Mid-term (2022) End of Strategy (2026)
KEQ No. 3 – What is the state of waterway values?	Mid-term (2022) End of Strategy (2026)

Where possible analysis will combine multiple lines of evidence to help draw conclusions about whether long term targets for values and conditions are on-track or not. A similar 3 point traffic light evaluation will also be made for the values and conditions i.e.

- On-track to meet long term targets
- Slightly off-track to achieving long term targets
- High chance that long term targets will not be met

If long term targets appear to be off-track then a deeper analysis to understand why will be undertaken. This process also looks at multiple lines of evidence – integrating PO performance, relevant values and conditions and other contextual data. Each section outlines possible lines of enquiry to assist in the evaluation process.

While the MERI framework outlines the governance arrangements for how decisions will be made regarding evaluation outcomes, the following are examples of potential changes which made need to be made:

- Re-prioritise efforts to fast track works into priority locations
- Modify existing performance objectives or create new ones and secure funding
- Undertake further investigation into underlying causes
- Modify the monitoring program
- Change the long term targets

Estuary values and conditions will be reviewed at mid-term but it is unlikely that we will have significant enough data available for a full analysis and evaluation. However, other types of information that compliment monitoring data will be considered at mid-term review such as whether any significant incidents have occurred across the region (e.g. bushfire) or at a specific estuary such as pollution events. A focus of the mid-term review will be on determining the best metrics to use and analysing the available data (and complimentary information) to see what indications there are that trajectories are on track.

End of strategy review

The end of strategy review will occur in 2026, two years before the end of the strategy implementation period. This allows the strategy evaluation to inform the target setting process of the next strategy, which will begin to be developed in 2027.

The end of strategy review will build on the outcomes of the mid-term review. The PO groups that were the focus of the mid-term review will automatically become the focus of the final review so as to determine if actions taken to bring them back on track have succeeded. Any other PO groups that have significantly lagged in the intervening period will also be reviewed. Successes will equally be evaluated to see whether key learnings can be transferred to other areas.

The potential lines of enquiry for the end of strategy evaluation of performance objectives should link back to the Key Evaluation Question 4 and 5. in the MERI particularly those relating to efficiency, legacy and appropriateness.

Key values and conditions will also be reviewed and trajectories of achievement of progress toward the long term targets evaluated. All of this data analysis will be preparation and support for the development of the next strategy.

Relevant research and intervention monitoring outcomes will be integrated into the strategy progressively but the end of strategy review process provides an opportunity to reset direction and formulate the next suite of questions that will drive continuous improvement.

Part A: MONITORING IMPLEMENTATION

Overview

There are 159 estuary-specific Performance Objectives (EPOs) across the five catchments and 45 Regional Performance Objectives (RPOs) that cover all waterway types. To simplify the way the catchment POs are managed they have been grouped.

Sub-catchment performance objective monitoring – estuaries

There are 7 performance objective groups relevant to estuaries and within each group there are themes (see Table 3, see HWS website for fact sheets on the PO groups https://healthywaterways.com.au/).

Each PO group has a section with further details about what data needs to be collected when delivering works associated with these POs alongside a rubric outlining how we will determine if these PO's are on track.

Table 3. Summary of performance objective groups for estuaries and their monitoring.

PO group	PO theme (total #)	POs covered in this Estuary MEP	Related regional POs
Vegetation	Maintain or improve vegetation quality	Protect/Enhance estuarine vegetation condition and reduce threat of invasive plant species to significant estuarine vegetation communities. Improve estuarine vegetation condition to moderate. Enhance estuarine emergent vegetation condition that provides instream habitat for fish Enable lateral and longitudinal migration of estuarine vegetation communities on the floodplain to allow adaptation to climate change risks.	RPO-29 Programs, standards, tools and guidelines are in place to protect wetland vegetation communities from urban and rural threats, including adequate planning controls. RPO-30 Climate change resilient revegetation management practices are understood and implemented by selecting plant species, provenances and vegetation communities that are suited to projected future climatic conditions. RPO-31: A risk-based approach is adopted to prevent, eradicate and contain pest plants and animals (including deer) and protect waterway assets RPO-32 Programs are in place to protect and enhance sites of biodiversity significance associated with the region's waterways, such as through Melbourne Water's Sites of Biodiversity Significance Strategy.
Flow regimes	Maintain or improve flow regimes in unregulated systems	Protect refuge habitats through maintaining critical stream flow components.	RPO-12: Water for the environment continues to be managed and delivered to the region's rivers and wetlands and recovery options continue to be investigated
	Increase environmental water reserve in regulated systems	Reduce flow stress to the Little River and Werribee estuaries.	
Adaptive management and Research	Responding to climate change	Plan to enable lateral and longitudinal migration of estuarine vegetation communities on the floodplain to allow adaption to climate change risks.	RPO-10: An adaptive pathways approach is adopted to understand and manage the risks of climate change on waterways RPO-30 Climate change resilient revegetation management practices are understood and implemented by selecting plant species, provenances and vegetation communities that are suited to projected future climatic conditions.
Habitat	Re-engage floodplains	Identify opportunities and undertake planning to re-engage estuarine floodplains in the long-term.	RPO-32: Programs are in place to protect and enhance sites of biodiversity significance associated with the region's waterways, such as through Melbourne Water's Sites of Biodiversity Significance Strategy RPO-31: A risk-based approach is adopted to prevent, eradicate and contain pest plants and animals (including deer) and protect waterway assets
	Increase connectivity for fish passage	Improve longitudinal connectivity in estuaries.	
	Protect specific values and habitat	Reduce the threat of invasive animals such as foxes, cats and dogs to key estuarine habitats.	
Community places	Increase access to and along waterways, wetlands and estuaries by filling gaps and improving connections to existing path networks.	Investigate opportunities to improve access for on-water activities, and improve connections with existing path networks. Maintain/Enhance site appropriate opportunities for recreation (boating, fishing, walking/cycling). Maintain/Enhance site appropriate facilities that support passive enjoyment and recreation.	RPO-43: The social values framework, information and methods used to develop values assessments, targets and performance objectives are further developed and improved during the life of the Healthy Waterways Strategy RPO-19: Options to transform modified waterways by creating more natural, community-loved spaces are identified and implemented RPO-21: The many benefits of waterways investment are tracked and understood

PO group	PO theme (total #)	POs covered in this Estuary MEP	Related regional POs
Water quality	Reduce sedimentation from run-off associated with construction for urban development	Monitor and reduce the threat of catchment sediment impacts on the estuary.	RPO-23: The potential impacts of emerging contaminants of concern such as microplastics, pesticides and pharmaceuticals and toxic chemicals are better understood and mechanisms to respond collaboratively developed RPO-24: Risk-based programs are in place to mitigate sources of urban pollution (licenced and unlicensed discharges) to protect bays and waterways
	Improve water quality from agricultural land practices	Implement rural land program in catchment to minimise sediment and nutrient loads to the estuary.	
	Maintain recreational water quality	Artificial estuary mouth openings are only undertaken when a risk assessment concludes that opening conditions are low risk for the environment	
	Reporting	Continue to monitor estuary water quality through the EstuaryWatch program and Melbourne Water monitoring sites.	

3. Vegetation

These performance objectives are aimed at maintaining or improving estuarine vegetation condition, reducing the threat of invasive plant species and enhancing emergent estuarine vegetation for fish habitat. They are also addressing the need to protect estuarine habitat by increasing the area of land available around the estuary, and managing that land, to enable migration of estuarine vegetation as sea levels rise due to climate change.

Estuary Performance Objectives within the Vegetation Group are summarised in Table 4, the approach to monitoring and scoring these is summarised in

Table 5 and

Table 6., and the requirements for data management are summarised in Table 7.

Table 4. The number of performance objectives within each theme of the Vegetation group.

EPO Theme	No POs	Example PO wording	Associated management actions	Relevant estuaries
Maintain or improve vegetation quality	29	Protect/enhance estuarine vegetation communities through targeting/reducing threats from key invasive species.	Weed control Pest Control	Little River, Werribee River, Skeleton Creek, Laverton Creek, and Kororoit Creek Estuaries Stony Creek (PPB), Maribyrnong River and Moonee Ponds Creek Estuaries Yarra River Estuary Elwood Canal, Mordialloc Creek, Patterson River and Kananook Creek Estuaries Balcombe Creek, Sheepwash Creek, Chinamans Creek, Stony Creek (WPB), Merricks Creek, Olivers Creek, Warringine Creek , Kings Creek , Watson Creek, Tooradin Road Drain, Yallock Creek, Cardinia Creek, Deep Creek, Bunyip River, Lang Lang River and Bass River Estuaries
	2	Improve estuarine vegetation condition to moderate.	Establish vegetation (revegetate, regeneration) Maintain vegetation	Sheepwash Creek and Lang Lang River Estuaries
	2	Enhance estuarine emergent vegetation to provide instream habitat for fish.	Establish emergent vegetation that is preferred by fish	Yarra River and Maribyrnong River Estuaries
	17	Investigate opportunities to/enable lateral and longitudinal migration of estuarine vegetation communities on the floodplain to allow adaptation to climate change risks.	Removal of structures Potential acquisition of land Re-establishment of lateral connectors	Little River, Werribee, Skeleton, Laverton and Kororoit Creek Estuaries Balcombe Creek, Sheepwash Creek, Creek, Chinamans Creek, Stony Creek (WPB), Merricks Creek, Warringine Creek, Kings Creek, Olivers Creek, Watson Creek, Tooradin Road Drain, Cardinia Creek, Deep Creek, Bunyip River, Yallock Creek , Lang Lang River and Bass River Estuaries

Table 5. Summary of monitoring approach and scoring criteria for vegetation performance objectives

Performance objective	Monitoring			Scoring criteria				
				Annual and Mid-term				Final term
	Indicators	Report format (due date)	Specifications/assumptions	On-track	Slightly off-track	Significantly off-track	Lines of enquiry if target not met	
Protect/enhance estuarine vegetation communities through targeting/reducing threats from key invasive species	Vegetation maintained (ha)	Polygon of extent of 'Active Management' e.gg ha of weed managed or surveillance conducted. (Annual) Case Study (2022 and 2026)	Despite no specific ha target being articulated in the PO, the area of estuary that has been actively managed* in the previous year as a % of the overall estuary vegetation area will be mapped Vegetation needs to be maintained to a minimum level 3 Any area under active management in the mapped estuary area (Appendix E) and the 20 m buffer of the remaining length of the estuary counts. Once current weed threat has been assessed, a ha target may be developed for each estuary. "Not started" means no record of active management (weed control) has occurred since 2018. "In progress" means active management (weed control) is in place "Complete" means active management in place (e.g. surveillance or similar) and weed threat is low#.	Estuary vegetation PO's are meeting annual rubric (Table 6)	Up to 20% below on track	More than 20% below on track	Are there major cost differences between estuaries and between delivery mechanisms? Is polygon data of Active Management being captured? Is the rubric style adequate to track performance? Are weed control efforts in estuaries effective and efficient? Are there new and emerging threats present? Are we managing the greatest threat present? What other obstacles have hampered weed control efforts in estuaries? What new information regarding management of estuaries is available?	Weed threat in all estuaries is low Saltmarsh and other significant vegetation types have been protected
Improve estuarine vegetation condition to moderate. *Note that this performance objective is under review to determine whether it can merged with very similar PO's for protect/maintain /improve* • *Sheepwash Creek Estuary* • *Lang Lang River Creek*	Vegetation maintained (ha) And Vegetation extent (ha)	Polygon of extent of 'Active Management' e.gg ha of plants established or maintained.						Estuary vegetation has been improved to moderate
Enhance estuarine emergent vegetation to provide instream habitat for fish. (Yarra and Maribyrnong River Estuaries only)	Emergent vegetation extent (ha)	Polygon of extent of 'Active Management' Annual progress report	An initial investigation will be conducted to look at options and feasibility of improving fish habitat in the Yarra and Maribyrnong Estuaries If emergent vegetation is deemed the best way to deliver the outcome then works planned will be counted at final site audit				What other factors may prohibit establishment of emergent vegetation in the Yarra and Maribyrnong estuaries? What other opportunities have been explored to increase fish habitat? E.g. fish hotels	Fish habitat has been enhanced in the Yarra and Maribyrnong Estuaries
Investigate opportunities to enable lateral and longitudinal migration of estuarine vegetation communities on the floodplain to allow adaptation to climate change risks.	NA	Mid-term Status report (not, started, in progress, completed)	A regional investigation to look at opportunities for lateral and longitudinal migration of estuarine vegetation will be conducted This will be linked to the climate change investigation outlined in the Adaptive Management section High risk estuaries with good migration opportunities present will be prioritised	Regional investigation complete by mid-term	Regional investigation started by mid-term	Regional V investigation not started by mid-term	What are the major impediments to migration of estuary vegetation?	Priority estuaries have plans in place to support migration of estuarine vegetation

* Active Management is the necessary management and/or surveillance monitoring required to ensure the vegetation meets the definition of level 3 (Medium) estuarine vegetation quality.

**'Management is on-ground works such as weed control or planting.

*** Surveillance is an inspection of an area of vegetation where weed threat is low and has been for a significant period (e.g. for more than 2 years). The next surveillance period needs to be defined. Ideally these will be re-inspected every 2 years

- # A "low weed threat" level is defined as:

  (a) <5% cover abundance with high-threat species of weed present, or

  (b) <25% cover abundance with no high-threat species of weed present.
- High-threat weed species are those listed in the Ecological Vegetation Class benchmark and other species that are defined as "highly invasive" in White et al (2018).
- Other weed species which have the ability to 'displace native vegetation' can be defined as those that are "moderately invasive" under the category 'potential for invasion' in White et al. (2018).

Table 6. Annual progress target for vegetation PO.

Catchment	18/19	19/20	20/21	21/22	22/23	23/24	24/25	25/26	26/27	27/28
Werribee	1 of 5 POs are in progress	2 of 5 POs are in progress	3 of 5 POs are in progress	4 of 5 POs are in progress	4 of 5 POs are in progress	All POs in progress	All POs (at least) in progress. 1 POs complete	All POs (at least) in progress. 2 POs complete	All POs (at least) in progress. 3 POs complete	All POs (at least) in progress. 4 POs complete
Maribyrnong	1 of 4 POs are in progress	1 of 4 POs are in progress	2 of 4 POs are in progress	3 of 4 POs are in progress	All POs in progress	All POs in progress	All POs (at least) in progress. 1 PO complete	All POs (at least) in progress. 2 POs complete	All POs (at least) in progress. 3 POs complete	All POs complete
Yarra	1 of 2 POs are in progress	1 of 2 POs are in progress	All POs in progress	All POs in progress	All POs in progress	All POs in progress	All POs (at least) in progress 1 PO complete	All POs (at least) in progress 1 PO complete	All POs complete	All POs complete
Dandenong	1 of 4 POs are in progress	2 of 4 POs are in progress	2 of 4 POs are in progress	3 of 4 POs are in progress	3 of 4 POs are in progress	All POs in progress	All POs (at least) in progress. 1 PO complete	All POs (at least) in progress. 2 POs complete	All POs (at least) in progress. 3 POs complete	All POs complete
Westernport	3 of 18 POs are in progress	6 of 18 POs are in progress	9 of 18 POs are in progress	12 of 18 POs are in progress	15 of 18 POs are in progress	All POs in progress	All POs (at least) in progress > 4 POs complete	All POs (at least) in progress > 8 POs complete	All POs (at least) in progress > 11 POs complete	All POs (at least) in progress > 14 POs complete

Table 7. Data collecting and reporting responsibilities for each vegetation PO theme

Performance objective	Indicators	Monitoring method / data type	Data collection responsibility	Processing and reporting responsibility	Data storage system	HWS website Report Card
Protect/enhance estuarine vegetation communities through targeting/reducing threats from key invasive species	Vegetation maintained (ha) Number of PO's started, in progress or complete	Polygon of extent of 'Active Management' e.g. ha of weed managed. Polygon extent of 'Surveillance' e.g. weed threat inspection Work Order or equivalent	Melbourne Water Service Delivery -WLOs and Grants officers / stream frontage assessors Parks Victoria - ? PPWP CMA?	Melbourne Water - CAM	MapBox Maximo Grants Tracker PV systems?	Polygons of area under management per estuary (contextual data) Polygons of total estuary vegetation extent per estuary (contextual data to show what is not managed) No. PO's started, in progress and complete (against rubric) (combine on website with below to become protect/maintain/improve) Graph of % of estuary vegetation under management per year (contextual data) Case study at 2022 and 2026 e.g. Spartina
Improve estuarine vegetation condition to moderate.	Vegetation maintained (ha) Vegetation extent (ha) Number of PO's started, in progress or complete	Polygon of extent of 'Active Management' Work Order or equivalent	Melbourne Water WLOs Grants officers / stream frontage assessors	Melbourne Water - CAM	MapBox	Polygons of area under management per estuary Polygons of estuary vegetation extent per estuary Cumulative graph of ha management per year No. PO's started, in progress and complete (against rubric) (combine on website with above to become protect/maintain/improve)
Enhance estuarine emergent vegetation to provide instream habitat for fish. (Maribyrnong River Estuary only)	As above Vegetation extent (ha) Number of PO's started, in progress or complete	Polygon of extent of 'Active Management' Work Order or equivalent	Melbourne Water Service Delivery Parks Vic?	Melbourne Water - CAM	MapBox	Polygon of emergent vegetation works in Yarra and Maribyrnong estuaries Status report
Investigate opportunities to enable lateral and longitudinal migration of estuarine vegetation communities on the floodplain to allow adaptation to climate change risks.	NA	Progress report	Melbourne Water – Integrated Planning (Waterways and Biodiversity Planning) and CAM	Melbourne Water	na	Status report

4. Water for Environment

The management of environmental water is considered either regulated or unregulated. In regulated rivers (those with dams), some of the environmental water reserve is made up of the entitlement held by the Victorian Environmental Water Holder (VEWH). This includes the Yarra, Tarago and Werribee. Not all regulated rivers have an environmental entitlement. Unregulated rivers (those without dams), are managed through private diversions in Stream Flow Management Plans or local management plans. It is critical, especially in the face of climate change that environmental water continues to be managed and delivered to the region's waterways and that recovery options continue to be investigated.

The performance objectives set out in the Strategy are aimed at maintaining critical flow components (e.g. freshes, low flows) to protect instream environmental values, increasing environmental flow reserves and reducing flow stress associated with diversions..

The Environmental Water Resources team at Melbourne Water have developed a MERI framework (Melbourne Water 2018b), implementation plan (Melbourne Water 2018c) and a supplementary Monitoring Design report (Robinson 2019). The KEQs for the MERI focus largely on the delivery of the various programs Melbourne Water has in place for environmental water management. The Estuary MEP intends to align where possible with the evaluation methods outlined in this MERI plan.

The flow regime PO group are the management levers that link to flow regime condition which supports the key environmental values of fish, birds and vegetation and the key social values of community connection, access and recreation.

- Estuary Performance Objectives within the Flow Regimes Group are summarised in Table 8, the approach to monitoring and scoring these is summarised in
- Table 9, and the requirements for data management are summarised in

Table 10.

Table 8. The number of performance objectives within each theme of the Flow Regime group.

EPO sub-group	# POs	Example PO wording	Associated management actions	Relevant estuaries
Maintain or improve flow regimes in unregulated systems	4	Maintain critical flow components in refuge reaches to protect instream environmental values.	• Environmental Entitlement releases from dams • diversion restrictions and bans • irrigation management • farm dam modifications	Stony Creek (Port Phillip Bay) Estuary Maribyrnong River Estuary Moonee Ponds Creek Estuary Little River Estuary
	1	Identify opportunities to maintain and improve the flow regime in the Werribee River downstream of the Werribee diversion weir to support platypus populations.		Werribee River Estuary

EPO sub-group	# POs	Example PO wording	Associated management actions	Relevant estuaries
		Note that this performance objective is under review as platypus are not known to favour estuaries as habitat and the PO indicates the river between the diversion weir and the bluestone weir that marks the top of the estuary.		
	1	Reduce the threat of flow stress on Little River (e.g. climate change, diversions and water for domestic and stock uses) by developing and implementing agreed environmental watering objectives.	• Work with stakeholders to develop environmental watering objectives. • Review existing flow management plans and assess success of implementation	Little River Estuary
Increase environmental water reserve in regulated systems	1	Investigate opportunities to increase the environmental water reserve is increased by 7 GL by 2028 to meet ecological watering objectives and cover projected shortfalls.	• Planning, investment and advocacy activities. • Purchasing environmental entitlements/allocations.	Werribee River Estuary

Table 9. Summary of monitoring approach and scoring criteria for flow regime performance objectives.

<table>
<tr><th rowspan="3">Performance objective</th><th colspan="3">Monitoring</th><th colspan="5">Scoring criteria</th></tr>
<tr><th rowspan="2">Indicators</th><th rowspan="2">Report format

(due date)</th><th rowspan="2">Specifications/assumptions</th><th colspan="4">Mid-term</th><th rowspan="2">Final term</th></tr>
<tr><th>On-track</th><th>Slightly off-track</th><th>Significantly off-track</th><th>Lines of enquiry if target not met</th></tr>
<tr><td rowspan="2">Maintain critical flow components in refuge reaches to protect instream environmental values.
Note that this performance objective is under review to determine whether it is an appropriate target in the following systems:
• Moonee Ponds Creek Estuary
• Stony Creek (Port Phillip Bay) Estuary.</td><td>Management plan in place (Environmental Water Management Plan or Local Management Rules)</td><td>Annual progress report (as per Rivers MEP)</td><td>That EWMP's are the appropriate tool to be tracking</td><td>Management plan has been developed and a large proportion (80% or more) of actions are being implemented</td><td>Management plan has been developed but a less than 80% of actions are being implemented</td><td>Management plan is not in place and no actions are being undertaken</td><td>Barriers to implementation of the plan (e.g. stakeholders not supportive, action not feasible, lack of resources)</td><td>Management plans are implemented an achieving critical flow protection.</td></tr>
<tr><td colspan="8">• Maribyrnong River Estuary: To be monitored as per Maribyrnong River SCPO (Identify and implement opportunities to maintain or improve the flow regime in refuge reaches to support platypus populations and other instream values.) See Section 6.2 of Rivers MEP
• Little River Estuary: To be monitored as per Little River Lower SCPO (Maintain critical flow components in refuge reaches in Little River (Worrin-yaloke) to protect instream environmental values and platypus (perridak). See Section 6.2 of Rivers MEP</td></tr>
<tr><td>Reduce the threat of flow stress on Little River (e.g. climate change, diversions and water for domestic and stock uses) by developing and implementing agreed environmental watering objectives.
Note: This PO is under investigation to see whether it can be merged with Little River Lower SCPO and the Maintain critical flow components in refuge reaches to protect instream environmental values PO above. See Section 6.2 in Rivers MEP</td><td colspan="8">Will be monitored as per Little River Lower SCPO (See Rivers MEP section 6.2)</td></tr>
<tr><td>Identify opportunities to maintain and improve the flow regime in the Werribee River downstream of the Werribee diversion weir to support platypus populations.

Note that this performance objective is under review to determine whether it is an appropriate target.</td><td colspan="8">Will be monitored as per Werribee River Lower SPO (Identify and implement opportunities to maintain or improve the flow regime in refuge reaches to support platypus populations.)</td></tr>
<tr><td>Investigate opportunities to increase the environmental water reserve is increased by 7 GL by 2028 to meet ecological watering objectives and cover projected shortfalls.</td><td colspan="8">Will be monitored as per Werribee River Lower SPO: "Investigate opportunities to increase the environmental water reserve is increased by 7 GL by 2028 to meet ecological watering objectives and cover projected shortfalls".</td></tr>
</table>

Table 10. Data collecting and reporting responsibilities for each flow regime PO theme.

Indicators	Monitoring method / data type	Data collection responsibility	Processing and reporting responsibility	Data storage system	Data provided on HWS website
Investigation undertaken into options for protecting values and management plan in place	Status Report	Southern Rural Water	Southern Rural Water	na	Target on track at mid-term Progress report
Environmental watering objectives developed	Progress report	Southern Rural Water	Southern Rural Water	na	Target on track at mid-term Progress report

5. Adaptive management and research

The performance objectives set out in the Strategy are aimed at ensuring that climate change adaptation is being adequately considered in planning for social and environmental estuary values.

Estuary Performance Objectives within the Adaptive Management Group are summarised in Table 11, the approach to monitoring and scoring these is summarised in Table 12 and the requirements for data management are summarised in Table 13.

Table 11. The number of performance objectives within the Adaptive Management and Research Group.

EPO Theme	# POs	Example PO wording	Associated management actions	Relevant Estuaries
Responding to Climate Change	4	Climate change adaptation plans in place for social and environmental values associated with the estuary.	Development of a climate change plan	Elwood Canal, Kananook Creek, Mordialloc Creek and Patterson River Estuaries

Table 12 Summary of monitoring approach and scoring criteria for adaptive management performance objectives

Performance objective	Monitoring			Scoring criteria				
				Mid-term and final review				Final term
	Indicators	Report format (due date)	Specifications/assumptions	On-track	Slightly off-track	Significantly off-track	Lines of enquiry if target not met	
Climate change adaptation plans in place for social and environmental values associated with the estuary.	# of plans developed and implemented	Status report 2022 2026	Plans must consider government agreed sea level rise predictions That each plan is comprehensive enough to protect social and environmental values in estuaries against the major impacts of climate change. That adequate options are available and practical to enable adaptation. That funding is available to implement plans developed.	Plans developed for 2 or more estuaries by mid-term Implementation of recommendations in progress	1 of 4 plans developed by mid-term Implementation of recommendations in progress	0 of 4 plans developed by mid-term	Are implementation time frames appropriate (note – some actions may be appropriate over a longer time horizon than the 10 year strategy). Review of responsibilities for plan development across agencies and barriers to development (e.g. funding/governance/political constraints). Review of knowledge gaps preventing management from being undertaken.	Climate change adaptation plans are developed for all estuaries

Table 13. Data collecting and reporting responsibilities for each adaptive management PO theme.

Indicators	**Monitoring method / data type**	**Data collection responsibility**	**Processing and reporting responsibility**	**Data storage system**	**Data provided on HWS website**
Climate change adaptation plans in place for social and environmental values associated with the estuary.	# of plans developed and implemented	Melbourne Water - Integrated Planning	Melbourne Water – Integrated Planning	na	Target on track at mid-term Progress report

6. Habitat

This Group includes all the Performance objectives relating to instream connectivity (i.e. fish passage) and about re-engaging estuaries with their floodplain and wetlands for multiple benefits. It also includes a group that is about protecting specific habitat for birds.

The aim of the *re-engaging floodplains* theme is to identify opportunities to remove barriers to lateral exchange (e.g. levees, roads, infrastructure, hardened edges) that prohibit estuaries inundating their floodplains and wetlands. The *improving / increasing connectivity for fish passage* theme is concerned with removing barriers to tidal exchange and fish movement along two estuaries. The *mitigate threats to physical form* theme addresses the risk of activating acid sulphate soils in the Kananook Creek estuary during dredging and any artificial estuary mouth opening. The *pest animal* group are aimed at protecting bird roosting sites from disturbance threats that reduce the habitat value of the site or cause it to be abandoned. For example, through predation of eggs and/or frequent disturbance causing energetically costly responses such as increased movement or sub-optimal foraging patterns.

Estuary Performance Objectives within the Habitat Group are summarised in Table 14, the approach to monitoring and scoring these is summarised in Table 15, and the requirements for data management are summarised in

Table 16.

Table 14. Summary of Estuary performance objectives within the Habitat Group.

EPO sub-group	# POs	Example PO wording	Associated management actions	Relevant estuaries
Re-engage floodplains	16	Identify opportunities to re-engage estuarine floodplains /and wetlands. Improve floodplain connectivity to moderate	Remove artificial structures that disconnect estuaries from their floodplains and wetlands.	Kananook Creek, Sheepwash Creek, Chinamans Creek, Stony Creek (WPB), Merricks Creek, Warringine Creek, Kings Creek , Olivers Creek, Watson Creek, Tooradin Road Drain, Cardinia Creek, Deep Creek, Bunyip River, Yallock Creek, Lang Lang River and Bass River estuaries
Improve / increase connectivity for fish passage	2	Improve longitudinal connectivity and tidal exchange in estuary by removing barrier at Racecourse Road.	Removal of instream barriers.	Skeleton Creek and Kororoit Creek estuaries
Mitigate threats to physical form	1	Ensure that estuary mouth management considers acid sulfate soil risk.	Assess the risk of acid sulfate soils activation prior to artificial estuary openings.	Kananook Creek
Protect specific values and habitat	19	Protect estuary roosting sites from excessive disturbance from humans, vehicles, dogs, foxes and cats.	Revegetation of sites – planting, direct seeding to increase screening. Management of recreational use – using infrastructure to divert people, their cars and their pets away from roosting areas. Pest control – directly removing predators such as foxes and their dens. Restricting access – banning domestic pets from reserves.	Little River, Werribee River, Skeleton Creek, and Kororoit Creek Estuaries Sheepwash Creek, Chinamans Creek, Stony Creek (WPB), Merricks Creek, Warringine Creek, Kings Creek, Olivers Creek, Watsons Creek, Tooradin Road Drain, Cardinia Creek, Deep Creek, Bunyip River, Yallock Creek, Lang Lang River and Bass River Estuaries

Table 15. Summary of monitoring approach and scoring criteria for Habitat performance objectives.

Performance objective	Monitoring			Scoring criteria					
	Indicators	Report format (due date)	Specifications/assumptions	Mid-term and final review				Final term
				On-track	Slightly off-track	Significantly off-track	Lines of enquiry if target not met	
Identify opportunities to re-engage estuarine floodplains /and wetlands.	% of estuary perimeter where barrier removed/ estuary edge rehabilitated.	Status update (2022 and 2026) Spatial line of areas of artificial barrier and areas	An initial step will need to be undertaken to quantify the length of apparent estuary barrier (from aerial imagery) that is a barrier to flood plain connectivity. Removal/rehabilitation works will be considered for inclusion toward the target if they enable the movement of water laterally out of the main channel. Methodology will be developed to quantify the ha of floodplain re-engagement achieved and additional indicator developed	Investigation to determine potential has been conducted by mid-term	Investigation has begun but has not been completed by mid-term	Investigation not begun by mid-term	Reasons why lateral barrier removal has not been successful (e.g. flood risk, land tenure) and how/whether these can be overcome. Whether there are alternative methods for increasing floodplain connectivity that are more acceptable to stakeholders/easier to implement.	Actions recommended by investigation have been completed
Improve floodplain connectivity to moderate (Kananook Creek only)	Investigations undertaken into estuary barrier, priority for removal and the pathway to removing it.	Status update (2022 and 2026)	Improvement in score will be assessed at mid-term and final, according to the Physical Form – lateral connectivity measure (for the estuarine wetland connectivity condition).	Investigation to determine potential has been conducted by mid-term	Investigation has begun but has not been completed by mid-term	Investigation not begun by mid-term		Physical form score = moderate
Improve longitudinal connectivity and tidal exchange in estuary.	Investigation of fish barriers in priority reaches	Annual Progress report	Initial investigations will be undertaken to confirm the presence and context of the barriers in Skeleton Creek and Laverton Creek (Racecourse Rd) If investigation concludes that work is required, target can be counted once the fishway has reached practical completion.	Planning for fishway installation at Kororoit Creek is underway AND all barriers have been identified in the Skeleton Creek estuary. (or investigations determines removal is not required)	Not all target barriers have been identified in the Skeleton Creek estuary OR planning for fishway installation at Kororoit Creek is not underway.	Not all target barriers have been identified in the Skeleton Creek estuary AND planning for fishway installation at Kororoit Creek is not underway.	Whether alternative fish barriers should be targeted for intervention instead of those listed. Have fish barriers identified in these POs been sufficiently identified and prioritized alongside other fish barrier removals outlined in the Rivers MEP?	Target barriers have been removed. OR Target barriers have been investigated and removal is not required

Ensure that estuary mouth management considers acid sulfate soil risk.	Proportion of artificial openings undertaken according to EEMSS/ASS risk management protocol.	Status update (2022 and 2026)	That an appropriate risk management protocol is followed when deciding whether to open the Kananook Creek estuary. That the potential for acid sulfate soil activation is monitored before, during and after estuary opening.	Risk assessment has been undertaken if estuary has been opened and ASS risks have been managed OR estuary mouth has not been artificially opened in the previous year		Estuary mouth has been opened without appropriate risk assessment in place AND/OR ASS risk has not been successfully managed when estuary mouth has been opened	What other factors need to be managed when the estuary mouth is opened?	Risk assessment protocol are in place and Estuary Mouth and Acid Sulfate Soil risks managed appropriately
Protect estuary roosting sites from excessive disturbance from humans, vehicles, dogs, foxes and cats.	Estuary roosting sites protection plan developed and implemented.	Progress report 2022	For all 19 estuaries that this performance objective is relevant to, one plan will be developed and implemented. Plan will consider: • Key species at risk • Key threats at each site • Management actions Prioritised sites and actions	Plan in place and on track	Plan in place but not being substantially implemented	Plan not in place	Whether there are knowledge gaps regarding the needs for protection of roosting sites Is there a conflict between the achievement of these PO's and the Community Places PO's to increase access? Causes of variability in implementation across sites (e.g. land manager, tenure, level of site use, lack of infrastructure)	Plan fully implemented

Table 16. Summary of data collection, processing, storage and website reporting for habitat performance objective themes

Indicators	Monitoring method / data type	Data collection responsibility	Processing and reporting responsibility	Data storage system	Data provided on HWS website
Investigations undertaken into estuary barrier, priority for removal and the pathway to removing it.	Status updates in 2022	Melbourne Water IP	Melbourne Water	NA	Status update 2022 and 2026 % of estuary perimeter where the barrier removed/ estuary edge rehabilitated
% of estuary perimeter where barrier removed/ estuary edge rehabilitated.	Status updates in 2022 Spatial line of areas of artificial barrier and areas removed	Melbourne Water IP	Melbourne Water	TBD	Status update 2022 and 2026 Assessment of opportunities to re-engage estuarine floodplains
Investigation of fish barriers in priority reaches	Status updates in 2022	Melbourne Water – CAM	Melbourne Water	NA	# of fish barriers investigated or removed in Skeleton Creek and Laverton Creek - annual progress report
Proportion of artificial openings undertaken according to EEMSS/ASS risk management protocol.	Status updates in 2022	Melbourne Water – Service Delivery in collaboration with others	Melbourne Water	NA	Status update 2022 and 2026 Case study of ASS risk management at Kananook Creek at mid-term and final review
Estuary roosting sites protection plan developed and implemented.	Status update 2022 and 2026	Parks Victoria	TBD	TBD	Status update 2022 and 2026

7. Community places

This group of performance objectives is centered around social value outcomes, particularly maintaining and improving access to and along estuaries at priority locations to benefit the key values of amenity and recreation. Access to estuaries enables people to derive value from a range of experiences including walking and cycling along the estuary corridor and access to the estuary itself for swimming/ paddling/ boating and connections to points of interest. Increases in access in the estuary should not impact on any other values and conditions

Estuary Performance Objectives within the Community Places Group are summarised in Table 17, the approach to monitoring and scoring these is summarised in Table 18 and the requirements for data management are summarised in

	18/19	19/20	20/21	21/22	22/23	23/24	24/25
Werribee	0 of 7 POs are in progress	0 of 7 POs are in progress	0 of 7 POs are in progress	2 of 7 POs are in progress	4 of 7 POs are in progress	All POs are in progress	All POs (at least) in progress > 1 POs complete
Maribyrnong	0 of 5 POs are in progress	0 of 5 POs are in progress	0 of 5 POs are in progress	2 of 5 POs are in progress	3 of 5 POs are in progress	All POs are in progress	All POs (at least) in progress > 1 PO complete
Yarra	0 of 2 POs are in progress	0 of 2 POs are in progress	0 of 2 POs are in progress	1 of 2 POs are in progress	1 of 2 POs are in progress	All POs are in progress	All POs are in progress
Dandenong	0 of 8 POs are in progress	0 of 8 POs are in progress	0 of 8 POs are in progress	3 of 8 POs are in progress	7 of 8 POs are in progress	All POs are in progress	All POs (at least) in progress > 2 PO complete
Westernport	0 of 21 POs are in progress	0 of 21 POs are in progress	0 of 21 POs are in progress	8 of 21 POs are in progress	16 of 21 POs are in progress	All POs are in progress	All POs (at least) in progress > 5 POs complete

Table 20.

Table 17. Summary of Estuary performance objectives within the Community Places Group.

EPO Theme	# POs	Example PO wording	Associated management actions	Relevant estuaries
Increase access to and along waterways, wetlands and estuaries by filling gaps and improving connections to existing path networks.	26	Maintain and support existing high value opportunities for access and recreation/passive enjoyment, including walking, cycling, boating and fishing activities.	Maintaining shared pathways and amenity facilities (benches, bathrooms, picnic tables, boat/canoe ramps , boardwalks etc.)	Werribee River and Kororoit Creek estuaries Elwood Canal, Kananook Creek, Mordialloc Creek and Patterson Rive estuaries Stony Creek (Port Phillip Bay) and Maribyrnong River Yarra River estuary Balcombe Creek, Chinamans Creek, , Merricks Creek, , Kings Creek, Olivers Creek, Tooradin Road Drain, , Bunyip River, Lang Lang River and Bass River estuaries
	17	Enhance appropriate access and recreation opportunities	Renewing or building new infrastructure e.g. paths, or amenity facilities	Skeleton Creek, Laverton Creek and Kororoit Creek estuaries Elwood Canal estuary Moonee Ponds Creek estuary Balcombe Creek, , Stony Creek (WPB), Warringine Creek, , Olivers Creek, Tooradin Road Drain, Cardinia Creek, Deep Creek, Bunyip River and Lang Lang River

Table 18. Summary of monitoring approach and scoring criteria for Community Places performance objectives.

<table>
<tr><th rowspan="3">Performance objective</th><th colspan="3">Monitoring</th><th colspan="5">Scoring criteria</th></tr>
<tr><th rowspan="2">Indicators</th><th rowspan="2">Report format
(due date)</th><th rowspan="2">Specifications/assumptions</th><th colspan="4">Annual</th><th rowspan="2">Final term</th></tr>
<tr><th>On-track</th><th>Slightly off-track</th><th>Significantly off-track</th><th>Lines of enquiry if target not met</th></tr>
<tr><td rowspan="2">Maintain and support existing high value opportunities for access and recreation/passive enjoyment, including walking, cycling, boating and fishing activities.</td><td rowspan="2">Km of existing pathways maintained

Location of other access related assets maintained near estuaries e.g. boat ramps, seats, jetties</td><td rowspan="2">Spatial line or point (annual)

Status update</td><td rowspan="2">Mapping of existing paths and the proportion that are maintained every year

Any maintenance of access facilities is done so as not to harm any environmental conditions or values e.g. estuary vegetation and lateral connectivity

“Maintain” can be surveillance inspection or active works on an existing asset.

“Not started” means no evidence of maintenance activity

“In progress” means evidence of some maintenance activity on >50% of access-related assets

“Complete” means evidence of some maintenance activity on >80% of access-related assets</td><td colspan="3">See Rivers MEP for catchment scale tracking of access increase</td><td rowspan="3">Constraints to installation (e.g. tenure, presence of other assets, land managers, ongoing management responsibility issues)

Has improvements to access been at the expense of environmental values e.g. estuary vegetation lateral connectivity, bird roosting etc.

How have the potential conflicts between increasing access and protecting roosting habitat for birds been managed?</td><td rowspan="3">Access and recreation around estuaries has been maintained or improved (from 2018 baseline)

Improvements have been made to point access in the estuary over life of the strategy</td></tr>
<tr><td rowspan="2">Community Places PO’s are meeting rubric (see Table 19)</td><td rowspan="2">Community Places PO’s are 20% below rubric</td><td rowspan="2">Community Places PO’s are >20% below rubric</td></tr>
<tr><td>Enhance appropriate access and recreation opportunities including walking, cycling, boating and fishing activities.</td><td>Kms of new or renewed access paths established to or along estuaries

Location of other new or renewed access related assets built near estuaries e.g. boat ramps, seats, jetties</td><td>Spatial line or point (annual)

Status update</td><td>Mapping of length of new access path established (in construction or delivered).

Mapping of improved points and connections (i.e. new bridge, accessibility features, gates, boat ramps, benches/seats)

Any asset renewal or new build is done so as not to harm any environmental conditions or values e.g. estuary vegetation and lateral connectivity

“Not started” means no evidence of new or renewed assets activity

“In progress” means new or renewed asset process has been initiated

“Complete” means new build or renewal is final and maintenance activity has been scheduled</td></tr>
</table>

Table 19 Annual progress target for community places PO's

Catchment	18/19	19/20	20/21	21/22	22/23	23/24	24/25	25/26	26/27	27/28
Werribee	0 of 7 POs are in progress	0 of 7 POs are in progress	0 of 7 POs are in progress	2 of 7 POs are in progress	4 of 7 POs are in progress	All POs are in progress	All POs (at least) in progress > 1 POs complete	All POs (at least) in progress > 3 POs complete	All POs (at least) in progress > 5 POs complete	All POs complete
Maribyrnong	0 of 5 POs are in progress	0 of 5 POs are in progress	0 of 5 POs are in progress	2 of 5 POs are in progress	3 of 5 POs are in progress	All POs are in progress	All POs (at least) in progress > 1 PO complete	All POs (at least) in progress > 3 POs complete	All POs (at least) in progress > 4 POs complete	All POs complete
Yarra	0 of 2 POs are in progress	0 of 2 POs are in progress	0 of 2 POs are in progress	1 of 2 POs are in progress	1 of 2 POs are in progress	All POs are in progress	All POs are in progress	All POs (at least) in progress > 1 POs complete	All POs (at least) in progress > 1 POs complete	All POs complete
Dandenong	0 of 8 POs are in progress	0 of 8 POs are in progress	0 of 8 POs are in progress	3 of 8 POs are in progress	7 of 8 POs are in progress	All POs are in progress	All POs (at least) in progress > 2 PO complete	All POs (at least) in progress > 4 POs complete	All POs (at least) in progress > 6 POs complete	All POs complete
Westernport	0 of 21 POs are in progress	0 of 21 POs are in progress	0 of 21 POs are in progress	8 of 21 POs are in progress	16 of 21 POs are in progress	All POs are in progress	All POs (at least) in progress > 5 POs complete	All POs (at least) in progress > 10 POs complete	All POs (at least) in progress > 15 POs complete	All POs (at least) in progress > 20 POs complete

Table 20. Summary of data collection, processing, storage and website reporting for each indicator.

Indicators	Monitoring method / data type	Data collection responsibility	Processing and reporting responsibility	Data storage system	Data provided on HWS website
Km of existing pathways maintained Location of other access related assets maintained near estuaries e.g. boat ramps, seats, jetties	Spatial line (annual) Point data (annual) Status update	Melbourne Water (team?) Local councils Parks Victoria	Melbourne Water (team?) Local councils Parks Victoria	MapBox	Annual tracking of the extent of access that is maintained or enhanced (line and point data) at subcatchment scale An assessment of performance i.e. on-track/off-track for the access POs at the catchment and regional scale
Kms of new or renewed access paths established to or along waterways Location of new or renewed access –related facility	Spatial line (annual) Point data (annual) Status update			MapBox	

8. Water Quality

The performance objectives set out in the Strategy are aimed at monitoring and reducing threats (such as sediment and nutrients) to estuarine water quality from the urban and rural catchment.

The water quality theme of *reducing sedimentation run-off from construction activity* consists of one performance objective for the Balcombe Creek estuary focussing on monitoring and reducing input of sediment to the estuary. The *improving water quality from agricultural land practices* theme includes one performance objective, applicable to seven estuaries, that focuses on implementing land management improvement programs (e.g. Melbourne Water's Rural Land Program) in the catchment to reduce sediment and nutrient loads. The Rural Land Program provides technical assistance and funding to landholders to support them to undertake works in drainage areas (such as waterways, wetlands, gullies, dams, drains) that keep soil and nutrients on the land and out of waterways. The water quality theme *recreational water quality* includes performance objectives for both Merricks Creek and Balcombe Creek estuaries to ensure that risk assessments are undertaken and followed prior to any artificial estuary entrance opening being undertaken.
The theme *reporting* is aimed at ensuring that estuary water quality monitoring programs run by Melbourne Water and community members remain active at Balcombe and Merricks creek estuaries.

Estuary Performance Objectives within the Water Quality Group are summarised in Table 21, the approach to monitoring and scoring these is summarised in Table 22, and the requirements for data management are summarised in Table 23.

Table 21. Summary of Estuary performance objectives within the Water Quality Group.

EPO sub-group	# POs	Example PO wording	Associated management actions	Relevant estuaries
Reduce sedimentation from run-off associated with construction for urban development	1	Monitor and reduce the threat of catchment sediment impacts on the estuary.	Manage sediment run-off from construction or land clearing	Balcombe Creek estuary
Improve water quality from agricultural land practices	7	Implement rural land program in catchment to minimise sediment and nutrient loads to the estuary.	Optimise fertiliser application Improve farm tracks and feedlots to reduce sediment runoff Vegetate headwater streams Reduce stock access to streams	Watsons Creek, Cardinia Creek, Deep Creek, Bunyip River, Yallock Creek, Lang Lang and Bass River Estuary catchments
Recreational water quality	2	Artificial estuary mouth openings are only undertaken when a risk assessment concludes	Risk assessment before estuary is artificially opened	Balcombe Creek, Merricks Creek estuaries

		that opening conditions are low risk for the environment.		
Reporting	2	Continue to monitor estuary water quality through the EstuaryWatch program and Melbourne Water monitoring sites	Continuation of funding for EstuaryWatch Continuation of support for community groups to participate	Balcombe Creek and Merricks Creek Estuaries

Table 22. Summary of monitoring approach and scoring criteria for each water quality performance objective theme

Performance objective	Monitoring			Scoring criteria				
	Indicators	Report format (due date)	Specifications/assumptions	Mid-term				Final term
				On-track	Slightly off-track	Significantly off-track	Lines of enquiry if target not met	
Monitor and reduce the threat of catchment sediment impacts on the estuary.	Monitoring site in place and monitoring occurring regularly (see Water Quality estuary condition)	Case study 2022 and 2026	Progress toward reducing the threats of catchment sediment impacts reported via case study at mid-term and final. If mid-term data and case study indicates significant threat then catchment sediment sources identified by investigation and program developed	Monitoring is in place Case study	No monitoring occurring Case study	No monitoring occurring No case study	What activity in the catchment is contributing to sedimentation of the estuary? Is the frequency and duration of monitoring enough to give reliable estimates of sediment load?	Evidence of sedimentation of Balcombe Creek estuary is reduced
Implement rural land program in catchment to minimise sediment and nutrient loads to the estuary.	ha rural land treated	Quantitative (catchment scale) Cumulative ha - upstream catchment of estuary Status update 2022 and 2026 Case study (2022 and 2026)	Rural land treated includes vegetation and/or fencing of headwater streams and streamside zones Targets are reported at catchment scale in alignment with Rivers MEP Program activity in any upstream subcatchment of the estuary will reduce impacts to estuary. Contributions made by land stewardship programs such as Landcare and Westernport Biosphere will follow as much as possible the methodology of the MW Rural Land Program	See Water Quality rural land theme in Rivers MEP for catchment scale tracking Program activity in all 7 subcatchments (or upstream subcatchments)	Program activity in 4 of 7 subcatchments (or upstream subcatchments)	Program activity in 2 of 7 subcatchments (or upstream subcatchments)	See Rivers MEP Has funding been sufficient to promote rural land stewardship programs in these catchments? What other barriers to the uptake of rural land programs have hindered progress? Are the areas of land being treated by improved rural land management projects addressing the largest sediment sources?	Rural land targets have been achieved for Westernport Program activity has occurred in nominated subcatchments (or upstream subcatchments)
Artificial estuary mouth openings are only undertaken when a risk assessment concludes that opening conditions are low risk for the environment	Risk assessment	Status update 2022 and 2026	Risk assessment process outlined in Estuary Entrance Management Support System (EEMSS) has been followed	Risk assessment has been undertaken every time the estuary has been opened artificially	Risk assessment has been undertaken half the time the estuary has been opened artificially	Risk assessment has never been undertaken when the estuary has been opened artificially	Is there sufficient awareness in the community and amongst estuary managers of the risks associated with artificial estuary mouth opening? Does this performance objective apply to other estuaries in the region? Are there viable alternatives to estuary mouth opening that will solve the community problem?	Estuary mouth opening always utilise a risk assessment

Continue to monitor estuary water quality through the EstuaryWatch program and Melbourne Water monitoring sites.	# of Estuary Watch groups	Progress report (annual)	EstuaryWatch funding continues. Volunteers continue to be supported by the program. Volunteers continue to participate in EstuaryWatch monitoring in Balcombe and Merricks Creek.	EstuaryWatch sites active at both Balcombe and Merricks estuaries	EstuaryWatch sites active at either Balcombe or Merricks estuaries	EstuaryWatch sites at both estuaries has ceased	Is the EstuaryWatch program still funded? Have volunteer monitors been well supported? Has volunteer interest been maintained? Survey of community members that have been involved in the past (reasons for no longer being involved, barriers to participation etc.)	EstuaryWatch continues at both Balcombe and Merricks Creek estuaries
	# of MW estuary monitoring sites active		Funding for the MW long term water quality monitoring program continues. Water quality monitoring data is collected at least every two months and includes parameters outlined in the Yarra and Bay Report Card	Both Balcombe and Merricks Creek estuaries have at least one monitoring site	Either Balcombe or Merricks creek estuary have no monitoring sites	Both Balcombe and Merricks Creek estuaries have no monitoring sites	Does the MW long term water quality monitoring program have continued funding? How is the data being combined with other WQ data being collected to improve the overall estimate of determination WQ?	Both Balcombe and Merricks creek estuaries continue to be monitored through the MW long term water quality monitoring network

Table 23. Data collecting and reporting responsibilities for each water quality theme.

Indicators	Monitoring method / data type	Data collection responsibility	Processing and reporting responsibility	Data storage system	Data provided on HWS website
Monitoring site(s) in Balcombe Creek	WQ monitoring parameters Case study	Melbourne Water (Customer and Strategy) Estuary Watch	Melbourne Water (CWQ team)	Envirosys Estuary Watch database	Case study with data graphed
ha rural land treated	Mapping of area of land treated through the rural land program Status update and case study	Melbourne Water (WW&L) PPWP CMA? Westernport Biosphere land stewardship program?	Melbourne Water (Service Performance)	MapBox Grants tracker PPWP CMA system? WP Biosphere system?	Project locations on map Cumulative target graph Case study
Estuary mouth risk assessment	Risk assessment completed and estuary opened only in accordance with the risk assessment Status update	Melbourne Water (WW Parks Vic?	Melbourne Water (team?)	None at present	TBD
# of EstuaryWatch groups active	Count of groups	Melbourne Water (Waterwatch team)	Melbourne Water (Waterwatch team)	EstuaryWatch data base	Count of Estuary Watch groups active as compared to 2018
# of MW estuary monitoring sites active	Count of sites	Melbourne Water(CWQ team)	Melbourne Water(CWQ team)	Envirosys	Count of sites active as compared to 2018

- Review of Melbourne Water Estuary Monitoring program.

PART B: KEY VALUES SURVEILLANCE MONITORING

Audience and needs

The target audience for Part B of the Estuary MEP are people who are tasked with tracking the progress of key value targets for estuaries. In particular, this includes Melbourne Water's Waterways and Biodiversity team within Integrated Planning. Their knowledge needs include:

- How the current state of key values is being measured
- How key value monitoring results will be compared to target expectations.

Safety

Safety has been a key consideration in designing the monitoring programs. Melbourne Water is responsible to ensure a safe workplace and seek ways to prevent unwanted events in relation to staff and contractors. Melbourne Water seeks opportunities to eliminate, substitute and reduce through reviewing methodologies that are inherently more risky than identified alternatives, whilst still ensuring we address the key evaluation questions in the MERI Framework. Hazards and controls were rigorously identified for all waterway monitoring and these are recorded in a Waterway Monitoring Safety Risk Register, which is a Melbourne Water controlled document that will be reviewed annually.

Key evaluation question and monitoring objectives

The current state (as at 2018) and trajectory of each of the six key values for estuaries has been defined by the HWS at each priority estuary in the region. Key values are monitored under:

KEQ No. 3 – What is the state of waterway values? • KEQ 3a: To what extent are key values on the predicted trajectory?	Mid-term (2022) End of Strategy (2026)

Monitoring against these questions is due to be reported on at Strategy mid-term (2022) and final term (2026). It is unlikely that mid-term evaluation will be possible for all estuary values or conditions because little data was available to establish the current state at 2018. The focus of the Estuaries MEP to 2022 (mid-term review) will be to establish monitoring programs, develop relevant metrics and methods for analysis and establish a confidant baseline. Where there is existing data on values (e.g. for fish IEC development (2010-12) and Victorian Saltmarsh study) every effort will be made to make some kind of meaningful mid-term evaluation. In general, the evaluation of whether values are on track to meet long term targets will more likely be the focus of the end of strategy. The evaluation approach and method are summarised in Table 24.

Table 24. Summary of KEQ monitoring for estuary key values.

KEQs addressed	Evaluation approach and method	Data required to inform evaluation	Who judges progress and success?
KEQ No. 3 – What is the state of waterway values?			
Sub question 3a. To what extent are key values on the predicted trajectory?	Comparative methods – the status of key values will be compared to predicted target trajectory in the Strategy where enough data is available. Evaluation will be undertaken based on the methods outlined for each key value below.	Specific to each key value (see sections below).	Regional Leadership Group HWS Science Panel

The following primary objectives for broad-scale monitoring to address HWS MERI requirements include:

- Track against long term targets
- Understand landscape scale changes
- Track where management intervention is required

A summary of data collection methods for estuary values is outlined below in Table 25

Table 25 Summary of key value monitoring and evaluation

Key Value	Monitoring method (Change from HWS 2018)	Indicator	Other information to support evaluation	Monitoring frequency	Monitoring locations	Monitoring responsibility	Baseline data	Evaluation/reporting method and frequency
Birds	Field surveys of estuaries (professional) (New)	Native estuarine species richness	No species breeding No. listed species No species roosting at site	Monthly over Spring and Summer	14 estuaries	Melbourne Water (Waterways and Biodiversity team) to commission	To be established by 2022	Consolidation of data, development of metrics and establishment of baseline by 2022 and evaluation at end of strategy (2026)
Fish	eDNA fish catch (New)	Presence/absence	sex ratios, recruitment, body condition (TBC – metrics in development)	eDNA: twice per year (autumn and spring)	All 29 estuaries (eDNA) 5-6 estuaries (fish catch)	Melbourne Water (Waterways and Biodiversity team) to commission	To be established by 2022	Consolidation of data, development of metrics by 2022 and evaluation at end of strategy (2026)
Vegetation	Vegetation quality Vegetation extent Transect analysis (New)	Vegetation Vision Scores 1-5 EVC location and extent Plant Diversity, Plant Compositions, Plant Productivity		Every 4 years	All 29 estuaries	Melbourne Water (Waterways and Biodiversity team) to commission	To be established by 2022	Review of data at mid-term (2022) and evaluation at final term (2026)
Amenity	TBD by 2021							
Community connection	TBD by 2021							
Recreation	TBD by 2021							

9. Fish

Forty species of fish have been recorded in the region's estuaries, of which six have a conservation status listing. Species include the Australian Mudfish (*Neochanna cleaveri*), a range of gobies (Gobiidae spp.), eels (*Anguilla* spp.), Australian Grayling (*Prototroctes maraena*) and Black Bream (*Acanthopagrus butcheri*) (Melbourne Water 2011). Fish utilise estuaries in a number of ways, depending on their lifecycle and feeding needs. Fish species are grouped into functional groups as outlined below.

Non-estuarine dependent – Marine: Species in this group are regularly recorded from estuaries but are more commonly found in the marine environment. They only move into the estuary on flood tides or when freshwater discharge has decreased and salinity levels in the estuary are close to that of seawater.

Non-estuarine dependent – Freshwater: These species are generally only found in an estuary during periods of high freshwater inflows or may also be found in wetlands adjacent to the estuary.

Estuarine dependent - Seasonal Facultative and Obligate: Estuarine dependent, seasonal group species use the estuary at different times in their life history. Species in the seasonal facultative group often utilise the estuary as juveniles but also utilise sheltered marine embayments. Use of the estuary for migration, between the sea and freshwater, is an essential part of the lifecycle for species in the seasonal obligate group.

Estuarine Dependent – Permanent: Species in this group are able to complete their entire lifecycle in the estuary.

The section below outlines the approach to broad scale surveillance monitoring for fish. Knowledge gaps, research and intervention monitoring activities associated with fish are outlined in Part D.

Monitoring objectives

The following primary objectives for broad-scale monitoring to address HWS MERI requirements include:

- Regularly assess/report the status of fish populations at priority estuaries.
- Establish an estuary monitoring program that will build the body of data and enable the assessment of long term (~20 year) outcomes for fish in estuaries
- Use presence/absence of species to assess progress towards the HWS targets at the priority estuary and catchment scale.
- Develop a better understanding of fish health at key estuaries by targeting particular species and key questions.

Indicators

Estuary fish in the HWS (2018)

The assessment of the current state of the estuarine fish key value incorporated the AVIRA rare or threatened species and landscape features value categories as well as the Estuary Entrance Management Support System (EMSS) (estuary asset score for fish) which is outside of the AVIRA scoring framework (HWS Resource Document, 2020). The highest of the three metrics was assigned as the current status.

All available data were used during the assessment. This included local fish surveys that had been carried out in a number of estuaries, studies focusing on specific species such as the Grayling and Black Bream, data on fish collected during the development of the IEC assessments in 2010 to 2012 as well as data from the Victorian Biodiversity Atlas. But many estuaries had no data. Alternate data sources to those recommended in the AVIRA framework were required because of this lack of data.

Estuary fish in the Estuaries MEP

The intent of the estuaries MEP is to improve our data on estuary fish both in order to improve our confidence about the current and target trajectories (particularly for those estuaries where no fish data was available) but also to improve our overall understanding of fish in estuaries.

Habitat Suitability Models that were used as the basis for the fish baseline and rivers targets set out in the strategy do not currently extend to estuaries because many predictor variables were specific to rivers. It is therefore likely that individual estuary assessments will continue to be required moving forward.

Environmental DNA (eDNA) will become the primary focus of determining fish presence and absence in an estuary. This will be supplemented with fish population health indicators developed based on fish catch data. Data will come together in a multiple lines of evidence approach to become part of the overall determination of fish condition (where possible) at the mid-term and final review period.

The use of multi-metric indexes for fish in estuaries has been developed and adopted in several countries and in other areas of Australia (Harrison and Whitely, 2004; Hallett *et al.* 2012). The development of the Victorian Index of Estuary Condition by DELWP (in progress) will include a fish sub-index and these and a number of candidate fish metrics are being explored during this process (Warry and Reich, 2010.).

A list of indicators that will be collected for fish, and the data type used to support each indicator, are presented in Table 26

Table 26 List of fish indicators and what they can be used for.

Indicators	What it's useful for	Data source
Presence/absence	Understanding spatial distribution of fish across the region The calculation of metrics using presence/absence data.	eDNA, fish catch surveys
Species abundance Catch per unit effort CPUE - Fish catch surveys – per species trends over time	Spatial and temporal trends of abundance across selected estuaries in the region. The calculation of metrics using relative abundance measures.	Fish catch surveys
Population health (Recruitment) – number of adults, sub-adults and juveniles for estuary dependant species.	Population health and appropriate use of estuary as habitat - Spatial and temporal analysis can indicate whether the ratios are adequate.	Fish catch surveys
Population health (Fish body condition) – presence of parasites or others noticeable diseases	Population health - Trends over time	Fish catch surveys

A combined multi metric fish index will be explored to determine the most appropriate metrics for the region. Rubrics will be developed once metrics and estuary fish health categories have been derived. An example rubric is included in Table 27

In addition to the rubric below a data analysis plan will be developed that will outline other questions of interest and provide some detail as to how data will be analysed in order to answer these.

Table 27 Summary of monitoring approach and scoring criteria for fish

Monitoring			Evaluation			
			Final			
Indicators	Methodology	Specifications/Assumptions	On-track	Slightly off-track	Significantly off-track	Lines of enquiry if target not met
Species presence/absence	eDNA (triplicate samples – upper, middle, lower estuary zones)	Each of 29 estuaries will be sampled twice at 3 locations per estuary (upper, middle lower) by 2022 and twice again by 2026 Data will be used to calculate fish metrics (e.g. Table 32)	*To be developed* *Example for Werribee*: At final evaluation, 4 of 5 estuaries in the catchment have fish index scores that are the same as 2010 baseline or better	*To be developed* *Example for Werribee*: At final evaluation, 2 of 5 estuaries in the catchment have declined by at least one score from 2010 baseline	*To be developed* *Example for Werribee*: At final evaluation, 3 of 5 estuaries in the catchment have declined by at least one score from 2010 baseline	Is the reporting of estuaries at catchment scale problematic? Is the rubric appropriate? Is there enough data to calculate the 'best available' reference with enough confidence? Are fish population guilds responding differently over time? e.g. permanent resident vs seasonal facultative vs obligate guilds?
Fish species abundance	Fish catch surveys Catch per unit effort (CPUE)- per species	Key estuaries (e.g. those with the longest data set or where key species or particular management questions are important), will be the focus of live trapping. Sampled once, before mid-term and again before final strategy. Data will be used to calculate fish metrics (Table 32)				
Recruitment – number of adults, sub-adults and juveniles	Fish catch surveys					
Fish body condition – presence of parasites or others noticeable diseases	Fish catch surveys					

Data Collection (how, where, when)

How

Environmental DNA (eDNA)

Environmental DNA (eDNA) – DNA that an organism sheds into the environment - provides a relatively new, cheap, quick and non-invasive method for detecting species that is also safer for operators undertaking surveys. Environmental DNA is an emerging survey technique that has the potential to transform biodiversity monitoring in freshwater and estuarine ecosystems. Melbourne Water has invested significantly in developing eDNA based monitoring methods with the aim of implementing monitoring programs that are efficient, cost effective and safe (Tingley *et al*, 2020).

In the past fish data collection has required fish to be caught, identified and measured. A range of capture methods exist that include various methodologies of netting (of varying net sizes and water column depths) and electrofishing (differing in voltages and times used to stun fish), each tending to preference specific size ranges and species. As such, existing data sets of estuary fish in the region are inconsistent and the varying collection methods makes comparisons over time complex.

The use of eDNA shows promise as a technique that will largely become the core of future fish monitoring programs. Water samples are quicker and easier to collect and consistent methods of collection and analysis can be more easily established and adhered to. Also, the eDNA collected from one water sample can be analysed for a wide range of species (not just fish) and samples can be stored and analysed differently if required at a later date.

Currently, eDNA is most useful for determining the presence or absence of a species. Various useful metrics can be derived from presence/absence data such as those listed in **Error! Reference source not found.**. These metrics can be compared over time at an estuary and between estuaries across the region. A range of 7 potential metrics were developed for the trial IEC fish component (Warry and Reich, 2011), 5 of which can be derived using eDNA presence/absence data.

Based on MW/EnviroDNA proposed sampling strategy (Tingley *et al.* 2020) we propose triplicate eDNA samples (upper, mid and lower estuary extent) of all 29 estuaries four times over the strategy time frame (twice before mid-term and twice again before 2026). This means that trend analyses at individual estuaries may be possible by the end of strategy, especially when it is likely that some estuaries will have older presence/absence datasets available to add to the analysis (e.g. estuaries sampled as part of the development of the draft IEC fish subindex).

Fish catch

There is some information that eDNA cannot currently provide such a species abundance, evidence of recruitment, evidence of fish health etc. (King *et a*l, 2020). So it is proposed that additional information will be collected by fish catch methods at some estuaries once in every 5 year period of the strategy. A monitoring design report prepared by fish experts is currently in development (Bond, N *et al* in preparation) that will help define how fish catch data will be used in determining overall estuary fish population health.

The two sets of data may be combined to generate an additional range of metrics and the development of a multi-metric Estuary Fish Health Index will be explored as a possible way to assess integrate data for this value. At this stage this is an area for further exploration that is likely to be explored in future iterations of the Estuaries MEP.

Where

Regional surveillance monitoring (eDNA) of estuarine fish will be undertaken at all 29 priority estuaries (see Table 2).

Targeted fish catch data will be collected at a subset of estuaries that have been previously sampled for the development of the IEC, so that previous catch data can be used as comparison. This survey effort is likely to address questions of interest relating to the population health rather than whether a species is present or not.

When –

It is planned that two rounds of eDNA sampling of all 29 estuaries will be undertaken by 2022 and another two rounds by 2026. Triplicate samples will be collected and analysed at each estuary; one each located in the upper, middle and lower zones of the estuary.

It is anticipated that fish catch data will be collected at target estuaries once before mid-term and again before 2026.

A summary is presented in Table 28.

Table 28. Summary of the fish monitoring method and data for the HWS website.

Monitoring method	Where monitoring is required	Monitoring frequency (when)	Key purpose	Monitoring responsibility	Baseline data	Data storage and access	HWS Report Card
eDNA (triplicate samples – one each in upper, middle, lower estuary zones)	All 29 priority estuaries	Twice by 2022 (one in spring, one in autumn) Twice again by 2026 (one in spring, one in autumn)	Region-wide surveillance	Melbourne Water (Waterways and Biodiversity team) to commission	'Best available' based on 2010 trial IEC method.	MW fish data base	Fish survey locations Fish species regional status updates (similar to Native Fish Report Card (https://www.nativefishreportcard.org.au/) Trends over time of fish metrics and multi-metric at estuaries where adequate data is available Catchment scale on-track/off track
Fish catch survey	Sub set of estuaries (TBD)	Once by 2022 (autumn) Once again by 2026 (autumn)	Targeted species or management questions	Melbourne Water (Waterways and Biodiversity team) to commission			

Data storage, processing and access

Table 29 below provides a summary of where data is stored, how it can be accessed and processing requirements.

Table 29. Summary of data storing processing and access requirements for estuary fish values.

Monitoring method	Data storage	Data access requirements	Data processing requirements	Data processing responsibility
eDNA	Fish database (in development)	TBD	Data selection from database and GIS. Metric calculations for each estuary	Melbourne Water IT (spatial selection) then Melbourne Water/ Integrated Planning (score calculation)
Fish catch survey	Fish database (in development)	TBD	Researchers to collate and analyse (ARI, Melbourne Water, universities, council etc. as appropriate)	Researchers (or Agency staff) Melbourne Water Waterways and Biodiversity team

Evaluation - data analysis and reporting

Collation of available data

Data collation and storage of fish data in the estuaries will be improved. This will be tackled over the next 12 -18 month as fish data bases and data collation activities will be the initial focus. This will allow us to better understand how much data we have at some estuaries as well as seeing where we have none.

Data analysis

Data analysis is an area that is under development for the Estuaries MEP. Warry and Reich (2011) sampled fish in two seasons across the region for the development of the IEC between 2010 and 2012.Whilst the purpose of the IEC was to establish a statewide benchmark which will invariably be different to the needs of local strategy assessment, their work provides a lot of relevant information on methodology (e.g. establishment of reference based on 'best available') and will inform and support the development of local metrics. We will endeavor to use the 2010-12 data in combinations with two rounds of eDNA data collected over the 10-year strategy time frame to analyse for trends over time at some estuaries where sufficient data is available. It is noted that the work of the IEC highlighted that estuary fish were highly variable between samplings and between seasons. Some differences between Port Phillip Bay estuaries and Westernport estuaries were able to be detected for some fish metrics but within each embayment differences between estuaries were not consistently significant. It may be that the most meaningful assessment of estuary fish metrics over time is made between the embayment's rather than between estuaries.

Data analysis will be discussed with key expert and developed further once data collation and the first round eDNA sampling is complete. A monitoring design report prepared by fish experts that will discuss option for data analysis is currently under development (Bond *et al.* in preparation).

Mid-term evaluation

Due to estuary values and conditions being significantly less well developed, the focus of the mid-term evaluation will be on collating and analysing available data, including the first round of data outlined above, determining which of the available metrics is most appropriate to track changes over time and developing an evaluation rubric. Further detail on this will be developed by 2022 through the data analysis plan.

Final evaluation

To be confirmed post mid-term but should include an assessment of changes over time, answering questions outlined in the data analysis plan developed by 2022, climate change impacts, reassessment of the indicator and analysis of critical background conditions. We will also endeavour to determine if estuary fish value appears to be on track to achieve the long term target set in the strategy.

Emerging /complimentary monitoring methods

New opportunities for the use of eDNA in environmental monitoring continue to be developed. For example, changes in the relative amounts of nuclear and mitochondrial eDNA have even been used to monitor spawning of endangered fish (Bylemans et al. 2017 cited in Tingley et al 2020). This could be a technique that is explored over the course of the strategy time frame to look more closely at the role of estuaries as breeding places.

10. Birds

Estuaries provide important bird habitat for nesting, foraging and roosting. Over 70 species of birds recorded in the region's estuaries have a conservation status listing. Thirty-four of these species are particularly associated with estuaries.

Higher numbers of listed species were associated with all estuaries entering the western and northern parts of Port Phillip Bay and two estuaries on the eastern shore (Kananook and Balcombe Creeks). Higher numbers were also reported from four Westernport Bay estuaries: Merricks Creek, Tooradin Road Drain, Yallock Creek and Bass River. Further monitoring is required to determine whether any estuary provides critical habitat for particular species. Sixteen of the region's estuaries are listed as Important Bird Areas, and several are included within the boundaries of the region's Ramsar sites, particularly in the Westernport Ramsar wetland. Some estuaries have an important function as drought refuges and can support large numbers of bird species, particularly when areas of open water inland are scarce.

The section below outlines the approach to broad scale surveillance monitoring for birds. Knowledge gaps, research and intervention monitoring activities associated with birds are outlined in Part D.

Monitoring objectives

The following primary objectives for broad-scale monitoring of birds to address HWS MERI requirements include:

- Regularly assess/report the status of bird populations at priority estuaries.
- Use species richness, breeding and the presence of listed species to assess progress towards the HWS targets at the priority estuary and catchment scale.
- Better understand the health of regional bird populations through collection and analysis of this data to inform an improve management.

Indicators

Estuary birds in the HWS (2018)

For the 2018 Healthy Waterways Strategy, an index was developed to determine bird values status at each priority estuary and to set long-term targets using records of listed bird species as well as formally recognised significance of the site for birds (e.g. listed under the Ramsar convention, East Asian-Australasian Flyway Site, Directory of Important Wetlands in Australia or as an important bird area or important habitat for migratory birds in AVIRA). Data sources included the Victorian Biodiversity Atlas records, AVIRA, Melbourne Water bird survey records and the Melbourne Water SoBS database.

Estuary birds in the Estuaries MEP

On review of the relevant literature and from our knowledge of estuary birds a number of estuarine bird measures were explored that could be used to track bird status every four years and which have the potential to be sensitive to on-ground management interventions. They are as follows:

- Species richness
- Presence of threatened species
- Evidence of attempts to breed by multiple species

- Evidence of roosting – species in number greater than 50 individuals (to be developed with further on ground testing)
- Expected species appropriate for dominant habitat type (to be developed and tested on ground)

An updated estuary bird index/metric will be developed as enough data is gathered and the use of different bird guilds will be explored (similar to Hansen and Menkhorst, 2014). Similarly, a rubric for judging how condition is tracking at both estuary and catchment scale will be developed once appropriate metrics have been determined. Table 30 outlines the indicators that will be collected for estuary birds and Table 31 summaries the monitoring approach.

Table 30. Summary of indicators for birds and how they can be used.

Indicator	What it's useful for
Species richness	The variety of estuarine birds reliant on using the estuary
No. of species recorded breeding over period	Estuaries are critical breeding areas for some shore nesting species
No. of listed species of estuarine bird (both threatened and migratory) recorded over the period	Threatened or migratory species have particular importance for conservation management. This metric modifier weights estuary bird communities by the number of these important species found at a site, to ensure that sites with otherwise low numbers and variety of waterbirds but which support listed or migratory species are not under scored. .
No. species of estuarine birds using sites for roosting (only count sp. with greater than 50 birds roosting)	Estuaries are important areas for bird roosting
To be developed: The proportion of bird species as a reflection of the dominant estuary habitat (or similar)	Reflects the use of an estuary by species that are most appropriate for the surrounding habitat

Table 31. Summary and monitoring approach and scoring method for estuary birds

<table>
<tr><th colspan="3">Monitoring</th><th colspan="4">Evaluation</th></tr>
<tr><th rowspan="2">Indicators</th><th rowspan="2">Methodology</th><th rowspan="2">Specifications/Assumptions</th><th colspan="4">Mid-term and Final</th></tr>
<tr><th>On-track</th><th>Slightly off-track</th><th>Significantly off-track</th><th>Lines of enquiry if target not met</th></tr>
<tr><td>Native species richness</td><td rowspan="5">Professional bird survey
Subsample of estuaries to be monitored (Table 37)
Methodology to be used based in Hansen and Menkhorst 2014
Sampled monthly for 6 months over spring and summer
To be developed: estuary bird metrics.</td><td rowspan="5">All birds observed are recorded
Estuary length divided into 200m transects
Estuaries less than 4km long – 100% of transects are counted,
between 4 and 8 km long - 75% transects are counted,
longer than 8km – 50% transects are counted
Habitat noted for each observation, e.g. in reeds, on mudflats
Counts are made of channel, banks and riparian zone out to 50m either side of top of bank
Use of scope is mandatory</td><td colspan="3" rowspan="5">*To be developed by mid-term*</td><td rowspan="5">*To be developed by mid-term*</td></tr>
<tr><td>No. Native species recorded breeding over a period</td></tr>
<tr><td>No. of listed species of estuarine bird recorded</td></tr>
<tr><td>No. species of estuarine birds using site for roosting (only count sp. with greater than 50 birds roosting)</td></tr>
<tr><td>*To be developed:* The proportion of bird species as a reflection of the dominant estuary habitat (or similar)</td></tr>
</table>

Data Collection (how, where, when)

Field sampling

How

There is currently no regular monitoring of birds in estuaries in the region, although sporadic bird surveys may have been conducted by Birdlife Australia or by EstuaryWatch volunteers. These surveys usually produce species lists for part of an estuary but are of limited value in assessing the distribution of key estuarine species. They do not allow a systematic comparison between estuaries, nor an evaluation of key estuarine habitats for birds. The only significant estuary bird data was collected between 2010 and 2012 as part of the Index of Estuary Condition (IEC) development process (Hansen and Menkhorst, 2014).

The survey methodology developed during the IEC trial is the basis of the monitoring program proposed here (with some modification in sampling frequency) but further development of metrics and rubrics will be required when enough data has been collected.

Birds are mobile by nature and waterbirds, in particular, are responsive to rainfall and conditions inland which means estuary bird counts can be variable due to factors independent of local estuary condition (Hansen and Menkhorst, 2014; Mullins and Craig, 2020). As such, it is not expected that variability between estuaries will always be significant or due to conditions in a particular estuary but are more reflective of broader conditions both regionally and nationally.

Data collected by volunteers, in particular BirdLife Australia have been the main source of bird data for Melbourne Water for many years. While this continues to be the main way we propose to collect data for rivers and wetlands, we propose using professional bird monitoring services for estuaries as the investment in acquiring high quality, high reliability data and a relatively few locations when so little data is available is considered warranted.

As the IEC trial demonstrated that birds did not vary significantly between estuaries we are proposing to focus monitoring efforts on 14 of the 29 estuaries, use professional bird surveys (rather than rely on volunteers) and conduct 6 monthly samples per estuary per year.

The survey protocol developed as part of the IEC trial will initially be adopted here (Hansen and Menkhorst, 2014). In brief it is outlined below:

- Estuary is divided into 200m sequential transects starting from the estuary mouth and working upstream, either walking or by car.
- Birds counts are made of the channel, banks and riparian zone out to 50m either side of top of bank
- Use of a scope is mandatory
- All species observed are recorded
- Habitat used is noted for each observation e.g. in reed beds, on mudflats, etc.
- For estuaries less than 4 km long – 100% of transects are counted; those between 4 and 8 km long - 75% transects are counted; estuaries longer than 8 km – 50% transects are counted

Breeding behaviours are described using the terms below (modified from Mac Nally 2007).

Rank	Behaviour
1	Feeding of young out of the nest
2	Young birds seen or heard
3	Feeding of young in the nest
4	Presence of juveniles
5	Adults carrying food
6	Adults on the nest
7	Courtship/ mating

Record of bird species that are using the estuary for roosting will be made, if approximately 50 or more birds of the one species are seen roosting.

Where

Surveillance monitoring of estuarine birds will initially be undertaken at the estuaries in the region that were included in the IEC trial (Hansen and Menkhorst, 2014) plus one or two additional estuaries known to be important for birds where some previous monitoring data is available (Table 32).. Analysis of data over time may allow this number to be reduced.

Table 32 Estuaries of the region to be monitored for birds.

Estuary name
Balcombe Creek estuary
Bass River estuary
Bunyip River estuary
Cardinia Creek estuary
Chinamans Creek estuary
Kororoit Creek estuary
Little River estuary
Maribyrnong River estuary
Merricks Creek estuary
Warrangine creek estuary
Watsons creek estuary
Werribee River estuary
Yallock Creek estuary
Yarra River estuary

When

We propose monthly surveys at 14 estuaries over the spring and summer period (~6 months, or six surveys per estuary per year).

Table 33. Summary of the bird monitoring method and data for the HWS website.

Monitoring method	Where monitoring is required	Monitoring frequency (when)	Monitoring responsibility	Baseline data	Data storage and access	HWS Report Card
Professional surveys using the method of Hansen and Menkhorst (2014)	13 estuaries (as representative of all estuaries, Table 37)	Monthly over spring and summer (or six counts per year over the period when migratory shorebirds are present and shore-nesting species will be breeding)	Melbourne Water (Waterways and Biodiversity team) to commission	IEC trial data (2010-12) Birdlife Australia database (where available)	Melbourne Water TBD	*To be developed e.g.* *Estuary bird scores (2022)* *Catchment scale scores (2022)* *Bird species regional status updates*

Data storage, processing and access

Table 34 below provides a summary of where data is stored, how it can be accessed and processing requirements.

Table 34. Summary of data storing processing and access requirements for estuary bird values.

Monitoring method	Data storage	Data access requirements	Data processing requirements	Data processing responsibility
Professional surveys using the method of Hansen and Menkhorst (2014)	MS Access database at: I:\MEL\1. SHARED FOLDERS (Waterways Group) Inflo Migration\Cross Team Information\Investigations Programs\Birds\1 Data Management\11 Data MapInfo GIS layer	Annual submission of updated Birdlife Australia database in MS Access format	Data selection and extraction through MS Access and GIS. Metric calculations TBD	Melbourne Water IT (spatial selection) then Melbourne Water/ Integrated Planning (score calculation)

Evaluation - data analysis and reporting

Data analysis of bird data is an area that is under development for the Estuaries MEP

Mid-term evaluation

For the majority of river values the mid-term review phase (2022) will focus on an assessment of progress towards the long term sub-catchment scale targets. The relevant KEQs are:

KEQ No. 3 – What is the state of waterway values?

- 3a. To what extent are key values on the predicted trajectory?

Due to estuary values and conditions being significantly less well developed the focus of the mid-term review will be on analysing the data that is collected and deciding on appropriate metrics and corresponding rubrics.

Final evaluation

To be confirmed post mid-term evaluation but should include an assessment of climate change impacts, reassessment of the indicator and analysis of critical background conditions.

Emerging /complimentary monitoring methods

eDNA sampling

The ability of eDNA to collect data on bird presence at estuaries is being explored through a 5 year monitoring program at a subset of priority estuaries. One challenge with using eDNA to evaluate estuary bird values includes the high mobility of these bird species and their associated frequent utilisation of multiple sites.
While eDNA techniques may be developed within the timeframe of the Strategy there will be a continued need for field-based data to validate eDNA results, at least for the duration of the strategy time frame. .

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11. Vegetation

Estuarine vegetation is essential to estuary ecosystem function, to support habitat for aquatic animals and has fundamental worth for its aesthetic appeal. Vegetation adjacent to estuaries (such as mangroves, seagrasses and saltmarshes) help to maintain water quality, assist with nutrient cycling, and provide a buffer to catchment-derived sediments, nutrients and other pollutants entering the marine environment. It also helps to stabilise coastal areas. In-stream vegetation such as sea grass beds are important nursery areas for fish. There are 21 Ecological Vegetation Classes (EVCs) that are considered to be estuarine i.e. those that are subject to inundation with brackish water. These include riparian and in-stream communities and species. These EVCs include coastal saltmarsh, sedgelands, seagrass meadows, reedbeds and grasslands.

There are over 60 species of flora recorded from the catchments of estuaries in the region that have a conservation status assigned to them (Arundel and Barton, 2007).

Vegetation as a key value and estuary vegetation as a condition are difficult to separate for the purposes of a broad scale surveillance monitoring program and evaluation over the long term. So we are considering them in a combined monitoring approach for the time being similar to the approach the Rivers MEP is taking. As vegetation data is collected and metrics are tested it may be possible to create separate rubrics.

Monitoring objectives

The following primary objectives for broad-scale estuary vegetation monitoring to address HWS MERI requirements include:

- Determine the extent of estuarine vegetation condition classes (Vegetation Visions)
- Determine the change to estuary vegetation extent over time
- Determine changes in Ecological Vegetation Class distribution over the long term
- Determine changes to estuarine plant diversity, composition and productivity
- Determine changes to weed species area of occupancy

Indicators

Estuarine vegetation in the HWS (2018)

For the 2018 HWS, the assessment of the estuarine vegetation as a value and as a waterway condition were very similar. The assessment of the estuarine vegetation value was based on the AVIRA method and incorporated elements of the rare or threatened species/communities and naturalness value categories. Naturalness categories were very similar to the degraded habitat measures (using fringing vegetation as a proxy) that were used as data to establish estuary vegetation condition.

Alternate data sources were required from those recommended in the AVIRA framework due to lack of data. Data sources included rapid on-site assessments and review of aerial imagery.

Estuarine vegetation in the Estuary MEP (2020-2026)

A new estuary vegetation method has been developed to align with vegetation monitoring proposed for the Rivers MEP (based on Melbourne Water's updated Vegetation Visions method, Dell, 2020a b). The Vegetation Vision assessment is a rapid method that is designed to assess a 20m width of vegetation (from top of bank) x 100m length at whole estuaries scale (see

Appendix C). It has also been adapted to encompass sampling saltmarsh and related vegetation; giving consideration to the structural scale of the vegetation, the distribution of saltmarsh EVCs and environmental impacts associated with sampling (Dell 2020b). Data will be collected for a variety of sub-indexes of the Vegetation Visions but an overall score 1-5 will be generated to indicate overall estuary vegetation score (Appendix C)

Additional data will be collected at a much finer scale and across a wider portion of the estuary to answer a range of additional questions, principally about how climate change is affecting estuary vegetation across the region (see Appendices D, E and F and Dell, 2020a and 2020b)

The main focus of the new monitoring program is to improve data we have available for estuary vegetation in the region and establish a data driven baseline condition so that we can understand how vegetation is trending relative to the long term targets in the HWS. A secondary objective of the monitoring is to understand how vegetation is responding to climate change. This can be viewed as a research question and a knowledge gap but is described here for completeness – particularly as data from these more detailed monitoring sites can be used in the overall vegetation quality assessments.

A list of indicators that will be the focus of the estuary vegetation monitoring program are listed in Table 35.

Table 35 List of vegetation indicators and what they are used for.

Indicators	What it’s useful for
Vegetation quality	This tell us about the diversity of the species present and the structure of the vegetation community. It provides information as to how established the vegetation community is and what potential habitat benefit it may be providing. It is also a good indicator of the potential resilience of the vegetation to particular threats.
Vegetation extent	This tells us about how large and connected the patches of estuarine vegetation are and helps us to target areas for improvement. Vegetation extent also tracks how the ecological vegetation class (EVC) is changing over time.
Threats	This tells us what threats to vegetation have been detected in the area which informs what kinds of works are required to maintain or improve e.g. weed control. It also helps us to understand the likely trajectory of the estuarine vegetation if management actions are not undertaken.

Monitoring			Evaluation			
			Mid-term and Final			
Indicators	Methodology	Specifications/Assumptions	On-track	Slightly off-track	Significantly off-track	Lines of enquiry if target not met
Vegetation quality	Vegetation Visions (rapid method – see Appendix C) every 3 years at each of 29 estuaries	Estuary longitudinal extent divided into 100m segments covering the length in the estuary 20m both sides Vision assessment done on each section. Score 1-5 It may be unclear whether some species are herbaceous or woody in estuarine vegetation. It is recommended for consistency that species are classified prior to monitoring. Summary statistics for total distance (km) of each Vision score category. Overall summary Vision score per estuary Overall summary Vision score at catchment scale	Establish baseline by 2022 (mid-term review) AND Vegetation Vision score is maintained or improved by end of strategy (catchment average)	Baseline not established by 2022 (mid-term review) AND/OR Vegetation Vision declines by one rating by end of strategy review (catchment average)	Baseline not established by 2022 (mid-term review) AND/OR Vegetation Vision declines by two or more ratings by end of strategy review (catchment average)	Is reporting at the catchment scale problematic? Has changing indicators and data sources (i.e. from AVIRA to Veg Visions) changed original target scoring at estuary scale? If Vision scores are not maintained at catchment scale, does detailed analyses of individual estuary vegetation visions scores highlight which sub scores are accounting for the most significant change over time? Do the detailed transect vegetation and soil data provide any further information to explain the changes over time? Plant Diversity, Plant composition and Plant Productivity? Are there relevant management actions that can be improved to change the outcome?
Vegetation extent	EVC extent (combination of sub-plot floristic data interpretation, aerial photograph interpretation and field observations) See methods outlined in Dell 2020b	The boundaries of EVCs and overall area of estuarine vegetation extent within the estuary area should be checked during each round of monitoring and re-mapped to 5 m accuracy. *To be developed* Aerial and drone methods will be explored to minimise unnecessary site damage of sensitive estuary vegetation.	To be developed	To be developed	To be developed	
Weeds Threat	Collected at same time as Vegetation Visions but separate data. Every 3 years at each of 29 estuaries See Table 55 Appendix C	*To be developed* Weed threat outside Vegetation Vision area will need to be assessed as well. Aerial and drone methods will be explored to minimise unnecessary site damage of sensitive estuary vegetation.	Weed threat has been maintained or reduced by one score by end of strategy (catchment average)	Weed threat has increased by one score by end of strategy (catchment average)	Weed threat has increased by two scores by end of strategy (catchment average)	Are there relevant management actions that can be improved to change the outcome? Has weed control been effective and efficient in estuaries? What other obstacles have hampered weed control efforts in estuaries?

Data Collection (how, where, when)

How -

Two types of vegetation data will be collected; Vision assessments and detailed transects.

Data collection methods are outlined in Appendix C and further in Dell, 2020a and 2020b.

Visions assessment

- Divide the estuary into 100 m segments using the stream centreline. Number segments sequentially from the coast inland.
- Undertake a Vegetation Visions assessment for each 20m (wide) x 100 m (long) segment, on both sides of the estuary (see Appendix C and Dell, 2020a)

Detailed transects

The methodology for assessing estuarine vegetation is outlined in Appendix D and Dell (2020b).
Maps of estuarine vegetation and detailed transects are in Appendix E. Maps originate from the Victorian Saltmarsh Study (2011).

Overall estuary vegetation EVC extent

Mapped data of estuarine EVC's was collected during the Victorian Saltmarsh Study (2011) at 17 of the 29 priority estuaries of the HWS (mapped in 2009).

This will be used as baseline information where possible and similar mapping exercises done to map current EVC extent compared to the 2009 extent.

12 of the HWS estuaries were not mapped in 2009, presumably because estuarine dependant vegetation was not present in significant enough patches to warrant inclusion. This will be checked and verified using recent aerial imagery and field verification made when mapping Vegetation Visions is undertaken.

Where and When –

Vegetation Visions – all estuaries every 4 years

Detailed transects - See estuary maps for plots and sub-plots for 16 of the 29 priority estuaries. Also every 4 years.

Overall EVC mapping to check against 2011 Victorian Saltmarsh study maps focussing on use of aerial imagery 2022 and again by 2026.

Data storage, processing and access

Table 34 below provides a summary of where data is stored, how it can be accessed and processing requirements.

Table 36. Summary of data storing processing and access requirements for estuary vegetation value.

Monitoring method	Data storage	Data access requirements	Data processing requirements	Data processing responsibility	HWS Report Card
Vegetation Quality (Vision and Detailed transect data)	New vegetation database?	Data available in data base by Jan 2022 and Jan 2026	TBC	TBC	*To be developed e.g.* *Proportion of estuary vegetation of different Visions scores*  *Catchment average Vision score on track/off track* *Estuary maps showing EVC extent* *Weed cover maps* *Catchment scale on track, off track*
Vegetation extent (including estuarine vegetation EVC)	ARC GIS	TBC	TBC	TBC	
Threat	ARC GIS	TBC	TBC	TBC	

Evaluation - data analysis and reporting

Data Analysis

Data analysis of Vegetation Vision and transect data will be undertaken according to a data analysis plan prepared by Dell, M (2020c).

In some cases, once we have determined a method for mapping estuarine dependant EVC's via aerial methods, we can utilise the data collected for the Victorian Saltmarsh Study in 2011 to compare and make some assessment of whether the EVC has significantly shifted or reduced.

Data, as it becomes available, may be displayed on the website.

Midterm evaluation

The mid-term review phase (2022) will focus on achieving a minimum set of baseline data, determining the appropriate metrics and aerial surveillance methods. No assessment of whether we are on track to achieving long term targets will be made. However, work will be done to develop a rubric that will combine Visions assessments, detailed transect data where relevant and overall Estuarine vegetation extent to be used in the final strategy review

The relevant KEQs are:
KEQ No. 3 – What is the state of waterway values?

- 3a. To what extent are key values on the predicted trajectory?

Final evaluation

To be confirmed post mid-term evaluation but should include an assessment of climate change impacts, reassessment of the indicator and analysis of critical background conditions.

Emerging /complimentary monitoring methods

The use of aerial imagery, collected either via satellite or drone will be investigated for its use in mapping the quality and extent of estuarine dependent EVC's and potentially weed threat at individual estuaries. The analysis of aerial imagery was an important data source used to develop initial maps during the Victorian Saltmarsh study (2011) that were validated in the field and later refined. This technique will be renewed and updated.

Spectral analysis (the measurement of the reflectance of a variety of wavelengths from the canopy of vegetation) is already being investigated for its use in mapping the quality of high value riparian vegetation and it is thought that this has potential use for estuary vegetation and potentially weeds as well.

This would be a significant improvement in monitoring techniques as it could be a cheap and effective monitoring tool that reduces the need to trample across sensitive vegetation in order to map it. It could also be useful in targeting specific areas for weed control that might have otherwise been missed because they are difficult to access.

One notable area of estuary vegetation that has not been mentioned is sea grass cover and extent. Sea grass mapping over time has been the focus of significant research (Melbourne Water, 2018) and though it is not included as part of the overall assessment of estuarine vegetation outlined here, the integration of sea grass cover as one of the vegetation classes should be investigated further as part of continuous improvement.

12. Amenity

Amenity is the pleasantness of waterways and its ability to provide a restorative escape. People appreciate the space, serenity and cooling effect that waterways provide.

The monitoring and evaluation plan for Amenity will be addressed as part of continual improvement by June 2021

13. Community Connection

Waterways connect the community with nature and each other. They are often used as locations for picnicking, music and entertainment and family and community gatherings

The monitoring and evaluation plan for Community Connection will be addressed as part of continual improvement by June 2021.

14. Recreation

The region's waterways are important community assets providing opportunities for activities on and alongside the water. These include passive and active recreation, active commuting, boating, swimming and fishing.

The monitoring and evaluation plan for Recreation will be addressed as part of continual improvement by June 2021.

Part C: WATERWAY CONDITIONS MONITORING

Audience and needs

The target audience for Part C of the Estuary MEP is people who are tasked with tracking the progress of the MEP and the achievement of condition targets for estuaries. In particular, this includes Melbourne Water's Waterways and Biodiversity team within Integrated Planning and the Catchment Asset Management team in Service Delivery. Their knowledge needs include:

- How the current state of waterway conditions is being measured
- How waterway condition monitoring results will be compared to target expectations.

Other groups that may have an interest in collecting or using waterway condition data include teams and organisations that manage environmental flows; undertake land management around estuaries; manage estuary mouth opening; who are responsible for the removal of fish barriers; and or undertake water quality monitoring.

Safety

Safety has been a key consideration in designing the monitoring programs. Melbourne Water is responsible to ensure a safe workplace and seek ways to prevent unwanted events in relation to staff and contractors. Melbourne Water seeks opportunities to eliminate, substitute and reduce through reviewing methodologies that are inherently more risky than identified alternatives, whilst still ensuring we address the key evaluation questions in the MERI Framework. Hazards and controls were rigorously identified for all waterway monitoring and these are recorded in a Waterway Monitoring Safety Risk Register, which is a Melbourne Water controlled document that will be reviewed annually.

Key evaluation question and monitoring objectives

The current state (as at 2018) and trajectory of each of the six environmental and one social waterway conditions for estuaries has been defined by the HWS at each priority estuary in the region. Key conditions are monitored under:

KEQ No. 2 - To what extent has progress been made towards the longer term environmental condition targets for estuaries? • KEQ No. 2a – To what extent are the conditions on the target trajectory? If not, what are the possible causes	Mid-term (2022) End of Strategy (2026)

Monitoring against these questions is due to be reported on at Strategy mid-term (2022) and final term (2026).

The following primary objectives for condition monitoring to address HWS MERI requirements include:

- Obtain adequate data to establish baseline estuary waterway condition status
- Assess and report on changes in estuary waterway conditions over the life of the Strategy

- Assess the trajectory of change in estuary waterway condition at the catchment scale over the longer term
- Identify emerging threats to estuary waterway condition at the individual estuary and catchment scale
- Inform the on-going management of individual estuaries, and estuary management programs in the region.

Summary table

An overview of the monitoring methods and indicators for each estuary waterway condition is provided in Table 37 below. Where monitoring methods and scoring methods have been changed since the 2018 HWS, the rationale for change, and a summary of the updated method is provided in subsequent sections alongside more detailed information regarding data collection.

Table 37. Summary of Waterway Condition monitoring for estuaries.

Waterway condition	Monitoring method	Indicators	Where and when data will be collected	Monitoring responsibility	Baseline data	HWS Report Card	Method revised from 2018 HWS?
Flow regime	Freshwater inflow	TBD by 2021	All 29 estuaries Once by 2022 and again by 2026	Melbourne Water – Integrated Planning, Waterways and Biodiversity team	2018 HWS data/Flow Stress Ranking data where available, there may be some gaps for estuaries to be filled	Score for each estuary Catchment scale on track, off track Mid-term (2022) and final (2026)	Updated method, greater data collection
Tidal exchange	Marine exchange	Structures and behaviours indicator (dredging history, training walls) Proportion of estuary mouth openings that are artificial	All 29 estuaries once by 2022, again by 2026.		2018 HWS data where available, there may be gaps for some estuaries to be filled.	Score for each estuary Catchment scale On track, off track Mid-term (2022) and final (2026)	Minor changes, additional data collection
Longitudinal extent	Upstream barriers in estuary	Presence of upstream barriers within the estuary	All 29 estuaries once by 2022, again by 2026.		2018 HWS fish barrier data	Score for each estuary Catchment scale on track, off track Mid-term (2022) and final (2026))	Expanded method, greater data collection
Water quality	Water quality sampling	pH, turbidity, DO, chlorophyll-a	Continuous monitoring (DO, pH, turbidity, chlorophyll). Comprehensive sampling at a subset of estuaries.		New method in development by 2022, Comparison with SEPP (Waters) values or with locally derived guideline value.	*To be developed* *Score for each estuary* *Catchment scale on track, off track* *Some data available annually* Final (2026)	New method
Estuarine vegetation	Vegetation quality Vegetation extent (EVC mapping) Invasive species monitoring	Vegetation Visions scores 1-5 EVC mapping by 2026 Weed mapping	All estuaries assessed every 4 years.		New baseline to be set	*e.g.* *Proportion of estuary vegetation of different Visions scores*  *Catchment average Vision score on track/off track* *Estuary maps showing EVC extent* *Weed cover maps*	New method
Estuarine wetland connectivity	Lateral connectivity	Proportion of the estuary comprising artificial structures; connection to wetlands.	All priority estuaries assessed in time for reporting.		2018 HWS data where available, there may be gaps for some estuaries to be filled.	Score for each estuary Catchment scale on track, off track Mid-term (2022) and final (2026)	Expanded method, greater data collection
Access	*To be developed by 2021*						

Waterway conditions in the 2018 Healthy Waterways Strategy

Due to significant time constraints during the development of the 2018 HWS and a lack of available data on the condition of the many estuaries in the Port Phillip and Westernport region, Melbourne Water commissioned a baseline data collation project on estuary values and threats using the Aquatic Values Identification and Risk Assessment (AVIRA) method and a rapid on-ground assessment (DELWP 2015). AVIRA was used to determine (as at 2018) the current state, current trajectory and target trajectory for waterway conditions and values, but assessments were frequently constrained by a lack of available data (Jacobs 2018). This process is outlined in the HWS Resource Document (Melbourne Water 2020).

AVIRA is a prioritisation method, not a monitoring one, and is therefore not suitable to be used as the basis of monitoring over the life of the strategy. Therefore, a review was undertaken of available estuary monitoring approaches to determine which existing methods could be adopted to monitor estuary waterway conditions. Based on this review monitoring methods, indicators and scoring methods have been updated to facilitate estuary monitoring over the life of the Strategy.

One approach reviewed was the Index of Estuary condition (IEC), a statewide snapshot method for assessing estuaries across the state, reporting on waterway condition, supporting management prioritisation and providing baseline data to assess long-term or large magnitude change in waterway condition (DELWP 2017). The IEC has 5 sub-indices including Physical form (comprising artificial barriers on the shoreline and artificial barriers in stream) Hydrology (comprising marine exchange and freshwater inflow) Water Quality (comprising turbidity and chlorophyll-a) Flora (comprising fringing vegetation and submerged vegetation) and Fauna (comprising fish assemblage structure). Some of these sub-indices broadly align with some of the waterway conditions of the HWS however there are limitations with using the IEC as a monitoring approach as it has been developed for Statewide use to comparatively bench mark all estuaries.

Whilst the IEC methodology was largely not adopted in the Estuaries MEP there is some natural alignment between the IEC sub-indices and the conditions chosen for monitoring in the MEP. Whilst the MEP conditions and the IEC sub-indices overlap, often the methods proposed for use in the Estuaries MEP are quite different as a reflection of the need for greater information to inform future management interventions and track condition change over time e.g. Estuary vegetation monitoring for the MEP focusses on the rapid assessment of the full longitudinal extent, includes detailed lateral transects in estuary-dependant vegetation and will map changes in vegetation community over time. In contrast the IEC Flora sub index comprises measures of fringing vegetation and submerged vegetation. Additionally the Estuaries MEP is not proposing to turn data into a scale (e.g.1-10) or to combine condition assessments into an overall single estuary score.

In other instances the methodology used for the IEC is considered suitable for the purpose of the MEP e.g. assessment of estuarine wetland connectivity and in-stream barriers will be assessed the same way as the Physical Form sub index but at a greater frequency than the IEC. In this instance the measures align well with key conditions that support the values, performance objectives in the strategy and appropriate management interventions.

Emerging monitoring methods (such as techniques based on remote sensing methods) have also been identified and will be investigated over the life of the Strategy to support continuous improvement.

Table 38 below compares the indicators proposed for use in the Estuaries MEP and the subindices and indicators used in the IEC

Table 38. Comparison between estuary conditions monitored in the Estuaries MEP and the Index of Estuary Condition.

Waterway condition for the Estuaries MEP	IEC sub indices and components
Flow regime - freshwater inflows	**Hydrology sub index** freshwater inflow Marine exchange
Tidal exchange Marine exchange	
Longitudinal extent – assessing presence of fish barriers in the estuary (artificial shorelines)	**Physical form sub-index** Artificial shorelines Artificial barriers
Estuarine wetland connectivity – assessing presence of barriers between estuary wetlands and the estuary (artificial barriers)	
Water quality pH, turbidity, DO, chlorophyll-a	**Water Quality sub index** Turbidity Chlorophyll-a
Estuarine vegetation Vegetation Vision for estuary longitudinal extent, Vegetation detailed transects, aerial imagery with ground verification	**Flora sub index** Fringing Vegetation Submerged Vegetation

Indicators shown in colour overlap between the IEC and the estuaries MEP but in some cases may not be monitored with the same methodology.

Data processing, storage and access

Table 39 below provides a summary of where Waterway condition data will be stored, how it can be accessed and processing requirements.

Table 39. Summary of data storing processing and access requirements for Waterway conditions.

Waterway condition	Monitoring method	Data storage	Data access requirements	Data processing requirements	Data processing responsibility
Flow regime	Hydrology -freshwater inflow	Hydstra flow gauge data	*To be developed*	Metric calculations through MS Excel at each priority estuary	Melbourne Water/ Integrated Planning (score calculation)
Tidal exchange	Marine exchange (permanently open estuaries).	*To be developed*	*To be developed*		
	Marine exchange (intermittently open estuaries).	*To be developed*	*To be developed*		
Longitudinal extent	Physical form – upstream barriers	Arc GIS	*To be developed*		
Water quality	Water quality sampling	Envirosys Hydstra Storm website – WQ buoy	*To be developed*		
Estuarine vegetation	As for vegetation monitoring (value) + invasive species monitoring (*To be developed*)	ArcGIS Vegetation database (in development)	*To be developed*		
Estuarine wetland connectivity	Physical Form – lateral connectivity	Arc GIS	*To be developed*		
Access	*To be developed by 2021*	*To be developed*	*To be developed*		

Evaluation - data analysis and reporting

Mid-term evaluation

Table 40 below explains the rubric which will be used to assess waterway condition trends in relation to the long term targets. The assessment will be made at the estuary scale, for estuaries where there are data available. The targets for waterway conditions are expected to be achieved over a 20-year scale and, as such, major changes are not expected following only four years of strategy implementation.

As the data underpinning the 2018 assessments for estuaries was often poor or patchy, and new monitoring methods have subsequently been developed, it is likely that a new baseline will need to be set (pending a review of how the 2018 and mid-term data compares), rather than using 2018 assessments for comparison. If so, evaluation will be undertaken at final term, or if possible, an assessment of trends will be made at the catchment scale.

Table 40. Rubric for assessing performance against long term HWS targets for estuary waterway conditions at the mid-term review (2022).

Performance rating	Performance criteria / evidence						
	Flow regime	Tidal exchange	Longitudinal extent	Water quality	Estuarine wetland connectivity	Estuarine Vegetation	Access
On-track to achieving long term target	Condition score equals or has increased by one category relative to baseline at the catchment scale.						
Slightly off-track to achieving long term target	Condition score has decreased by one category relative to baseline at the catchment scale.						
Significantly off-track to achieving long term targets	Condition score has decreased by two categories or more relative to baseline at the catchment scale.						

Final evaluation

The method for final evaluation will be confirmed post mid-term evaluation but should include an assessment of climate change impacts, a reassessment of the indicators and analysis of critical background conditions and consideration of additional KEQs where appropriate. See End of Strategy Review section 2.4

15. Flow regime

Estuaries are characterised by the mixing of fresh water derived from the river and marine water coming in from the ocean (Tagliapietra *et al.* 2009). In Australia the rivers and streams that deliver these materials to estuaries show pronounced intra- and inter-annual variability in runoff, and in many cases, very large floods relative to 'normal' discharge; conversely, fresh water inputs into an estuary can be minimal during drought.

The HWS **Flow Regime Waterway Condition** describes changes from 'natural conditions' to the (freshwater) flow regime. This indicator refers to freshwater riverine inputs only (and thus not to marine flows) and therefore includes phenomena related to upstream river regulation, such as increases in low-flow magnitude or reductions in high-flow magnitude, increase in the proportion of zero flow, changes to monthly streamflow variability and altered streamflow seasonality. Reductions in freshwater flow into an estuary are known to have marked impacts on ecological condition and amenity value (e.g. Gillanders and Kingsford 2002; Koehn and Crook 2013).

The flow regime condition supports the key environmental values of fish, birds and vegetation and the key social values of community connection, access and recreation.

Indicators

Flow regime in the 2018 HWS

For the 2018 HWS, the AVIRA altered flow regime metric was used to support the assessment of Flow Regime for the 29 estuaries in the region. This was based on Index of Stream Condition (ISC) data (increase in low flow magnitude, increase in high flow magnitude, increase in proportion of zero flow, change in monthly streamflow variability, altered streamflow seasonality) for estuaries where these data were available[2] and a measure of farm dam density in the catchment for other estuaries. Available data included ISC assessments and the Melbourne Water Estuary Prioritisation Tool.

Flow regime in the Estuary MEP (2020-2026)

An improved method for monitoring and scoring the freshwater flow regime for priority estuaries is still in development and will be finalsied during 2021.

Flow Regime Scores

A scoring method was developed for the 2018 HWS to categorise Flow Regime into very low to very high condition ratings. Please see the Healthy Waterways Strategy Resource Document (Melbourne Water, 2020) for a description of this method. The new scoring method will be updated to reflect the new monitoring method.

Low or declining scores could trigger investigations into the possibility of obtaining environmental entitlements, increased stormwater management, or farm dam removal in the catchment.

[2] Little River, Werribee River, Skeleton Creek, Kororoit Creek, Maribyrnong River, Yarra River, Balcombe Creek, Cardinia Creek, Deep Creek, Bunyip River, Lang Lang River, and Bass River estuaries.

Data collection (how, where, when)

Monitoring requirements for Flow Regime are outlined in Table 41.

Table 41. Summary of the Flow Regime monitoring method.

Indicator	Specification	Monitoring locations	Monitoring frequency	Monitoring responsibility	Baseline data
Total (catchment) storage	As per updated statewide method. Details to be confirmed in 2021.	All priority estuaries	Data collected in time to meet mid-term (2022) and final-term reporting needs (2026)	Melbourne Water (Waterways and Land team)	Set with new method in 2020, except where earlier data is available, or where comparisons between earlier scores and new scores are shown to be valid.

16. Tidal exchange

Estuaries in Australia are often classified on the basis of their geomorphology and dominant hydrological regime (e.g. Roy et al. 2001; Ryan et al. 2003). As outlined in the introduction to this report, most estuaries on the south-eastern coast of Australia are either permanently open and wave-dominated or intermittently closed and open lagoonal systems (i.e. ICOLLs). Estuaries within the region therefore include those that are permanently open to the sea, such as the mouths of the Werribee, Maribyrnong and Yarra Rivers, and those that are naturally intermittently open and closed to the sea (some estuary mouths periodically close when tidal currents and river discharge are unable to sufficiently erode the sediment being delivered onshore by wave action). Of the 29 HWS priority estuaries in the Port Phillip and Westernport region, many are small and only intermittently open to the sea or the nearby marine embayment, including Merricks Creek, Balcombe Creek, Little River, Chinaman's Creek, Sheepwash Creek and Skeleton Creek.

The timing and duration of estuary opening and the volume and timing of freshwater inflows are two major influences on estuarine condition, particularly water quality. When an estuary is open to the sea, freshwater and salt water will meet and either mix or stratify into a fresh surface layer and saline bottom layer. When closed, many estuaries will mix, although stratification can remain for long periods. Freshwater inflows bring plant nutrients, carbon and sediment, all vital for estuary function. If the volume of water is sufficient, this will not only result in mixing of the estuary, but can also open a closed bar. All of these changes are critical to the biological communities in estuaries (EPA 2011).

Entrances to permanently-open estuaries are frequently modified, frequently increasing marine influence. Typical interventions involve increasing the cross section by dredging and use of training walls to allow boat passage but can also include artificially constructed entrances such as cut drains. This can lead to naturally intermittent estuaries becoming permanently open (Pope et al. 2015). These interventions are commonly undertaken to support social values (such as recreation) and conditions (i.e. access) but can have unintended consequences for water quality and estuary values. Management of marine exchange seeks to balance these sometimes competing values.

The HWS **Tidal Exchange Waterway Condition** measures the ability of sea water and fresh water to mix in the estuarine environment, in both intermittently or permanently open estuaries. The tidal exchange condition supports the key environmental values of fish, birds, vegetation and the key social values of community connection, access and recreation.

Permanently open estuaries have significantly different hydrological characteristics to intermittently open and closed estuaries, therefore different metrics have been proposed for these two types of estuaries.

Indicators

Estuarine Tidal Exchange in the 2018 HWS

For the 2018 HWS, the AVIRA altered water regimes measure was used to support the assessment of estuary tidal exchange for 29 estuaries in the region. This assessment included:

- For intermittently open estuaries: Proportion of estuary openings that are artificial.
- For permanently open estuaries: Presence of training walls and or occurrence of dredging at the estuary mouth.

Data sources included local knowledge and the Melbourne Water Estuary Prioritisation Tool.

Estuarine Tidal Exchange in the Estuary MEP (2020-2026)

These 2018 HWS measures have been retained for Tidal Exchange over the life of the HWS.

Marine exchange

For the Tidal Exchange waterway condition, there is one indicator: 'Marine Exchange'. As marine exchange varies considerably depending on whether an estuary is permanently open or intermittently open and closed, this indicator will be measured in two different ways. For permanently open estuaries, it will be based on structures (such as training walls) and behaviours (such as dredging), for intermittently open estuaries, it will be based on the naturalness of estuary mouth openings.

For permanently open estuaries:

The Structures and Behaviours metric for permanently open estuaries quantifies actions and infrastructure that interfere with marine exchange. This includes whether the estuary has been dredged since the last assessment, the number of training walls, the presence of training walls and artificial increases in marine exchange in the parent system.

As it measures actions and infrastructure that do not change rapidly, it is not expected to be particularly dynamic over the life of the Strategy. However, it is a relevant measure of pressure on the estuary as dredging and the erection of built structures can alter the exchange of nutrients, biota and water between the estuary and ocean.

For intermittently closed and open estuaries:

The Mouth Openings metric for intermittently closed and open estuaries quantifies the proportion of estuary mouth openings that are artificial. Artificial opening can have negative consequences to biota as the oxygenated surface water quickly flows out on opening (Becker et al. 2009). It may also be useful to have data on openings to see whether this is increasing over the longer term with climate change, indicating an increasing issue in the community as well as an increasing threat from management. Tracking openings of intermittently opening estuaries will also focus attention and management action on illegal/unauthorised artificial openings, as a threat in a small number of estuaries.

Tidal Exchange Scores

A scoring method was developed for the 2018 HWS to categorise Marine Exchange into very low to very high condition ratings. Minor changes have been made to the scoring method to reflect the expectation that more data will be available for subsequent assessments (see Table 42).

Table 42. Scoring method for Tidal Exchange.

Score	Criteria	
	Permanently open estuaries	Intermittently closed and open estuaries
Very High	Essentially natural marine exchange: • No training walls have been constructed at the estuary mouth AND • Dredging of the estuary mouth does not occur AND • no major modification to marine exchange of 'parent' estuary where applicable	No artificial estuary mouth openings occur with non-environmental objectives.
High	Not applicable	< 25% of all estuary mouth openings are artificial with non-environmental objectives.
Moderate	Some modification: • No dredging of entrance BUT minor structures at entrance OR • artificially constructed entrance OR • major increase in marine exchange of 'parent' system	25% -50% of all estuary mouth openings are artificial with non-environmental objectives.
Low	Not applicable	
Very Low	Major modification: • Dredging of the estuary mouth occurs OR • Training walls have been constructed at the estuary mouth	>50% of all estuary mouth openings are artificial with non-environmental objectives

It is possible for scores to change over the longer term with management intervention (such as removal of training walls, altered dredging regimes or reduced artificial openings), though scores may move in a negative direction over the longer term if reduced freshwater inputs lead to additional artificial openings.

Changes in score could be used to trigger management such as:

- New dredging could trigger investigations to find a better solution to the issue being addressed by dredging or to better understand the cause (e.g. reduced freshwater flows).
- A large increase in artificial mouth openings could trigger investigations and measures to restrict digger access (for example) or liaison with estuary land manager (e.g. Parks Victoria).

Data collection (how, where, when)

Monitoring requirements for Tidal Exchange are outlined in Table 43.

Table 43. Summary of the Tidal Exchange monitoring method.

Indicator	Specification	Monitoring locations	Monitoring frequency	Monitoring responsibility	Baseline data
Marine exchange: Structures and behaviours indicator (dredging history, training walls)	Based on data regarding: Number of times that the estuary has been dredged since the last assessment. Whether training walls are present. Data sources can include: onsite investigation, interviews with waterway managers, review of aerial imagery, GIS layers of waterway infrastructure etc.	Werribee River, Laverton Creek, Kororoit Creek, Stony Creek (PPB), Maribyrnong River, Moonee Ponds Creek, Yarra River, Elwood Canal, Mordialloc Creek, Patterson River, Kananook Creek, Stony Creek (WPB), Warringine Creek, Kings Creek, Olivers Creek, Watsons Creek, Tooradin Road Drain, Cardinia Creek, Deep Creek, Bunyip River, Yallock Creek, Lang Lang River, Bass River	Data collected in time to meet mid-term (2022) and final-term reporting needs (2026)	Melbourne Water (Waterways and Land team)	2018 HWS data where available, there may be gaps for some estuaries to be filled.
Marine exchange: Proportion of estuary mouth openings that are artificial	Data sources include interviews with waterways/land managers (e.g. Parks Victoria, Melbourne Water staff), Estuary Entrance Management Support System records (if available). local observations, work orders, EstuaryWatch records etc.	Merricks Creek, Balcombe Creek, Little River, Chinaman’s Creek, Sheepwash Creek, Skeleton Creek	Data to be collected on events as they occur; data to be collated in time to meet mid-term (2022) and final-term reporting needs (2026)		

Emerging /complimentary monitoring methods

Review of aerial imagery

In the 2018 HWS, sources of data for estuary mouth openings were based on local knowledge and records of opening. This data source can miss unauthorised estuary openings as well as natural estuary openings, making it difficult to accurately measure the rate of both the artificial and natural opening. It is also an incomplete historical record, making it difficult to understand how the rate of opening (both natural and artificial) may have been changing over recent decades.

The availability of decades of Landsat aerial imagery may provide an opportunity to measure the future and past frequency of estuary opening to track whether this is changing over time and potentially increasing as an issue of management concern, as well as providing a more comprehensive measurement of opening rates. The potential to fill this knowledge gap has been identified in Part D of this document.

Installation of data loggers

The indicators used to monitor tidal exchange are based on the presence of infrastructure and/or management actions undertaken and for this reason are not expected to change rapidly over the life of the strategy, given that many of these structures and/or actions are part of long term programs. A potential replacement monitoring indicator that is more dynamic would involve the installation of water depth loggers. Water depth loggers could be used to monitor estuary opening, and would provide the estuary water height prior to opening, as well as information on the duration of openings and tidal exchange when open (Pope et al. 2015). This would enable a comprehensive picture of all openings (natural and artificial) to be developed over the life of the Strategy, as well as to track changes to estuary mouth openings over longer time frames, for example, in response to reduce freshwater flows due to climate change. To monitor long term climate changes, loggers could be installed at intervals rather than continuously, and could be used in conjunction with aerial imagery analysis to build a picture of estuary mouth change and movement over time.

Link to monitoring of social conditions

As noted in the introduction to this section, actions or infrastructure that impact tidal exchange (such as dredging or training walls) are often undertaken to support social values (such as boat access) As such this condition may in future be utilised for its connection to social values (e.g. recreation).

17. Longitudinal extent

Artificial barriers (e.g. weirs, road crossings) can prevent the movement of biota, particularly fish, up and downstream and can also reduce the diversity of estuarine habitat by blocking the movement of salt water upstream (Arundel et al. 2009).

The HWS **Longitudinal Extent Waterway Condition** quantifies the proportion of the estuary that is affected by constructed barriers that interfere with the longitudinal (i.e. up and down) movement of biota and water. It is essentially the same measure as Instream Connectivity in the Rivers MEP but specific to estuaries.

Indicators

Longitudinal Extent in the 2018 HWS

For the 2018 HWS, the AVIRA altered physical forms measure (which uses the presence of instream barriers as a proxy) was used to support the assessment of estuary longitudinal extent. Data sources included the Melbourne Water Estuary Prioritisation tool, available IEC assessments, site investigations and a review of aerial imagery and spatial data.

Longitudinal Extent in the Estuary MEP (2020-2026)

The 2018 HWS measure has been retained for longitudinal extent over the life of the HWS.

Estuary barriers

The Estuary barriers indicator measures the presence/absence of permanent or intermittent barriers to the movement of fish and flows. This is assessed by visual inspection as the percentage area of the estuary affected by an artificial instream barrier that fully or partially blocks the passage of water or fish, compared against the position of the natural or historic head of the estuary.

Each fish barrier is considered to be either a Full or Partial Barrier. A Full barrier allows no fish passage (e.g. large dams or structures), Partial barriers may allow fish passage upstream during high flows. If the barrier status is unknown, the barrier is assumed to be partial.

Where fishways have been installed to ameliorate a barrier, it is assumed that these are being maintained and are fully operational. The maintenance of fishways is being monitored under Regional Performance Objective #18.[3] A measure of fishway maintenance may be added as an indicator over the life of the MEP as part of a multiple lines of evidence assessment approach.

[3] RPO-18 Critical waterway health assets including stormwater treatment systems, fishways and erosion control structures, are maintained for their designated purpose or the same outcomes are delivered by alternative means.

Longitudinal Extent Scores

A scoring method was developed for the 2018 HWS to categorise Longitudinal Extent into very low to very high condition ratings. This scoring method has been adopted for monitoring over the life of the Strategy (see Table 42).

Table 44. Scoring method for Longitudinal Extent.

Score	Criteria
Very High	No artificial barrier occurs within estuary (either partial or full barrier).
High	1-25% of estuary is affected by an artificial barrier that interferes (partial barrier) with the movement of water (in a typical year)
Moderate	>25-50% of estuary is affected by an artificial barrier that interferes (partial barrier) with the movement of water (in a typical year)
Low	1-50% of estuary is affected by an artificial barrier that completely blocks (full barrier) the movement of water (in a typical year)
Very Low	>50% of estuary is affected by an artificial barrier that completely blocks (full barrier) the movement of water (in a typical year)

Removal of barriers (according to Estuary Performance Objectives) will improve scores and the construction of additional barriers will also worsen scores. Reduced freshwater flows may worsen scores if existing partial barriers do not experience enough high flows to allow fish to migrate, though this may be offset by sea level rise over the longer term.

Removal of fish barriers in estuaries will be managed as part of the larger Melbourne Water fish barrier removal program.

Changes in score could be used to trigger management such as:

- The presence of additional barriers should trigger removal where possible.
- The increasing impact of barriers (e.g. due to reduced flows with climate change) could trigger investigations into the need and potential for additional flows or works to enable fish passage past barriers.

Data collection (how, where, when)

Monitoring requirements for Longitudinal Extent are outlined in Table 45

Table 45. Summary of the Longitudinal Extent monitoring method.

Indicator	Specification	Monitoring locations	Monitoring frequency	Monitoring responsibility	Baseline data
Upstream barriers	Presence/absence of permanent or intermittent barriers (% area of estuary affected by artificial instream barrier that fully or partially blocks the passage of water or fish, compared to natural/historic head of estuary). Upstream extent of the estuary to be measured as per the Melbourne Water estuary layer (in development)[4]. Fish barriers are considered to be either full or partial/selective barriers (where is it conceivable that some fish and flow could pass the barrier during high flows).	All priority estuaries	Data collected in time to meet mid-term (2022) and final-term reporting needs (2026)	Melbourne Water (Waterways and Biodiversity team) to commission	2018 HWS data

[4] This spatial layer has been developed using several sources to infer estuary extent including vegetation mapping and previous mapping of estuary extent based on measurement of the upstream extent of saline intrusion and the presence of permanent barriers (see Pope et al. 2015 and Barton et al. 2008 for details of the method).

18. Water quality

There are several variables available to indicate water quality, such as turbidity, chlorophyll a concentration (chl-a), dissolved oxygen (DO) concentration or percent saturation, total nitrogen (TN) and total phosphorus (TP), and some aspect of water quality is monitored in almost every estuary monitoring program (e.g. Ward et al. 1998; Deeley and Paling 1999; United States EPA 2006; New South Wales Office of Environment & Heritage 2013; South Australian EPA 2013; Coad et al. 2014).

Water quality monitoring of microbes as indicators for recreation and other social values were not been considered in this version of the MEP but will be further considered as part of continual improvement work done for Recreation value by June 2021.

The HWS **Water Quality Waterway Condition** monitors a selection of water quality indicators that can be used to understand key threats to the estuary and to inform ongoing management of the region's estuaries and catchments.

Scale of monitoring/Estuaries to be monitored

Although reporting is only required under the HWS MERI Framework at mid-term and final term of the HWS, it is not possible to sample water quality appropriately at just these times. As water quality variables are closely linked to the prevailing environmental conditions and respond quickly to a wide range of factors, there is a high potential for confounding of results if sampling is undertaken at just a few discrete points, due to the high variability of the data. In other words, if sampling is not undertaken frequently enough, the resulting data is unlikely to yield meaningful results.

Water quality monitoring, whether undertaken using continuous monitoring probes or spot testing, is expensive and it is therefore not feasible to monitor all of the region's estuaries at a frequency sufficient to report accurately on water quality under the Estuary MEP. There also needs to be a management justification for the collection of data, for example, the ability to respond to poor water quality events with a management intervention.

This monitoring plan attempts to reconcile the need for monitoring that provides an appropriate level of frequency to be able to robustly assess water quality, within these resource and practical constraints. Therefore, as a temporal compromise (i.e. reduced frequency of monitoring) is inappropriate, a spatial compromise is proposed, with a reduced number of estuaries to be prioritised for monitoring. This will enable meaningful, useful data to be collected at a small selection of estuaries: the Werribee, Yarra, Maribyrnong and Bunyip River estuaries. These estuaries have been selected on the following grounds:

- management intervention options (e.g. environmental flow release) are available in response to poor water quality results.
- the estuaries are spread across different catchments in the region.
- the estuaries are highly visible to the Melbourne population.
- the estuaries are well used by the community for various recreational activities.
- the estuaries support environmental values (such as significant fish species).
- from a practical point of view, they are relatively close to Melbourne, and have several access points to enable monitoring.

For further detail on monitoring indicators, methods, locations and sampling frequency, please see *Proposed Water Quality Monitoring for Estuaries in the Port Phillip and Western Port region under the Healthy Waterways Strategy* (Jacobs 2020b).

Water quality monitoring is already undertaken by Melbourne Water under several programs. The Waterways WQ monitoring program is focussed mainly on monthly grab sample monitoring at freshwater locations (over 130 across the region) and this data has been used in the Yarra and Bay Report Card (https://www.epa.vic.gov.au/for-community/monitoring-your-environment/monitoring-victorias-water-quality/report-card-2018-19). The nutrient and sediment Loads monitoring program has been focussed on assessing catchment load contributions to embayments. This data has been brought together with hydrographic data on streams around Melbourne to develop a Port Phillip and Westernport Source Catchments water quality and quantity model. One of the applications of this model is that it can be used to estimate the load of nutrient delivered into estuaries and bays. One of the reasons that water quality monitoring in estuaries will be targeted is because the model will be used to estimate estuary loads at mid-term and final review Additionally, water quality monitoring buoys in the Werribee (year round) and Yarra (summer only) have been used to monitor water quality condition in rivers and inform the improvement made by environmental flow release. The buoys monitor temperature, dissolved oxygen, conductivity and chlorophyll-a (Werribee River only), with probes at 0.5 m, 1 m, 2 m and 4 m (Werribee) and 0.5 m, 2 m, 4 m and 6 m (Yarra) below the surface.

Indicators

Water Quality in the 2018 HWS

For the 2018 HWS, the AVIRA degraded water quality measure was used to support the assessment of estuary water quality for 29 estuaries in the region. This assessment included:

- ability to meet EPA guidelines for DO, turbidity, pH and chlorophyll-a
- potential of adjacent land to contain acid sulfate soils
- excessive growth of instream macrophytes and
- frequency of algal blooms.

There was a paucity of data on water quality available for use in the 2018 assessment. A detailed water quality monitoring program and estuary survey is therefore proposed for the Estuary MEP to enable robust monitoring and reporting over the life of the HWS and to fill existing knowledge gaps on estuaries in the region (see Part D of this document for further detail).

Water Quality in the Estuary MEP (2020-2026)

Four common water quality variables are recommended for estuary water quality monitoring in the Estuary MEP:

- Turbidity
- Dissolved Oxygen
- Phytoplankton biomass

- pH.

The recommended monitoring variables are summarised in Table 46 below and described in further detail in subsequent text.

While Total Phosphorus and Total Nitrogen are useful variables for monitoring as they reflect catchment impacts and can flag the threat of algal blooms, these will not be monitored in estuaries under this MEP. These variables can be estimated from data captured under existing water quality monitoring programs in the catchments (e.g. under Melbourne Water's existing waterways water quality program and Loads monitoring program) and cannot be captured by the proposed monitoring method (water quality buoys), resulting in additional cost and field work risk.

Investigations into the links between pollutants, water quality variables and environmental key values are currently being undertaken on behalf of Melbourne Water[5] (Part D). These will result in refinement of the conceptual models that underpin the HWS and recommendations regarding appropriate water quality monitoring for contaminants e.g. sediment quality monitoring in estuaries. Hence, contaminant monitoring has not been specified as a component to measure in this iteration of the Estuaries MEP, but may be included in the future as part of continuous improvement in a multiple lines of evidence approach.

Table 46. Summary of indicators for Water Quality and how they can be used.

Indicator	What it's useful for
Turbidity	Suspended sediment can limit seagrass growth, smother benthic habitats and transport contaminants. Causes can include catchment erosion, algal blooms, poor sediment management on construction sites, sewage treatment outfalls and dredging.
Dissolved oxygen	Low DO concentrations can have adverse physiological effects in aquatic organisms, such as fill kills, gill damage and immune suppression, and can lead to increased availability and toxicity of contaminants such as lead, zinc and copper
Phytoplankton biomass	Increasing chlorophyll-a concentrations can be used as an indicator of poor water quality and eutrophication.
pH	Low pH can indicate the activation of acid sulfate soils along the estuary and acid drainage, with the potential for major environmental impacts such as fish kills and the mobilisation of toxic heavy metals

Turbidity

Turbidity refers to the scattering of light in the water column and is easy to measure routinely. Turbidity in estuaries varies (1) vertically down the water column at a given location and (2) longitudinally along the length of the estuary. Vertical turbidity variations within the water column are a function of the upper layers being made up mostly of fresh waters coming from the catchment and hence being laden with suspended particles; the lower layers of the water column come from the ocean and are relatively clean and any particles in these oceanic waters may have been earlier precipitated as a consequence of

[55] Project undertaken as part of the Aquatic Pollution Prevention Partnership (AP3): "Developing methods to increase the efficiency and effectiveness of waterway health assessment within streams, wetlands and estuaries" (Project C3.3).

ionic effects of high salinity (Reid 1961). It is recommended that turbidity is recorded mid-channel in top and bottom waters, at 1 m below the surface and at 1 m above the bottom in most cases.

Variation along the estuary is an ecologically important consequence of the mixing of fresh and marine waters in a tidal-dominated estuary, since it indicates the zone of maximum turbidity near the upper limit of the tidal wedge (e.g. Uncles et al. 2002). This turbidity maximum is most often situated near where riverine fresh waters and oceanic sea waters meet, and is usually just upstream of the zone in the river where phytoplankton are at their maximum (e.g. Hughes et al. 1998). The location of the zone of maximum turbidity, however, varies longitudinally depending on the prevailing climatic conditions. In the absence of any detailed information on where this maximum-turbidity zone exists (as is currently the case for most estuaries in the region), turbidity will be measured as either (1) a half-point distance along the estuary or (2) to maximise convenience, at the location where other water-quality variables are monitored.

The criterion for interpreting turbidity measurements is the proportion of samples where turbidity exceeds State Environment Protection Policy Waters (Waters) (SEPP Waters) environmental quality indicators for estuaries. With data that are very nearly continuous (i.e. those collected with automated probes), this corresponds to the proportion of time where turbidity exceeds the SEPP (Waters) guidelines (Victoria 2018).

Dissolved oxygen

Dissolved oxygen (DO) is the amount of oxygen dissolved in water. The concentration of DO in an estuarine water sample reflects an equilibrium between four factors: (1) diffusion from the atmosphere into the water column; (2) oxygen production in the estuary (i.e. oxygenic photosynthesis from plants, including algae in the water column, algae attached to surfaces, submerged macrophytes); (3) the large number of metabolic processes that consume oxygen (i.e. respiration by plants, aerobic respiration by animals, aerobic respiration by bacteria, nitrification by bacteria, abiotic chemical oxidation of reduced chemical compounds produced as a consequence of anaerobic bacteria metabolism); and (4) the mass balance of imports or exports of oxygen-poor or oxygen-rich water coming from the river or the ocean.

Most metazoan aquatic organisms require oxygen concentrations to remain within specified concentration ranges for aerobic respiration, and changes outside of this range can have adverse physiological effects, such as fill kills, gill damage and immune suppression, and can lead to increased availability and toxicity of contaminants such as lead, zinc and copper (ANZECC/ARMCANZ, 2000).

The DO variable will be interpreted in terms of the proportion of samples exceeding SEPP (Waters) Environmental quality indicators for estuaries (Victoria 2018), which is expressed in terms of % saturation. As DO is such a temporally variable measure (linked to tidal cycles due to the tidal fluctuations in saltwater inputs), DO will be measured continuously and frequently (e.g. every 15 minutes) with automated probes at bottom and top of the water profile.

Phytoplankton biomass

Chlorophyll-a concentration is widely used as a simple, convenient and integrative surrogate for phytoplankton biomass (Wetzel and Likens 1991). This biomass is a function of at least four phenomena: (1) rate of algal production – i.e. how quickly the algae are growing,

which is partly controlled by nutrients; (2) other 'bottom-up' factors, such as light availability; (3) rates of predation – e.g. by zooplankton or viruses; and (4) other loss processes, especially sedimentation and wash-out. Only the first process is directly related to nutrients; the other three are not directly nutrient-related. Even so, long-term (or increasing) chlorophyll-a concentrations are often a very good indicator of poor water quality and eutrophication (Ward et al. 1998).
The criterion for interpreting chl-a measurements is the proportion of samples where chl-a exceeds SEPP (Waters) Environmental quality indicators for estuaries (Victoria 2018). With data that are very nearly continuous (i.e. those collected with automated probes), this corresponds to the proportion of time where chl-a exceeds the SEPP (Waters) guidelines.

pH

Low pH in estuarine waters can indicate the activation of acid sulfate soils (ASS) (the oxidation of iron-sulfides stored in the soil) along the estuary and acid drainage. The ingress of acidic water from active ASS can cause the pH to drop to values of ~2 to 4 (Sammut et al. 1996), with very major environmental impacts such as fish kills and the mobilisation of toxic heavy metals. Unexpectedly low pH is an important trigger for management intervention such as ASS remediation.

The criterion for interpreting pH measurements is the proportion of samples where pH exceeds SEPP (Waters) Environmental quality indicators for estuaries (Victoria 2018). With data that are very nearly continuous (i.e. those collected with automated probes), this corresponds to the proportion of time where pH exceeds the SEPP (Waters) guidelines.

Sampling frequency

Currently and historically, there has been minimal water quality monitoring in the region's estuaries that fit the requirements of estuarine WQ monitoring, and therefore minimal data to use to assess what the natural range of water quality variables are. There are however, estuarine water quality objectives set under the SEPP (Waters) 2018 for a range of water quality indicators (see Table 47), providing guidelines for percentile values (requiring enough data to be collected to determine the relevant statistical parameters).

Table 47. SEPP (Waters) Environmental quality indicators for estuaries (Victoria, 2018).

SEGMENT	ENVIRONMENTAL QUALITY INDICATOR								
	pH (pH units)	Dissolved oxygen (surface) (% saturation)	Dissolved oxygen (bottom) (% saturation)	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Turbidity (NTU)	Chlorophyll-a (µg/L)	Toxicants Water	Toxicants Sediment
	25th -75th Percentile	25th Percentile - Max	25th Percentile - Max	75th Percentile	75th Percentile	75th Percentile	75th Percentile	% protection	
Estuaries	7.0-8.0	80-130	30-130	90	1,000	10	3	95	Low

Data collection method

Data will be collected using data loggers. The use of data loggers has the following advantages:

- Reduced occupational health and safety risk compared with samples being taken manually in the field by staff or contractors.

- It is not practical to sample manually at the frequency required to accurately monitor estuarine water quality, especially for variables that change very quickly, such as DO for which less frequent sampling will be either pointless, or worse, lead to erroneous interpretations of water quality.
- Data collection can be provided as a single service by contractors (e.g. all maintenance/downloading/equipment rental can be provided as part of a service contract with minimum need for oversight by Melbourne Water).
- For frequently monitored variables, it is much cheaper than manual sampling, even taking into account the initial costs of the probes.
- Data can be obtained at all points in the tidal cycle and so variation induced by tidal cycles can be better understood and interpreted.

Sampling will be undertaken every 15 minutes using the data logger for turbidity, DO, chl-a and pH. Sampling every 15 minutes is sufficient to track diel changes with a manageable resulting data set.

Location of sampling

Sampling location within the water column depends on the characteristics of the estuary being monitored, in particular, the depth of water in the estuary and its mixing characteristics (i.e. fully stratified, partially stratified or well-mixed). As the estuaries being monitored are mostly large, at least top and bottom sampling will be required, as these estuaries are likely to be at least partially stratified by salinity and perhaps fully stratified all the time (except during floods, which will temporarily destroy any salinity-based stratification).

Preferably, prior to monitoring being undertaken, an array of probes should be deployed within the relevant estuaries to determine whether they are well mixed vertically, and if stratified, where in the water column the halocline is positioned. This will inform where sampling should be undertaken longitudinally/the location of the probes within the water column. If this step is not undertaken, then sampling should be undertaken at least at two points: one shallow (0.5m - 1 m) and one deep (~1 m above the bottom).

Water Quality Scores

A scoring method was developed for the 2018 HWS to categorise Water Quality into very low to very high condition ratings. Please see the Healthy Waterways Strategy Resource Document (Melbourne Water 2020) for a description of this method. This has been revised due to the new monitoring method and will be applied at the four target estuaries (see Table 48). The scoring method below has been developed based on the Yarra and Bay Report Card scoring approach undertaken by the Victorian EPA for classifying water quality. The process for calculating scores is as follows (adapted from EPA, 2020):

- At each estuary, individual water quality indicators are calculated from annual monitoring data, using the relevant statistic that applies to each indicator in SEPP (Waters). These results are then compared to the SEPP (Waters) environmental quality objectives for estuaries (Table 47).
- The ratings assigned to each indicator are summed and normalised to produce a water quality score out of 10 that corresponds to a rating of Very Low to Very High.
- To aggregate the ratings from the different indices into the one water quality index for each site the following equation is used:

$$WQI = \frac{10}{4n}\sum_{i=1}^{n} I_i - 0.5$$

where n is the number of indicators at the site and I_i is the indicator value at the site (Table 48).

While this is the method that is currently being used for grab sample data it is likely to require some further development in collaboration with the EPA to ensure that the index works appropriately for time series data where multiple depth data is collated and that the scoring method is appropriate for the estuaries of the region.. While a scoring table for mid-term and final term reporting has been provided, scores for each indicator can be integrated into the HWS Report Card or the EPA Yarra and Bay Report Card more frequently.

Table 48. Scoring method for Water Quality.

Score	Range	Criteria
Very High	8-10	Near-natural high quality waterways
High	6-8	Meets Victorian water quality standards
Moderate	4-6	Some evidence of stress
Low	2-4	Under considerable stress
Very Low	0-2	Under severe stress

Changes in score could be used to trigger management such as:

- Investigations into sediment and nutrient levels and sources.
- Increased buffer vegetation installation along riparian areas that are hotspots for nutrient inputs.
- Increased activity (or increased targeting of activity) to manage sediment on farms.
- Acid Sulfate Soil remediation.
- Release of environmental flows to flush sediments and improve dissolved oxygen.

Collection of baseline water quality data, currently lacking for most estuaries, will assist in understanding current water quality baseline and typical variation, enabling future trends or impacts to be identified more clearly and appropriate management actions taken.

Data collection (how, where, when)

Monitoring requirements for Water Quality are outlined in Table 49.

Table 49. Summary of the Water Quality monitoring method.

Indicator	Specification	Monitoring locations	Monitoring frequency	Monitoring responsibility	Baseline data
Water clarity: Turbidity	Proportion of samples/time that turbidity (NTU) exceeded SEPP (Waters) guidelines* at the surface and bottom of the water column, halfway along the estuary.	Werribee, Maribyrnong, Yarra and Bunyip River Estuaries.	Continuous (e.g. every 15 minutes), using data loggers. Reporting must be undertaken at a minimum of midterm (2022) and final term (2026) of the HWS (in line with the MERI framework), however, annual reporting with a monthly break down is possible and recommended to inform management.	Melbourne Water (Waterways and Biodiversity team) to commission	Data will be compared against SEPP (Waters) values for compliance. At mid-term and final.
Dissolved oxygen	Proportion of sample/times that DO (percentage saturation) at the surface and bottom of the water column exceeded SEPP (Waters) guidelines*.				
Phytoplankton biomass: chlorophyll-a	Proportion of samples/time that Chlorophyll-a (μg/L) exceeded SEPP (Waters) guidelines*.				
pH	Proportion of samples/time that pH exceeded SEPP (Waters) guidelines*.				

*State Environment Protection Policy Waters (Waters) (SEPP Waters) (Victoria 2018) see Table 47.

19. Estuarine wetland connectivity

Estuarine wetland connectivity is a measure of the proportion of the perimeter of the estuary that is connected to its fringing wetlands and floodplain. Estuarine wetlands provide a wide range of highly valuable ecosystem services such as protection against erosion and storm surges, flood control, nutrient cycling and providing essential habitat (as summarised in Rogers et al. 2014).

Indicators

Estuarine Wetland Connectivity in the 2018 HWS

For the 2018 HWS, the AVIRA reduced estuary connectivity (proportion of the estuary perimeter with artificial barriers) measure was used to support the assessment of estuarine wetland connectivity for 29 estuaries in the region, alongside an additional measure of the presence of wetlands. Data sources included local knowledge, the Melbourne Water Estuary Prioritisation Tool, rapid on ground assessments and review of aerial imagery.

Estuarine Wetland Connectivity in the Estuary MEP (2020-2026)

The 2018 HWS indicators have been retained for Estuarine Wetland Connectivity over the life of the HWS.

Lateral Connectivity

This measures the percentage of estuary perimeter that has artificial structures (such as seawalls, levee banks, jetties, bridges, platforms etc.), a measure of pressure and a proxy for intertidal habitat suitability and connectivity.

Connection to wetlands

Where estuarine wetlands are present on the floodplain, connectivity between the estuary and wetland can be assessed either in the field and/or via aerial imagery interpretation. Where priority wetlands are present, data collected from the Index of wetland condition hydrology sub index can also be used to inform this assessment (see the Wetlands MEP for a list of priority wetlands and a description of the monitoring methods). Priority estuaries with estuarine wetlands are listed in Table 50.

Table 50. Priority estuaries with estuarine wetlands.

Priority estuary	Catchment	Priority wetland	Wetland area
TBD			

Estuarine Wetland Connectivity Scores

A scoring method was developed for the 2018 HWS to categorise Wetland Connectivity condition into very low to very high condition ratings. This scoring method has been adopted for monitoring over the life of the Strategy (see Table 51).

Table 51. Scoring method for Estuarine Wetland Connectivity

Score	Criteria
Very High	Estuary has no artificial structures AND Wetlands fully connected to the estuary OR No estuarine wetlands exist naturally
High	n/a
Moderate	1-15% of the estuary perimeter has artificial structures OR Wetlands are connected to the estuary but less than natural
Low	n/a
Very Low	>15% of the estuary perimeter has artificial structures OR Wetlands are no longer connected to the estuary

A decline in score over time would indicate that barriers are increasing, highlighting this as a threat in a particular estuary or as a broader trend. An increase in score would suggest some removal of barriers and would demonstrate achievement of (or progress toward) targets.

Changes in score could be used to trigger management such as:

- identification of barriers, identification of estuaries at risk, and targets for barrier removal.

A proactive approach to protecting current estuarine floodplains (as well as areas for estuarine migration) from inappropriate development, such as planning overlays, based on updated waterway condition data has also been identified for development particularly for those estuarine floodplains most at risk from development (See Part D of this document).

Data collection (how, where, when)

Monitoring requirements for Estuarine Wetland Connectivity are outlined in Table 52**Error! Not a valid bookmark self-reference.**.

Table 52. Summary of the Estuarine Wetland Connectivity monitoring method.

Indicator	Specification	Monitoring locations	Monitoring frequency	Monitoring responsibility	Baseline data
Lateral connectivity	Record the proportion of the estuary comprising artificial structures. Record the nature of the barrier (e.g. seawalls, levee banks, jetties, bridges, platforms etc. tidal gates, artificial channelization). Note that "estuary perimeter" will need to be mapped to support repeated measurement. DELWP has floodplain extent mapping for estuaries within the IEC, estuaries outside of this assessment will require additional assessment, based on aerial imagery interpretation. Data sources can include on-ground assessments, review of aerial imagery, review of spatial datasets regarding assets and waterway manager knowledge.	All priority estuaries	Data collected in time to meet mid-term (2022) and final term reporting needs (2026)	Melbourne Water (Waterways and Biodiversity team) to commission	2018 HWS data where available, there may be gaps for some estuaries to be filled.

Emerging /complementary monitoring methods

Monitoring of wetland hydroperiod

Several remote sensing projects are in development that collect data on wetland extent and water regime for larger wetlands, such as monitoring of wetland hydroperiod. These techniques are being investigated for wetland monitoring in the HWS Wetlands MEP and could potentially be incorporated into monitoring of estuarine wetlands as they become available. These methods should enable the establishment of reference conditions/benchmarking for inundation patterns as well as an increased understanding of thresholds as data is available for several decades at an interval of fortnightly/monthly over this time period, depending on conditions.

Monitoring of wetland vegetation condition

The connectivity of an estuarine wetland to its estuary will influence the vegetation present. For example, barriers to connectivity between the estuary and the wetland may result in less inundation dependent vegetation and a transition away from saline tolerant species if the wetland shifts to a more freshwater regime. The condition of estuarine vegetation will be monitored as outlined in the Estuarine Vegetation Condition section of this document. Where possible, data resulting from estuarine vegetation monitoring will be used to indicate and interpret long term changes in estuarine wetland connectivity.

20. Estuarine vegetation

Estuarine vegetation is typically associated with plants which are adapted to saline or brackish conditions. This may include salt-sensitive vegetation on elevated banks within the flood zone across a range of riparian EVCs. The elevation difference between salt tolerant and salt sensitive vegetation closer to the coast can be minimal (<0.5 m), depending on surrounding topography and associated tidal influences. Coastal wetlands form a significant part of estuarine vegetation and these are dominated by Mangrove Shrubland and saltmarsh vegetation in Victoria (Boon 2012) which applies also to the Melbourne area. Along larger estuaries and further inland, steeper banks of estuaries may be occupied by a range of other vegetation types (Dell 2020).

For further detail on vegetation monitoring and evaluation see Section B: KEY VALUES SURVEILLANCE MONITORING Vegetation

21. Access

Social value related conditions, including Access, will be addressed as part of continual improvement by June 2021.

PART D: Research and intervention monitoring

The following section outlines the current intervention monitoring projects relevant to estuaries which are underway across the region along with current and future priority research areas.

When designing intervention monitoring and assessment, the following key considerations must be made:

- Does the literature review confirm that a scientific/ knowledge gap exists? i.e. It has not already been researched elsewhere and the research will produce concrete findings that can be adopted in some way (not just contributing to an already contested issue)
- Has monitoring and assessment been designed in a targeted way? i.e. Definition of the knowledge gap that needs to be filled or specific hypothesis is being tested.
- Has the monitoring and assessment been designed appropriately to meet objectives or the intent of the monitoring? And has the implications and costs of this been clearly communicated to decisions makers? i.e. Description of sampling technique, frequency, duration and spatial extent to achieve intent.
- Is it clear how the result is going to be used or what 'product' will be developed as a result of monitoring and assessment?

22. Research and intervention monitoring

Research

Research is any targeted investigation that aims to test hypotheses and to improve knowledge about a particular aspect of the complex system, especially through the testing of predictions (Peters 1991). Priority estuary research questions to be addressed during the life of the Strategy are listed in Table 53. Some of these can be easily filled, others will require a more extensive investigations such as review of the academic literature and/or targeted studies in the field. Note that there have been, over the past two decades or so, many investigations into the research needs of estuaries and other aquatic systems, and reference should be made to this older literature to gauge the extent to which prior recommendations have been heeded (e.g. see Fairweather 1999; Kennish 2004).

Intervention monitoring

Intervention monitoring and assessment is undertaken to assess the effectiveness of a specific, targeted action or intervention in the environment to reduce or prevent harm, or to answer a specific knowledge gap. The objective of assessing the effectiveness of a given management intervention means that intervention monitoring plays a crucial role in the adaptive management framework, by providing the new information essential to the proper functioning of the intervention-knowledge feedback loop.

Current research

Current research projects undertaken through Melbourne Waterway Research-Practice Partnership and the Aquatic Pollution Prevention Partnership (AP3) are outlined below:

Melbourne Waterway Research-Practice Partnership:

Testing critical assumptions of interventions and outcomes, and designing effective, efficient biodiversity monitoring to support strategy implementation (Project A2). This project will focus on supporting the overarching Monitoring, Evaluation, Reporting and Improvement (MERI) Framework and Plan for the 2018 Healthy Waterways Strategy. To do this, it will help identify critical assumptions between key Melbourne Water interventions, their relationships with environmental conditions, and subsequently, on the status/condition of key values of interest.

Geomorphic change & disturbance thresholds for the protection or recovery of stream form in urban catchments (Project A3). This project will develop physical form predictive tools to inform land development policy and planning, support delivery of the objectives of the 2018 Healthy Waterway Strategy and increase understanding of the Levels of Service that could be supported by streams draining urban catchments.

Urban flow ecology: Investigating relationships between flow, channel form, vegetation and ecosystem function (Project B1). This research will investigate how key aspects of the urban flow regime influence channel form and ecosystem values and services; and in turn how catchment runoff can be best managed to protect and restore streams in the urban environment.

Major sources and fate of sediments in streams, wetlands, estuaries and bays to inform management opportunities (Project B2). This project builds on recent work on sediment budgets in urban headwater settings, refining the urban sediment budget and investigating observations of runoff and sediments in rural and peri-urban areas. In particular, the project will build on the development of the dSednet model of Westernport bay catchment.

Understanding the interactions between groundwater, surface water and Groundwater Dependent Ecosystems (Project B4). This project will increase understanding of the interactions between groundwater, surface water and Groundwater Dependent Ecosystems (GDEs). In particular, it will seek to quantify the age and transit time distribution of ground- and surface waters, identifying GDEs that could be at risk of contamination.

How can retention, use and treatment of urban stormwater protect or provide natural flow regimes for waterway health? (Project C1). This project aims to test the assumption that stream protection, and potentially restoration is possible through catchment-based stormwater control measures (SCMs). It will do this by asking if stormwater runoff from urban developments can be adequately retained, used and treated to protect or restore stream ecosystem structure and function.

Effectiveness of rural land interventions to improve stream flows and water quality (Project C2)
This project will continue previous work on mitigating the impacts of rural runoff on waterway, in particular identifying the source of pollutants and the effectiveness of runoff control measures. The overall objective of this proposal is to develop a framework for our Rural Land Management Program to prioritise locations for investment and identifying the most appropriate rural runoff treatment measures.

Understanding the economics of urban water management for improved waterway health to inform effective investment frameworks and to drive regulatory or incentive changes (Project C4). This project will place the actions and changes required for waterway protection and restoration into an institutional analysis of the water industry. The approach will permit a formal reconciliation of the beneficiaries and cost-bearers of public, private and toll goods provided by the water industry and common-pool resources, with the primary outcome being a strong case for industry-wide review of integrated water management governance.

Evaluating direct seeding as a cost-effective revegetation technique (Project D3). This is a transition project, with the research phase concluding with the completion of data collection and synthesis of the data and knowledge acquired throughout the course of the project into tools and resources for use by Melbourne Water. The project will then become a Development Project (lead by Melbourne Water), that will look to embed direct seeding into MW business practice.

The impacts of 'next generation' citizen science programs (Project E1). This project will examine the adoption of 'next generation' digitally-mediated citizen science programs (such as the Frog Census app). In particular, it will consider the new forms of 'community' that might be supported by these technologies and the relationship with face-to-face and place-based volunteer experiences.

Aquatic Pollution Prevention Partnership (AP3):

Synopsis of the sources and impacts of pollutants on waterways and bays from urban and rural landscapes in the Melbourne Water Region (Project A1.1) The project will synthesise the sources, types and impacts of urban, rural and forest pollutants to receiving waterways.

Identification of cost effective opportunities for addressing pollutants from industrial catchments (Project A1.5) This project will first focus on a review of current practices for addressing pollutants from old and new industrial catchments including engineering treatment options, compliance and enforcement strategies, and behaviour change programs. The second phase of the project will identify industrials estates within the MW region that can be used to trial treatment options and best practices identified within the review.

Impacts of sediments from urban and rural stormwater on stream health (Project A2.4)
Overall this research program aims to understand the benefits and impacts of sediments and understand the effects of pollutants associated with these sediments from urban, rural and peri-urban land use to receiving waterways. The first part of the research will use Westernport as a case study to understand and assess the effects of pollutants in sediments generated from construction of new urban developments relative to impacts from existing urban and agricultural areas. It will also identify if current controls are appropriate and recommend tools for prioritising appropriate management

interventions. The project will be collaborative with Melbourne Waterway Research-Practice Partnership (MWRPP) Project B2.

Identifying and managing emerging contaminants of concern (Project B1.1) This project aims to keep a watching brief on the international literature for reports of new chemicals of concern, and to initiate programs in Melbourne to detect priority chemicals in the environment and, if necessary, their impacts on human health and the environment. Those chemicals warranting further investigation for their management will be dealt with in specific A3P programs.

Understanding the ecological impacts of untreated sewage inputs in waterways (Project B1.2B) The project aims to describe the characteristics of dry weather (sewer/septic leaks) and wet weather (ERS) untreated sewage spills to waterways and understand the relative ecological impacts from these sewages sources.

Developing methods to increase the efficiency and effectiveness of waterway health assessment within streams, wetlands and estuaries (Project C3.3) Through an analysis of current HWS conceptual models this project will identify key gaps in the knowledge of what indicators are needed to reliably predict the relationships between water quality condition and key environmental values, which will be used in developing the HWS Monitoring, Evaluation, Reporting and Improvement (MERI) framework. This project will also identify and develop new indicators (or tools) that can be used to better understand the link between water quality and stream health which ensure appropriate management options are undertaken.

What are the effects of chemicals frequently used by Melbourne Water along waterways on aquatic ecosystems and public health? (Project E2.4) To inform improved chemical use policies and practices, this project will identify chemicals used by MW in and around waterways, whether they are likely to be impacting on aquatic ecosystems and public health, and through a risk assessment approach identify management interventions or chemical alternatives for activities involving high environmental risk chemical use.

Understand the impact of litter, including microplastics, on the social and ecological values of waterways and bays (Project F5.1) The objective of this project is to develop a framework for conducting litter assessments to address different MW business needs in relation to litter management e.g. to identify sources and transport pathways of litter to inform implementation of preventative actions, assist in the prioritisation of various litter management scenarios based on cost-effectiveness, or determining the performance of litter traps.

Understanding the Westernport Environment (to be completed)

1. Sediment supply, seagrass interactions and remote sensing
2. Seagrass – nutrients, light and genetics
3. Hydrodynamic and sediment modelling to forecast seagrass coverage and recovery in Western Port
4. Ecological risks of toxicants in Western Port and surrounding catchments
5. Mangroves and Saltmarshes
6. Fish habitats, fish biodiversity and recreational fisheries
7. Population trends in waterbirds in Western Port: what do they tell us?

How findings from research and intervention monitoring projects will be disseminated?

Based on the Knowledge Exchange and Impact Framework 2018-2023 for the Melbourne Waterway Research-Practice Partnership, outcomes from research and intervention monitoring will be communicated in the following ways:

Approaches for dissemination of main findings will depend on the target audiences, stages and outcomes of the projects. Formal communication tools (see table) will be the dominant approach, but informal dissemination of information (personal communication) will also be used, especially during the initial phases of development of monitoring projects. This is possible due to the relationship between Melbourne Water and Research partnerships that fosters constant communication, through meetings and hot-desk work arrangements between the two.

Formal communication tools will be used throughout the project, and the choice and complexity of tools will depend on the stage of the project itself. Shorter communication tools (such as eBulletin), will be used at regular intervals for quick updates on the project and to communicate small important outcomes, while web-pages, for example, will be used for the duration of the project and beyond.

Three of the most important tools (through partnerships) are meetings, presentations and publications, and their use is dictated by the formal agreement between Melbourne Water and partnering universities.

Learning pathway	**Audience**
Annual research summit – combined summit for MWRPP and A3P partnerships, held annually	Researchers, Melbourne Water staff, external stakeholders
Presentations at catchment forums	Catchment forums (agencies and community)
MWRPP/A3P Technical Reports	Technical staff and interested community
Academic papers	Researchers, Technical staff and interested community
Project team meetings	Researchers, Melbourne Water staff
Melbourne Water lunch time seminars (Waterways and Wetlands group seminars)	Melbourne Water staff
External stakeholder presentations	External stakeholders
Email bulletins	Melbourne Water staff, external stakeholders
Conferences (oral and/or poster presentation)	Researchers
Field/Demonstrating days	Melbourne Water staff, external stakeholders
Webpages (MWRPP and A3P)	Melbourne Water staff, public, external stakeholders
Training course on sampling techniques	Melbourne Water staff (professional development)
Newspapers (local or state)	General public

Learning pathway	Audience
Guideline documents for monitoring	Melbourne Water and external stakeholders (CMAs)
Workshops	Melbourne Water staff, including demonstration of sampling techniques
Case studies	Melbourne Water staff, external stakeholders
Technical notes (one page document with summary of findings)	Any audience at training/workshop/demonstrating days

Priorities for future intervention monitoring and or research

Priorities for future intervention monitoring and research are determined through an annual research review process. The following list of priority knowledge gaps (Table 53) developed through the Estuary MEP development process will be considered for funding during this annual process. Key Research Areas were identified in the Healthy Waterways Strategy; links between the Key Research Areas and priority knowledge gaps are highlighted in the table.

Estuarine Vegetation mapping

To reduce cost and impacts to estuarine vegetation, the use of remote multispectral imaging should be explored as a means to identify EVC boundaries or the relative covers of indicator species. Such imagery may be obtained using a drone and would be relatively inexpensive given the timeframe of the monitoring. This method may remove the need for on ground vegetation boundary mapping, which may be more subjective and less accessible than a remote sensing method (Dell, 2020).

Controlled glasshouse experiments using estuarine indicator plants can provide useful insight into plant ecophysiological thresholds to climate, hydrology and other environmental variables (Johnson et al. 2016; Ravi 2019). Such research is outside the scope of the current monitoring however future investment by Melbourne Water may support such studies as an integrated approach to better understanding threats to estuaries.

It is recommended that smaller-scale research (fewer sites over less time) is undertaken separately to establish whether or not weed control is effective. The same will be required for control of other threats such as deer and other pest species, although the design will vary considerably depending on the threat and type of control. The results of third-party research on the effectiveness of management intervention may be adopted by Melbourne Water if the threat type and environment is comparable.

Melbourne Water has previously invested in research into developing methods for re-establishing estuarine vegetation such as mangroves in some of the estuaries where mangrove populations are declining. These methods could be further developed ready for broader scale implementation in similar ways to what is currently being done for direct seeding.

Table 53. Summary of priorities for future intervention monitoring or research.

Key Value / condition	Current critical knowledge gap	Rationale	Link to Healthy Waterways Strategy Key Research Area
All	Collation of existing information on the 133 waterways in the Melbourne Water region that flow into the sea.	Estuaries are a type of aquatic system that has been neglected for research and management for decades in Victoria. Some (29) of these estuaries were described following a rapid (2-day) assessment (Jacobs 2018) but there is no single collation to describe existing knowledge on the geomorphology, tidal regime, opening and closing conditions, presence of estuarine wetlands, ecological status, or social values of estuaries in the Melbourne Water region. This collation could also easily incorporate existing information to inform the estuaries MEP, such as the number of estuaries in the Melbourne Water region that are fringed with wetland vegetation. An audit along similar lines was prepared for estuaries in Gippsland (GHD 2005) and for some estuaries around Melbourne (Arundel and Barton 2007) but the lack of a comprehensive collation and inventory of what is known about all the estuaries in the Melbourne Water region is a clear knowledge and inventory gap. The preparation of such an inventory is the necessary first step in improving the management of estuaries (Finlayson 2003).	
Water quality	Are water quality variables (such as nutrient concentrations) useful in assessing the ecological condition of estuaries?	Data on water-quality variables (e.g. Total Nitrogen, Total Phosphorus, turbidity) are often collected as part of estuary monitoring programs. There is, however, considerable controversy as to how useful these measurements are in indicating the ecological condition of Australian estuaries (e.g. Scanes et al. 2007). The information gathered in this type of research would inform the water-quality monitoring component of the MEP.	• Understanding the environmental impacts of pollutants, including contaminants of concern, to inform risk-based management of waterways across the region. • Developing improved water quality indicators and monitoring methods to better understand the impacts of pollutants on waterway health. • Developing tools and approaches to assist in strategic planning of pollution management to protect biodiversity, amenity and recreation in waterways across the region. • Understanding the impact of climate change on water quality and management implications for the protection
Water quality	Can we model estuarine biogeochemistry to better predict the occurrence of algal blooms or of poor water quality that may lead to undesirable outcomes, such as fish kills?	Routine and event-based monitoring of estuaries can be expensive, and better predictive ability may be achieved by improving our understanding of how estuaries function ecologically, using biogeochemical models. Progress has been made along these lines in NSW (e.g. see Harris 2001: Webster and Harris 2004) but little or no corresponding research programs have been developed for	

Key Value / condition	Current critical knowledge gap	Rationale	Link to Healthy Waterways Strategy Key Research Area
		Victorian estuaries other than Woodland et al. (2015). The information gathered in this type of research would also inform the water-quality monitoring component of the MEP.	of aquatic biodiversity, amenity and recreation along waterways. • Quantifying ecosystem services in waterways for improving water quality to better account for the benefits of healthy waterways.
Water quality	What is the relationship between land use and estuarine condition in the estuaries of the Melbourne Water region?	Estuaries in the Melbourne Water region drain catchments with vastly different land uses, including intensive agriculture, urban environments and heavy industry. The influence that catchment land use has on estuarine condition would be a profitable avenue for research, especially given likely changes in land use in coming decades (e.g. increasing urbanisation). See for example Warry et al. (2016).	
Recreation, Community connection and Amenity	What is the impact of increased social use on estuary condition?	The Strategy aims to increase community interaction with estuaries, however increased usage may conflict with environmental goals for estuaries, making it less likely that these targets are met. For example, increased pedestrian/bike/dog walking access alongside estuaries may reduce these areas ability to support migratory or resident birds. There is some information available on this topic of recreation/ecology interactions for freshwater systems in Australia (e.g. Hadwen et al 2012) but very little for estuaries.	• Understanding and managing public health risks from recreation along waterways in the region. • Understanding the compatibility between social and environmental values and whether management actions are required to balance potentially competing objectives. • Refining our conceptual models and developing tools to support investment in waterway works for recreation and amenity
Flow regimes	What environmental (i.e. fresh water) flows are needed to maintain estuaries in the Melbourne Water region?	For most estuaries in the region, there is a very poor understanding of what freshwater flows are required to support key values.	• Developing improved approaches to flow data collection and data management to support flow management decisions. • Understanding and mitigating climate change effects on the hydrology of waterways, estuaries and wetlands. • Improving our understanding of the responses of key environmental values to flow regimes to refine our environmental flow objectives. • Developing tools and frameworks to assist improved decision-making in the management of flows to meet environmental flow objectives.

Key Value / condition	Current critical knowledge gap	Rationale	Link to Healthy Waterways Strategy Key Research Area
			• Improving our understanding of the hydrology of floodplains, wetlands and estuaries, including groundwater-surface water interactions to protect and improve aquatic biodiversity
Tidal exchange	What are the impacts of rising sea levels and a greater incidence of storm surges on Melbourne Water's estuaries?	Rising sea levels and an increased incidence of storm surges are both predicted as high-likelihood consequences of global climate change. The impacts of these two processes on estuaries in the Melbourne Water region is very poorly understood but is likely to be substantial.	• Understanding and mitigating climate change effects on the hydrology of waterways, estuaries and wetlands. • Improving our understanding of the responses of key environmental values to flow regimes to refine our environmental flow objectives
Tidal exchange	How can intermittently open estuaries be better managed? • What is the historical frequency of natural estuarine opening for intermittently open estuaries in the region? • What is the impact of reduced natural estuary mouth opening on estuary key values? • Should waterway managers consider opening intermittently open estuaries more frequently if there is a trend toward reduced natural estuary mouth openings and impact to estuary values?	Regional waterway managers have hypothesised that natural estuary mouth opening has reduced due to less freshwater entering estuaries (due to diversions and climate change). Whether this is correct, the impact of this on key values and the appropriate management response needs to be resolved to enable proactive management of this potential issue.	• Improving our understanding of management techniques that are most effective to protect and improve the ecological health of wetlands and estuaries • Understanding and mitigating climate change effects on the hydrology of waterways, estuaries and wetlands. • Improving our understanding of the responses of key environmental values to flow regimes to refine our environmental flow objectives
Estuarine wetland connectivity	What development is planned (or will be planned) for estuarine floodplains in the region over the life of the Strategy and how can the impacts be mitigated?	It would be beneficial to develop a way of flagging development that threatens the estuarine floodplain in a timely fashion to enable Melbourne Water and other waterway and land managers to intervene.	

Key Value / condition	Current critical knowledge gap	Rationale	Link to Healthy Waterways Strategy Key Research Area
Birds	Where are the locations of estuarine roosting sites for birds?	Mapping of key roosting sites will enable monitoring of the bird key value to be more targeted and will support the prioritisation of management works.	
Macroinvertebrates	The current and potential habitat value of estuaries for macroinvertebrates and the most appropriate metric to measure the macroinvertebrate value of estuaries.	There is a knowledge gap regarding the extent to which estuaries currently support macroinvertebrate species (a HWS key value) as well as their potential to. If macroinvertebrates are determined to be an appropriate inclusion as an estuary key value, then a method would need to be developed to measure this.	Improving our understanding of critical ecological processes and the ecology of key species to improve our conceptual and quantitative models
Fish	How much emergent vegetation is needed for fish habitat?	Performance objectives have been developed regarding enhancement of emergent vegetation in estuaries, to support fish species. The challenge for waterway managers is that it is not clear how much vegetation (and of what type) is an appropriate amount.	Improving our understanding of instream habitat conditions, threats and processes across the region to inform works planning.

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Appendix A: Estuary Fish

TBD by 2021

Appendix B: Estuary bird species list

(table is a combinations of estuary bird list from AVIRA (DELWP, 2015) and Hansen and Menkhorst (2014))

Common name	***Scientific name***	***Conservation status***
Australasian Bittern	*Botaurus poiciloptilus*	EN EN L - EN
Australasian Darter	*Anhinga novaehollandiae*	
Australian Pelican	*Pelecanus conspicillatus*	
Australian Pied Oystercatcher	*Haematopus longirostris*	
Australian Reed-Warbler	*Acrocephalus australis*	
Australian Shelduck	*Tadorna tadornoides*	
Australian White Ibis	Threskiornis moluccus	
Australian Wood Duck	*Chenonetta jubata*	
Azure Kingfisher	*Alcedo azurea*	NT
Black Bittern	*Ixobrychus flavicollis australis*	L - VU
Black Swan	*Cygnus atratus*	
Black-shouldered Kite	*Elanus axillaris*	
Black-tailed Godwit	*Limosa limosa*	VU
Brown Falcon	*Falco berigora*	
Brown Goshawk	*Accipiter fasciatus*	
Brown Thornbill	*Acanthiza pusilla*	
Chestnut Teal	*Anas castanea*	
Common Sandpiper	*Actitis hypoleucos*	
Crested Tern	*Thalasseus bergii*	
Dusky Moorhen	*Gallinula tenebrosa*	
Eastern Curlew	*Numenius madagascariensis*	VU
Eurasian Coot	*Fulica atra*	
Fairy Tern	*Sterna nereis nereis*	VU L – EN
Fan-tailed Cuckoo	*Cacomantis flabelliformis*	
Golden-headed Cisticola	*Cisticola exilis*	

Great Cormorant	*Phalacrocorax carbo*	
Great Egret	*Ardea alba*	L – VU
Great Knot	*Calitris tenuirostris*	L – EN
Grey Fantail	*Rhipidura albiscapa*	
Grey Plover	*Pluvialis squatarolaulva*	EN
Grey Teal	*Anas gracilis*	
Grey-tailed Tattler	*Heteroscelus brevipes*	L – CE
Gull-billed Tern	*Sterna nilotica macrotarsa*	L – EN
Hoary-headed Grebe	*Poliocephalus poliocephalus*	
Horsfield's Bronze-Cuckoo	*Chrysococcyx basalis*	
Intermediate Egret	*Ardea intermedia*	L – EN
Little Black Cormorant	*Phalacrocorax sulcirostris*	
Little Egret	*Egretta garzetta nigripes*	EN
Little Grassbird	*Megalurus gramineus*	
Little Pied Cormorant	*Microcarbo melanoleucos*	
Little Tern Sterna	*Sterna albifrons sinensis*	L – VU
Masked Lapwing	*Vanellus miles*	
Nankeen Kestrel	*Falco cenchroides*	
Nankeen Night Heron	*Nycticorax caledonicus hillii*	NT
Pacific Black Duck	*Anas superciliosa*	
Pacific Golden Plover	*Pluvialis fulva*	VU
Pacific Gull	*Larus pacificus*	
Purple Swamphen	*Porphyrio porphyrio*	
Red Knot	*Calitris canutus*	EN
Red-browed Finch	*Neochmia temporalis*	
Royal Spoonbill	*Platalea regia*	NT
Silver Gull	*Chroicocephalus novaehollandiae*	
Sooty Oystercatcher	*Haematopus fuliginosus*	NT

Straw-necked Ibis	*Threskiornis spinicollis*	
Striated Fieldwren	*Calamanthus fuliginosus*	
Swamp Harrier	*Circus approximans*	
Terek Sandpiper	*Xenus cinereus*	L – EN
Welcome Swallow	*Hirundo neoxena*	
Whimbrel	*Numenius phaeopus*	VU
Whiskered Tern	*Chlidonias hybridus javanicus*	NT
Whistling Kite	*Haliastur sphenurus*	
White-browed Scrubwren	*Sericornis frontalis*	
White-faced Heron	*Egretta novaehollandiae*	
White-fronted Chat	*Epthianura albifrons*	
White-winged Black Tern	*Chlidonias leucopterus*	NT
Yellow-faced Honeyeater	*Lichenostomus chrysops*	

Appendix C: Rapid Estuary Vegetation condition assessment - Vegetation Visions 2

The Melbourne Water Vegetation Visions 2 scale is an ordinal measure of vegetation condition, measured across five main variables.

1. Ratings should be applied to an area no larger than 1 ha. A representative area of 0.2 ha (20 x 100 m along one side of the waterway) is selected for scoring. The exception is Patch Shape and Fragmentation which should be assessed at the 1 ha scale (100 m x 100 m). Once selected an assessment should take no less than five minutes and no more than 15 minutes. The assessor assigns their most confident rating of each variable within the time allocated.

2. Determine the relevant EVC for which the vegetation being assessed best fits i.e. what is the likely EVC based on landscape context, remaining vegetation components and estimated/modelled EVC.

3 Familiarise with the table of criteria and then walk over selected 0.2 ha taking note of composition and cover of vegetation elements (3–5 min). Assign component scores (2–10 min) - record the relevant class of each variables e.g. A1, B2, C1, D1, E2. Sum ratings for each variable. Use the scale below to assign the score (e.g. 1 + 2 + 1 + 1 + 2 = 7) Score = 2, using the following rationale.

4 A1–A3 vegetation structure. This component is assessed by evaluating total site cover (not relative cover). A threshold of 10% total indigenous plant cover has been applied for mapping extent. Very Low quality native vegetation represents vegetation with some remnant components that may be increased in quality with suitable management. Low to very high patches meet the native vegetation definition of >10% total native plant cover. Determine whether the relevant EVC is a forest, woodland, woody treeless EVC or herbaceous treeless EVC and circle one quality value in one of A1, A2 or A3 only. Care should be taken to assess treeless examples of woodland EVCs under A1. Note – grassland and similar vegetation with a closed structure is not penalised for potential influence on plant diversity. This is regarded a short term disturbance factor and dominance of indigenous components over weeds is preferred.
Vegetation cover in escarpment or rocky outcrop EVCs is influenced by the availability of recruitment space. Total site cover should be assessed on a horizontal plane. Ensure that bryophyte and lichen cover on rock surfaces are included in combined plant cover estimates.

5. B1–B3 vegetation diversity. Diversity is assessed independently of plant age or size. Estimate category of species diversity. Refer to the terrestrial lifeform table below. Documentation of species names is not required. Count only species indigenous to the site. Include only lifeforms which are present at time of assessment.

6. C instream vegetation. Count number of instream plant lifeforms or species and assign relevant category.

7 D patch shape and fragmentation. Assess at ~1 ha scale (50 m up and down stream, 50 m laterally from waterway). A patch is contiguous native vegetation of any EVC which would gain a structure score of 2 or more. Assign score according to definition of patch shape and fragmentation in table.

8 E Regeneration. Regeneration assesses recruitment across vascular plant lifeforms. A recruit is any plant which is estimated to be 1–3 years old. Current season seedlings should not be included. Evidence of a recruit varies depending on species and it is up to the assessor to interpret the age of plants depending on site conditions. Recruitment cohorts may be evident. Evidence of fertile material is a poor predictor of plant maturity and should not be relied upon on its own. Recruits may include vegetative re-sprouts which are capable of growing into a new individual.

The tables below (Table 54 and
Table 55) provides corresponding scores 0–5 which allows data to be summarised for reporting. These reflect category intervals which were designed to resemble the original Vegetation Visions condition states. A total score of zero is summarised to 1 for consistency with the original method.

The final summary category for estuaries is the average of the total 100m plot scores converted to a 1-5 scale (example using mock data and scale table below). This gives better resolution than converting each plot total to the summarised score first, and then averaging the summarised score.

Mock data

	Structure	Richness	Instream	Patch shape	Regeneration	Sum (total score)
Plot 1	5	5	5	2	2	19
Plot 2	5	2	1	1	1	10
Plot 3	5	2	1	4	1	13
Plot 4	5	2	5	4	4	20
Plot 5	1	2	2	2	3	10
Plot 6	2	2	4	3	5	16
Plot 7	3	2	3	4	4	16
Plot 8	4	2	3	5	5	19
Estuary condition (average of summed plot scores)						15.375
				Medium		3

Score table
Total score

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	4	4	4	4	4	5	5	5	5	5

Summarised score.

Table 54: Vegetation Vision 2 - Vegetation quality criteria

Element	Quality					
	0 Absent	1 Very low	2 Low	3 Medium	4 High	5 Very high
A1 Structure **Forest and woodland**	Non-indigenous vegetation	One stratum with estimated cover ≤10%.	One stratum with estimated cover 31–50%. Two strata with estimated combined cover 11–30%.	Two strata with estimated cover 31–50%. Three or more strata with estimated combined cover 11–30%.	Three or more strata with estimated combined cover 31–50%.	Three or more strata with estimated combined cover >50%.
A2 Structure **Woody non-treed vegetation e.g. scrubs, heaths**	Non-indigenous vegetation	Estimated cover ≤10%	Estimated cover 11–25%	Estimated cover 26–50%	Estimated cover 51–100%, single stratum	Estimated cover 51–100%, two or more strata
A3 Structure **Non-woody non-treed vegetation e.g. grassland**	Non-indigenous vegetation	Estimated cover ≤10%	Estimated cover 11–25%	Estimated cover 26–50%	Estimated cover 51–75%	Estimated cover 76–100%,
B1 Richness **Forest and Woodland**	Non-indigenous vegetation	Very low species diversity (1–3 species)	Low species diversity (4–8 species)	Medium species diversity (9–15 species)	High species diversity (16+ species in less than 8 lifeforms)	Very high species diversity (16+ species in at least 8 lifeforms)
B2 Richness **Woody non-treed vegetation diversity e.g. scrubs, heaths**	Non-indigenous vegetation	Very low species diversity (1 species)	Low species diversity (2–6 species)	Medium species diversity (7–13 species)	High species diversity (13+ species in less than 7 lifeforms)	Very high species diversity (13+ species in at least 7 lifeforms)
B3 Richness **Non-woody non-treed vegetation e.g. grassland**	Non-indigenous vegetation	Very low species diversity (1 species)	Low species diversity (2–6 species)	Medium species diversity (7–13 species)	High species diversity (13+ species in less than 5 lifeforms)	Very high species diversity (13+ species in at least 5 lifeforms)
C **Instream vegetation composition**	None or non-indigenous vegetation	Instream vegetation of 1 species.	Instream vegetation of 2 species or lifeforms	Instream vegetation of 3 species or lifeforms	Instream vegetation of 4 species or lifeforms	Instream vegetation of 5+ species or lifeforms
D **Patch shape and fragmentation**	Non-indigenous vegetation	Native vegetation confined to 20 m from waterway on one side only, not longitudinally contiguous.	Native vegetation confined to 20 m from waterway on both sides of waterway, not longitudinally contiguous.	Native vegetation either longitudinally or laterally contiguous with native vegetation outside of assessment area, to within 100 m from boundary.	Native vegetation longitudinally and laterally contiguous with native vegetation outside of assessment area, >100 m from boundary in one direction.	Native vegetation longitudinally and laterally contiguous with native vegetation outside of assessment area, >100 m from boundary in both directions.
E **Regeneration**	Non-indigenous vegetation	No evidence of recruitment.	Little evidence of recruitment, few recruits present with restricted distribution.	Little evidence of recruitment, few recruits present with scattered distribution.	Recruitment clearly evident with more than a few recruits in less than half of lifeforms present. No evidence of canopy species recruitment in forests and woodlands.	Recruitment clearly evident with more than a few recruits in more than half of lifeforms present. May or may not include evidence of canopy species recruitment in forests and woodlands. ***OR*** If Recruitment clearly evident with more than a few recruits in less than half of lifeforms present, then evidence of canopy species recruitment required in forests and woodlands.

Restricted – confined to a single location with extent no more than a few square metres. Scattered – distributed in several locations although with one to several recruits in each location.

Table 55. Threat data collected within Vegetation Visions 2 assessment area

	0	1 Very low	2 Low	3 Medium	4 High	5 Very high
Weediness	Non-indigenous vegetation	Weed species >50% relative cover including highly invasive species.	Weed species >50% relative cover without highly invasive species **OR** Weed species 10–50% relative cover including highly invasive species.	Weed species 10–50% relative cover without highly invasive species.	Weed species <10% relative cover including highly invasive species.	Weed species <10% relative cover without highly invasive species.

Weeds include any plant taxon which is not regarded to be indigenous to the Melbourne region. Some taxa which are indigenous but have become weedy outside of their assumed natural range may be assessed as weeds. Weed cover is assessed as relative cover (i.e. percentage of total vegetation cover). Reference to 'Highly Invasive' weeds in White *et al*. (2018) is required to determine score, which is an estimate of the species capacity to invade and persist in natural ecosystems.

Threat	Observed	Not observed	Threat	Observed	Not observed
Rabbit pellets			Evidence of Phytophthora		
Rabbit warrens			Evidence of acid sulphate soil impacts		
Deer pellets			Native vegetation clearing		
Deer browsing			Stock access		
Deer wallows			Recent understorey fire*		
Fox scats			Recent canopy fire*		
Encroachment			Land slip or stream bank collapse		
Storm water / Grey water discharge			Soil surface erosion**		

*Estimated or known <3 years. **Conspicuous rill or gully erosion evident by exposed soil/clay and associated sediments.

Appendix D: Summary of Detailed Estuary Vegetation condition monitoring method.

The following is the survey method that will used to monitoring estuary vegetation every 4 years. This information will be used as Vegetation Visions which will help track vegetation quality and condition. The more detailed transect data will be analysed to contribute to some long term research questions to do with climate change and sea-level rise in estuaries. Estuary transects are mapped in Appendix E. For further detail please see Dell, 2020b.

Field survey set-up and data collection procedure for estuary vegetation

A. Divide the estuary into 100 m segments using the stream centreline. Number segments sequentially from the coast inland.
B. Undertake a Vegetation Visions assessment for each 100 m segment, on both sides of the estuary.
C. At each randomly selected transect site (Section 6 maps), run a tape and mark a subplot corner at 20 m intervals up to a maximum of 200 m (11 sub-plots in total). Install a stake at the start of the transect and record a magnetic bearing in the direction of the transect (Figure 4).
D. A sub-plot is a 2 x 2 m quadrat which is divided into 16 even squares (Figure 5).
E. At each sub-plot location, determine the EVC according to descriptions firstly in Victorian Saltmarsh Study (2011) and then according to DELWP EVC benchmarks for other vegetation.
F. A grid of nine sub-plots (Figure 5) is established at the nearest sub-plot location to the randomly selected location shown in estuary specific maps (red star). An additional stake is installed to allow relocation of the sub-plot grid (corner closest to estuary on transect line).
G. All vascular plant taxa are listed within each sub-plot. Data must be labelled to distinguish between isolated sub-plots and those which are part of a grid. Identification of plants should be made to infraspecific level where possible.
H. Species which are intercepted by a grid point in each sub-plot are recorded (25 points) (Figure 4). Each plant taxon which touches the point is recorded; more than one species may be recorded at each point. A point marker (rod) of 4–5 mm diameter is used.
I. Within each 1 m^2 cell of each sub-plot, the maximum height of shrubs, forbs and graminoids is recorded using a measuring staff (nearest 1 cm). Measurements are then averaged to obtain the mean maximum height for each lifeform at 4 m^2. The scientific name of the tallest shrub, forb and graminoid species is recorded at 4 m^2. Some herbaceous species such as *Phragmites australis* may need to be straightened on the measuring staff before measuring i.e. actual length of culm to apex rather than effective canopy height.
J. Soil percentage moisture, electro-conductivity and pH are recorded near the centre of each 4 m^2 using an electronic field meter.
K. Photographs are taken of the vegetation

  a. 3 x 3 grid plot – photo from the reference corner looking at the centre of grid (centre sub-plot).
  b. Photos are taken at full frame with a smart phone camera (equivalent to about 26 mm in 35 mm film camera) at 1.6 m from the ground.

L. The location of each stake is recorded with a standard GPS.

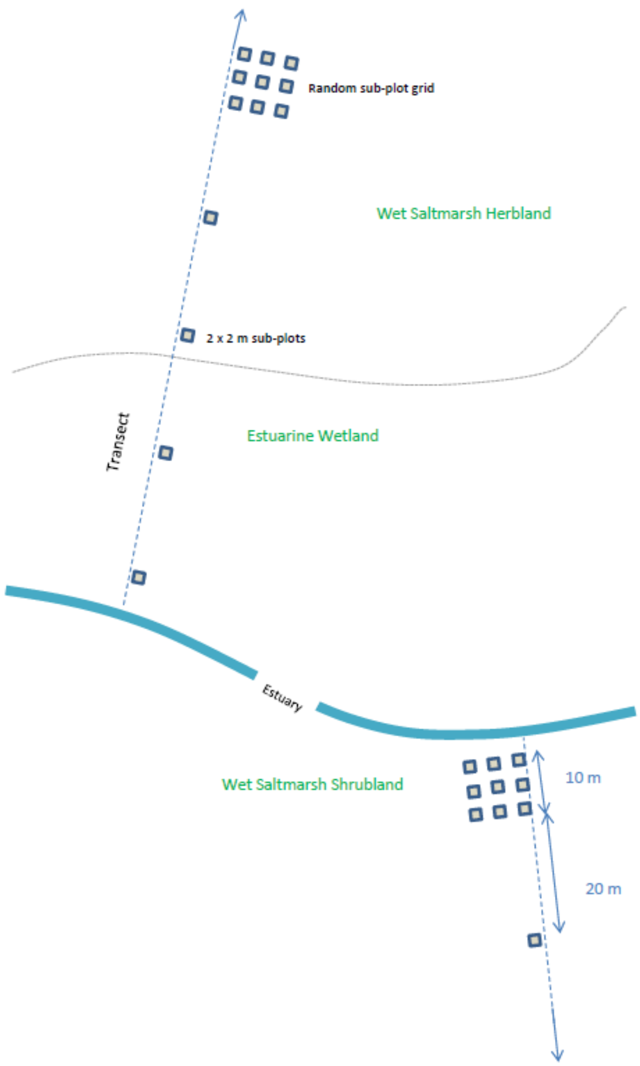


Figure 4. Example of grid and sub-plot transect layout for saltmarsh and related vegetation stratified by EVC (not to scale)

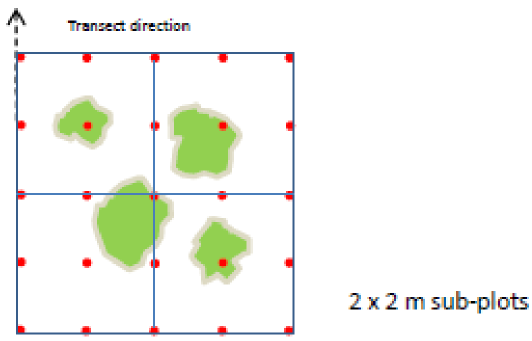
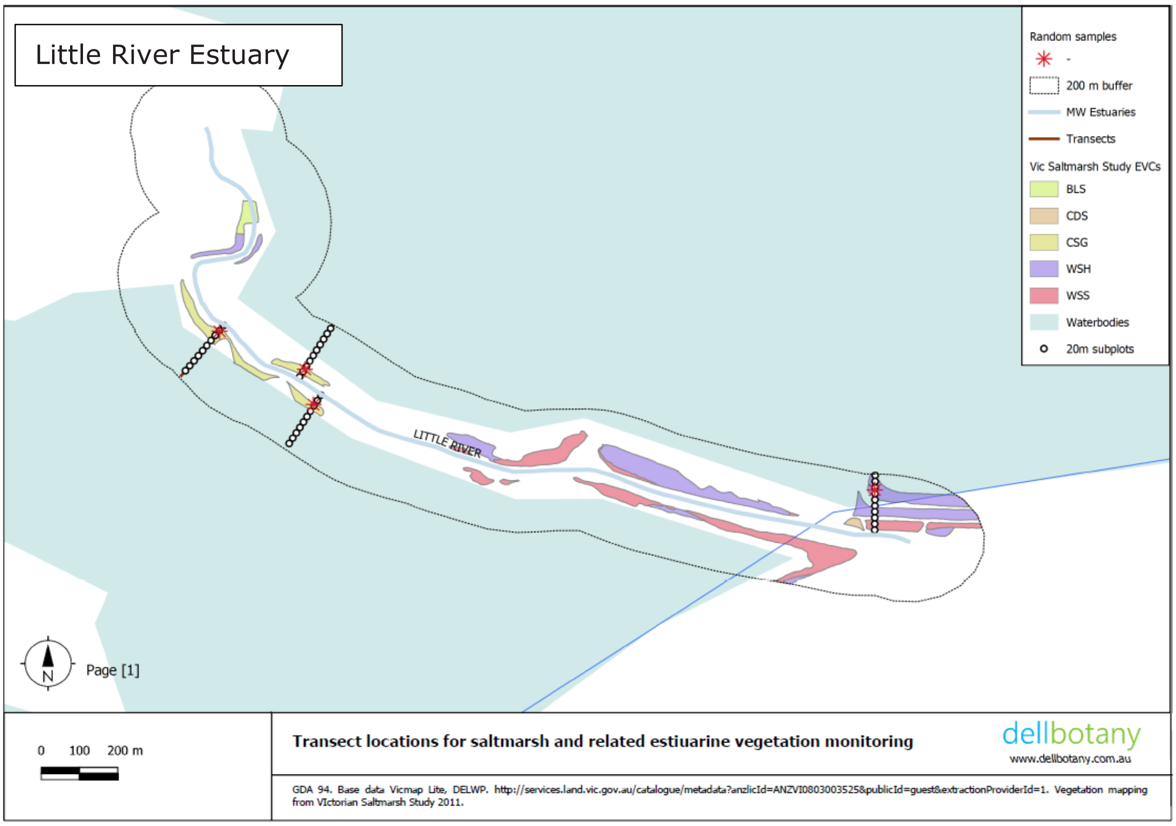
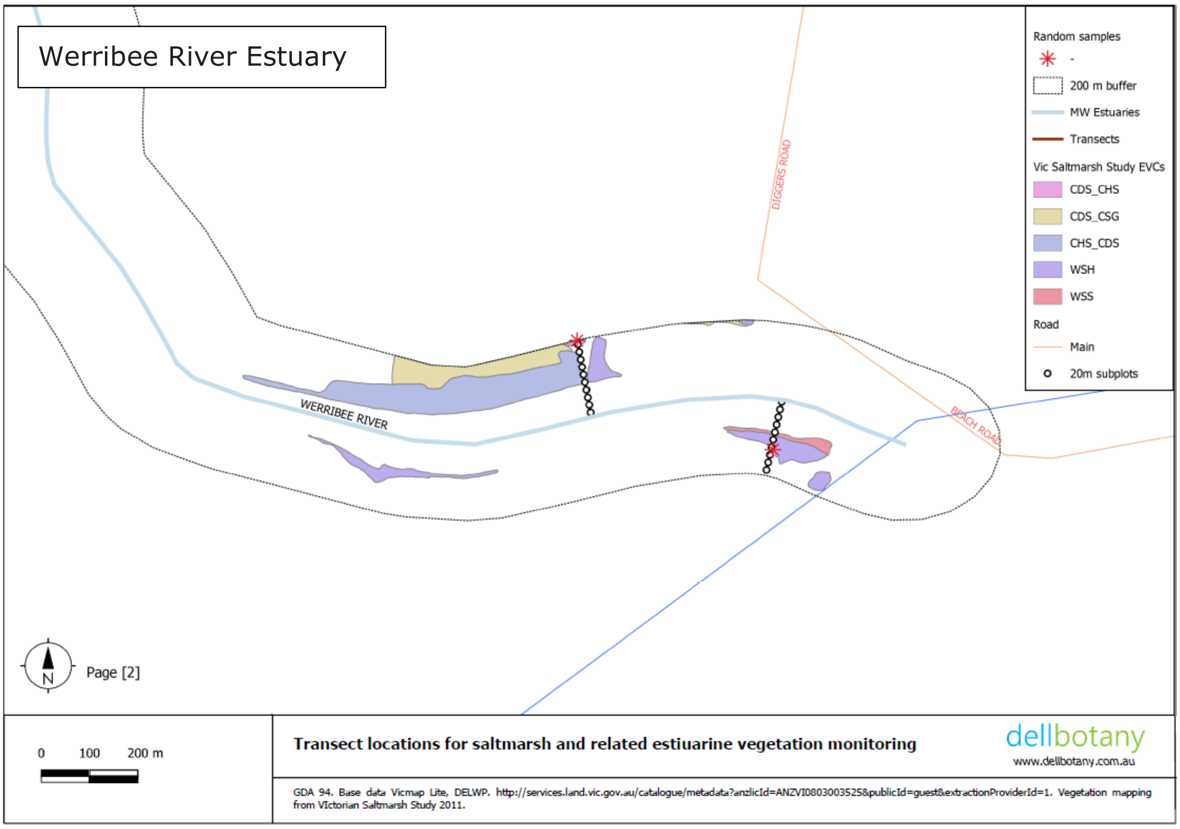


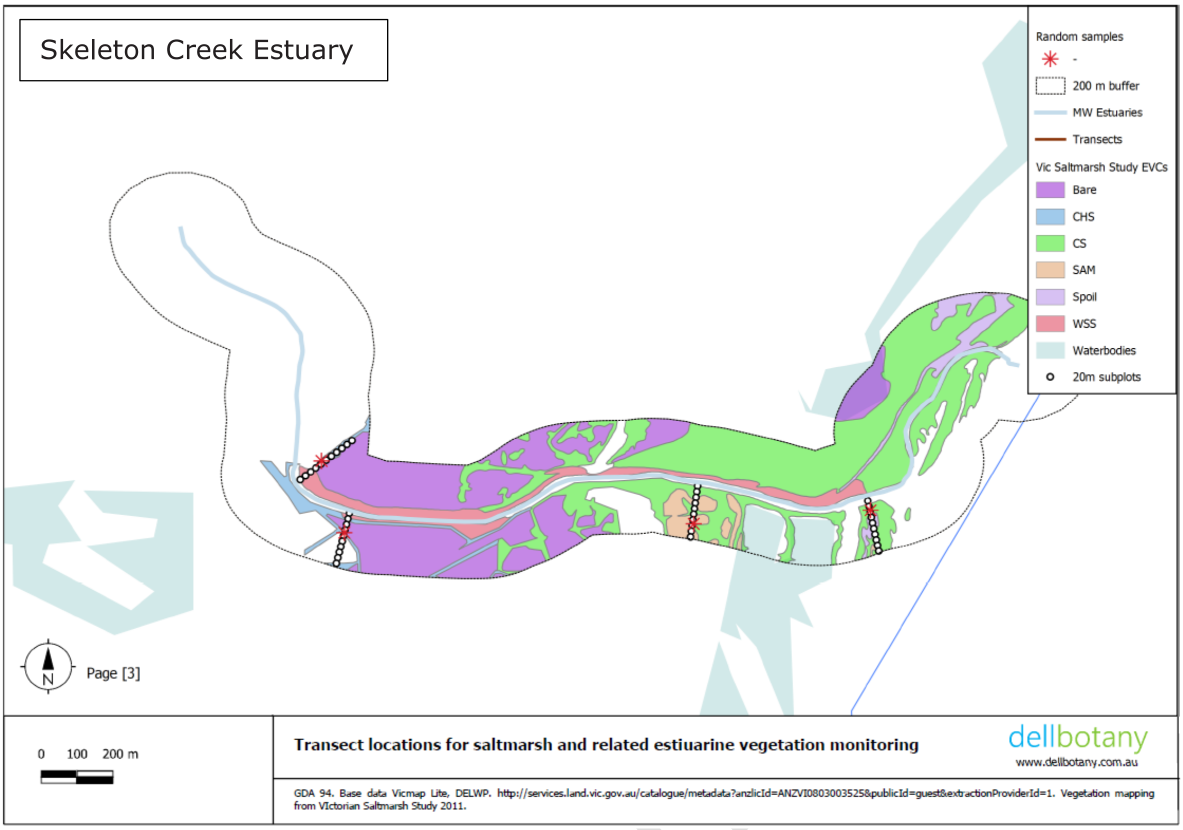
Figure 5. Point based cover sample of sub-plot (red dot

Appendix E: Estuary vegetation maps

(taken from Dell, 2020b –see legend abbreviations in Appendix F)






Skeleton Creek Estuary
Random samples
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200 m buffer
MW Estuaries
Transects
Vic Saltmarsh Study EVCs
Bare
CHS
CS
SAM
Spoil
WSS
Waterbodies
20m subplots
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0 100 200 m
Transect locations for saltmarsh and related estiuarine vegetation monitoring
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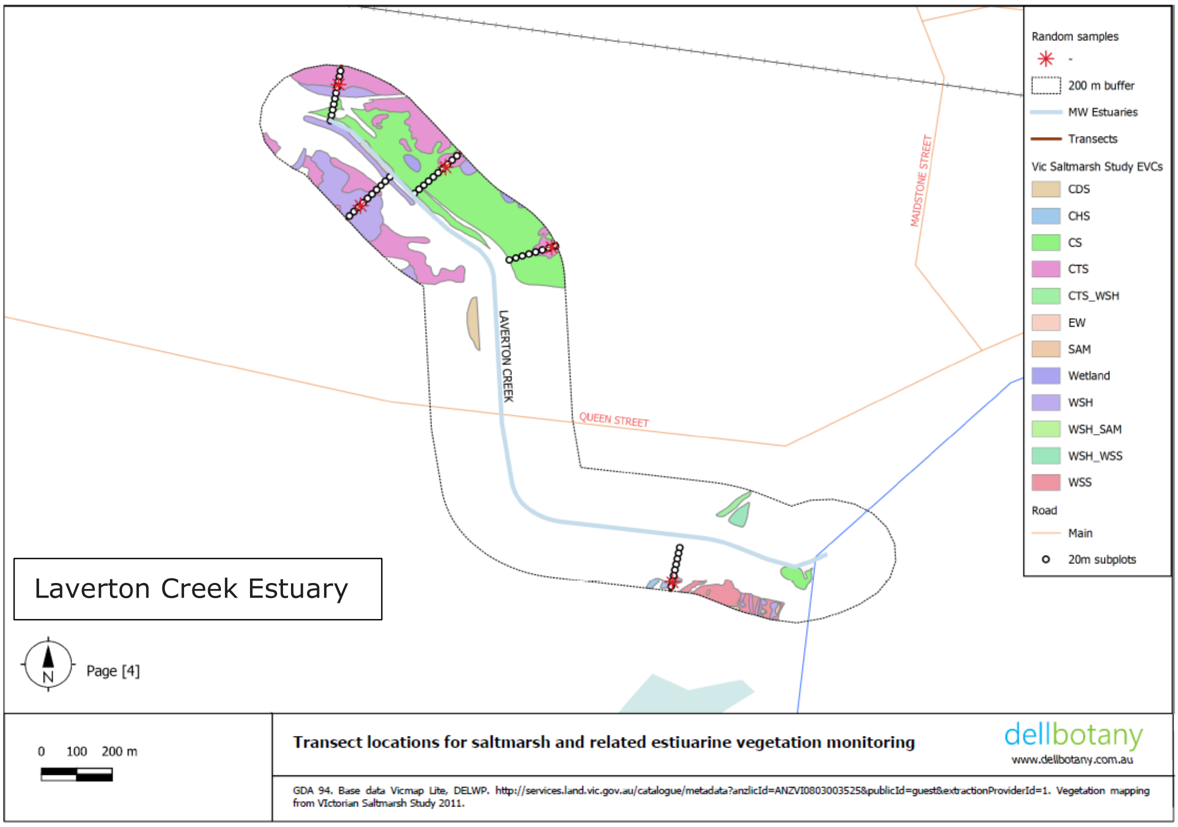
GDA 94. Base data Vicmap Lite, DELWP. http://services.land.vic.gov.au/catalogue/metadata?anzlicId=ANZVI0803003525&publicId=guest&extractionProviderId=1. Vegetation mapping from VIctorian Saltmarsh Study 2011.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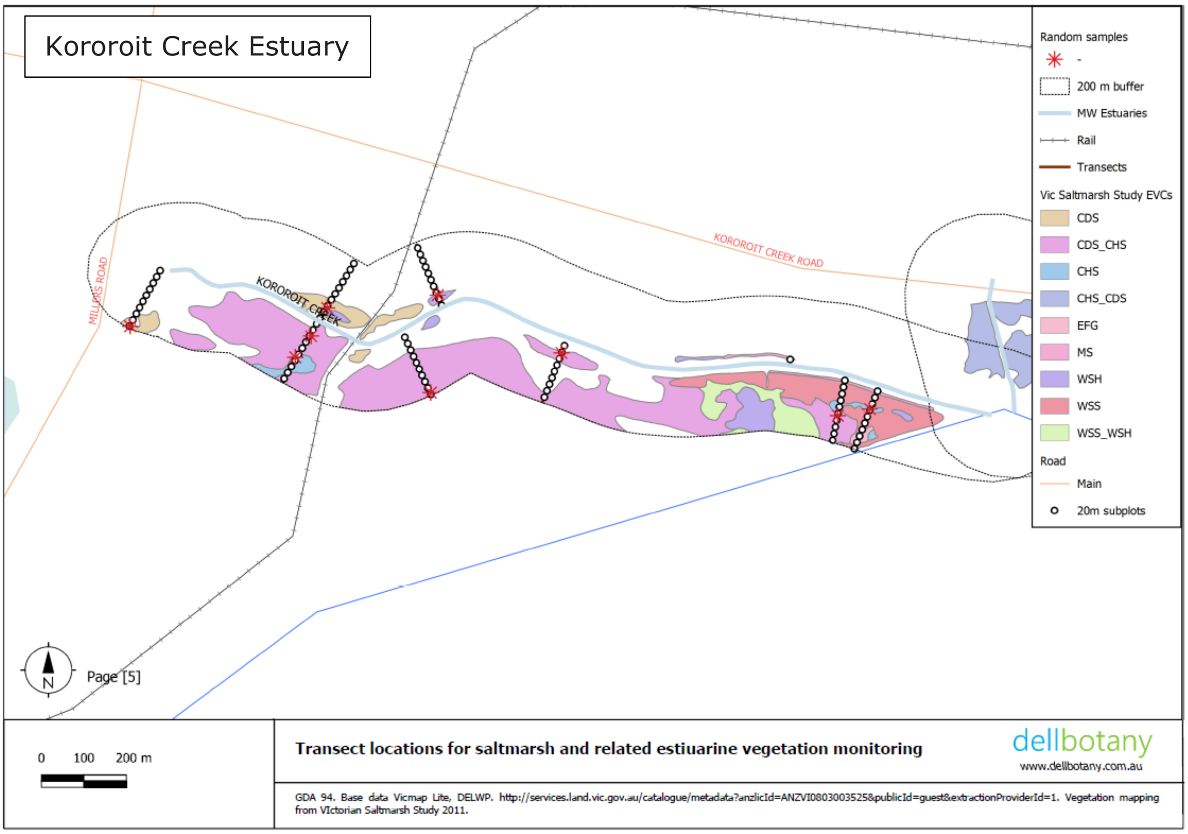
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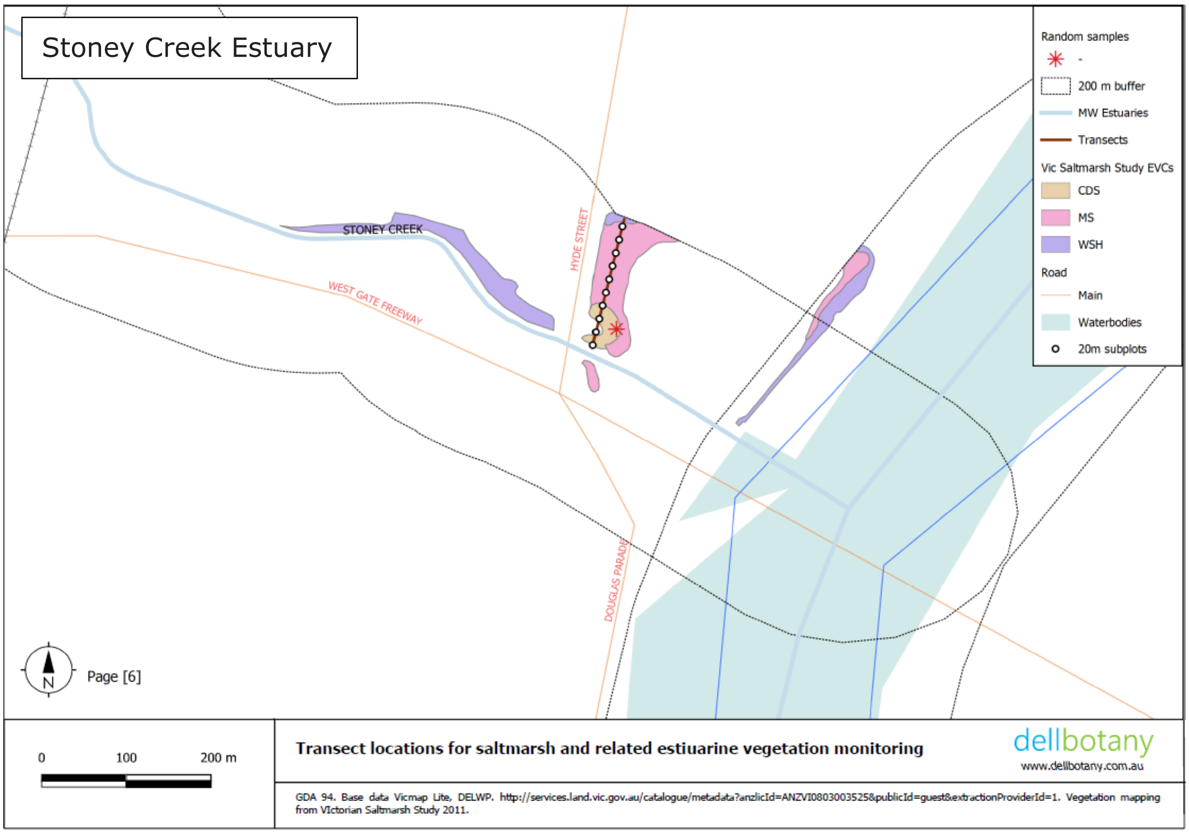
Stoney Creek Estuary
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Waterbodies
20m subplots
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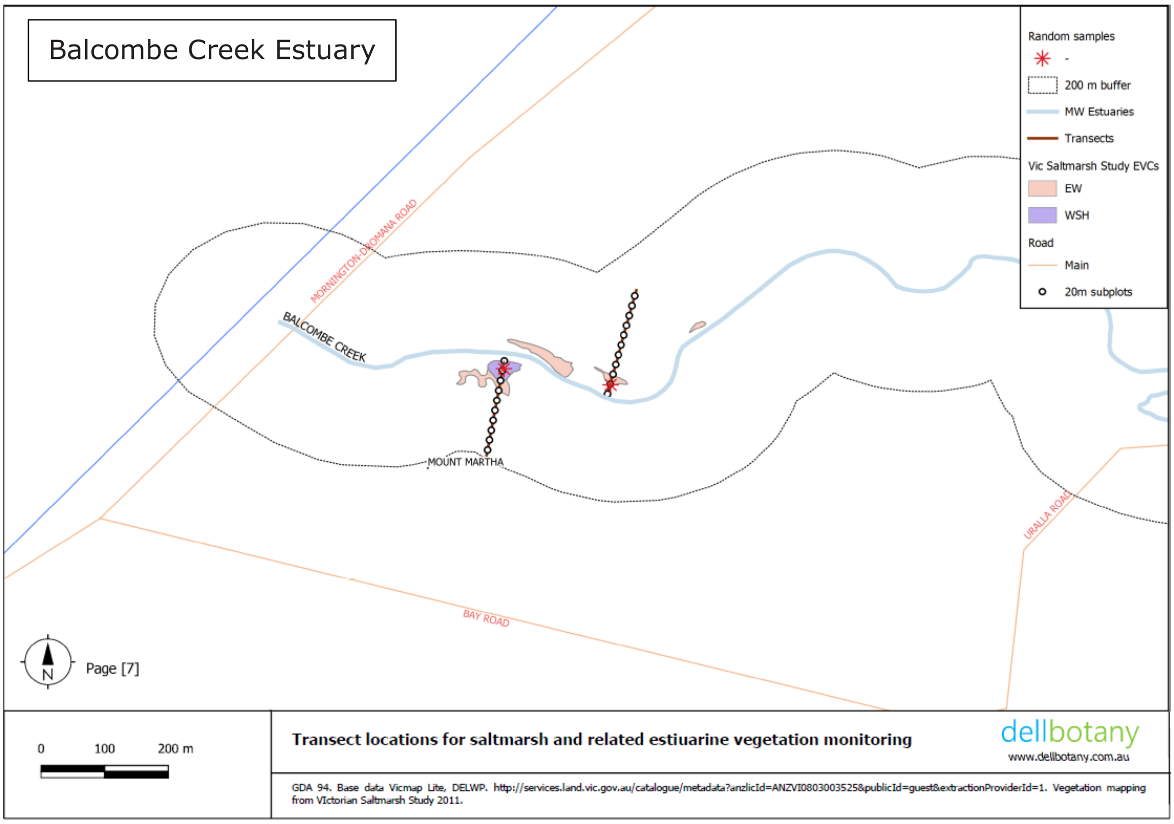
Balcombe Creek Estuary
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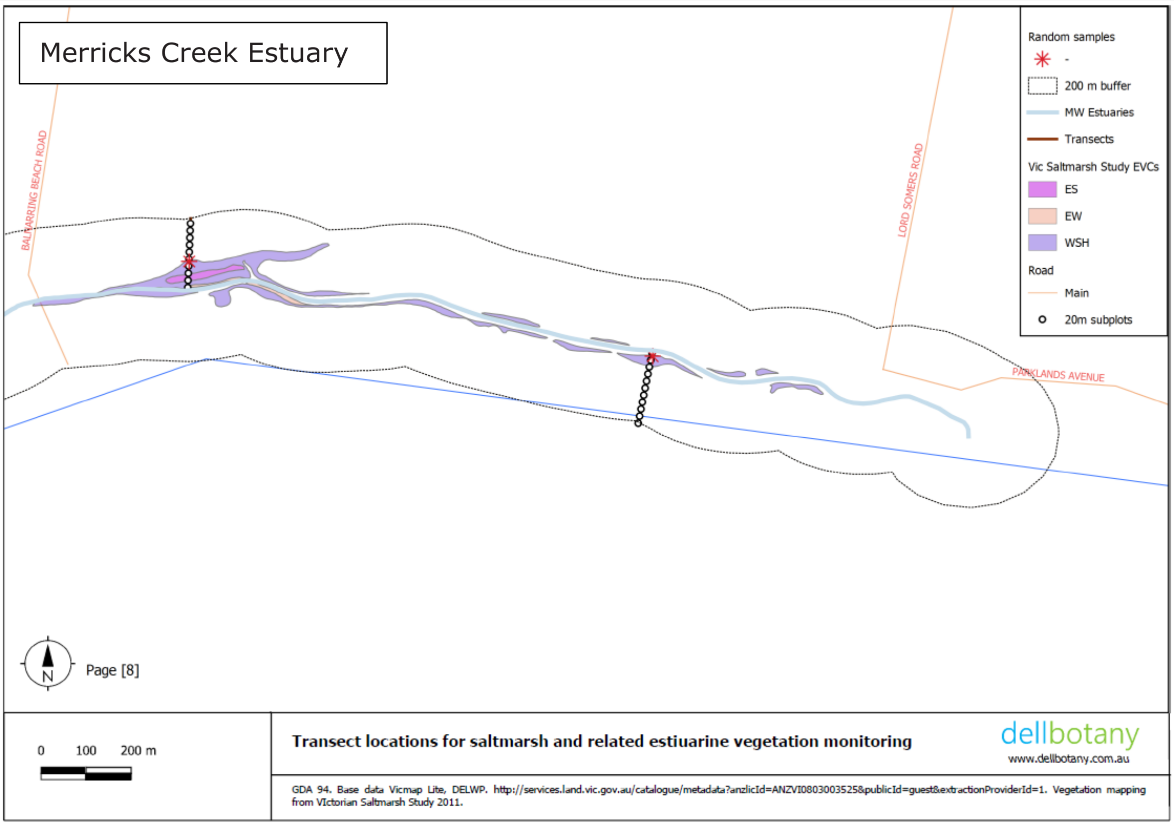
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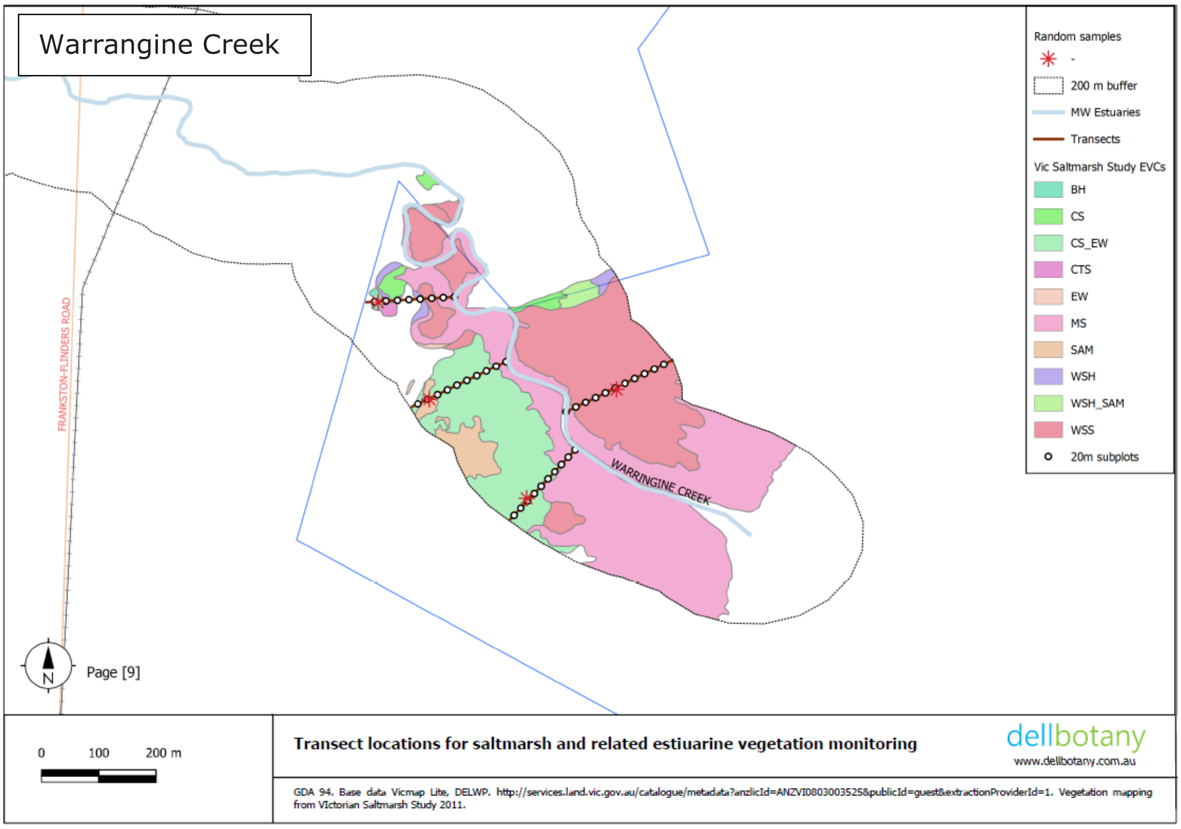
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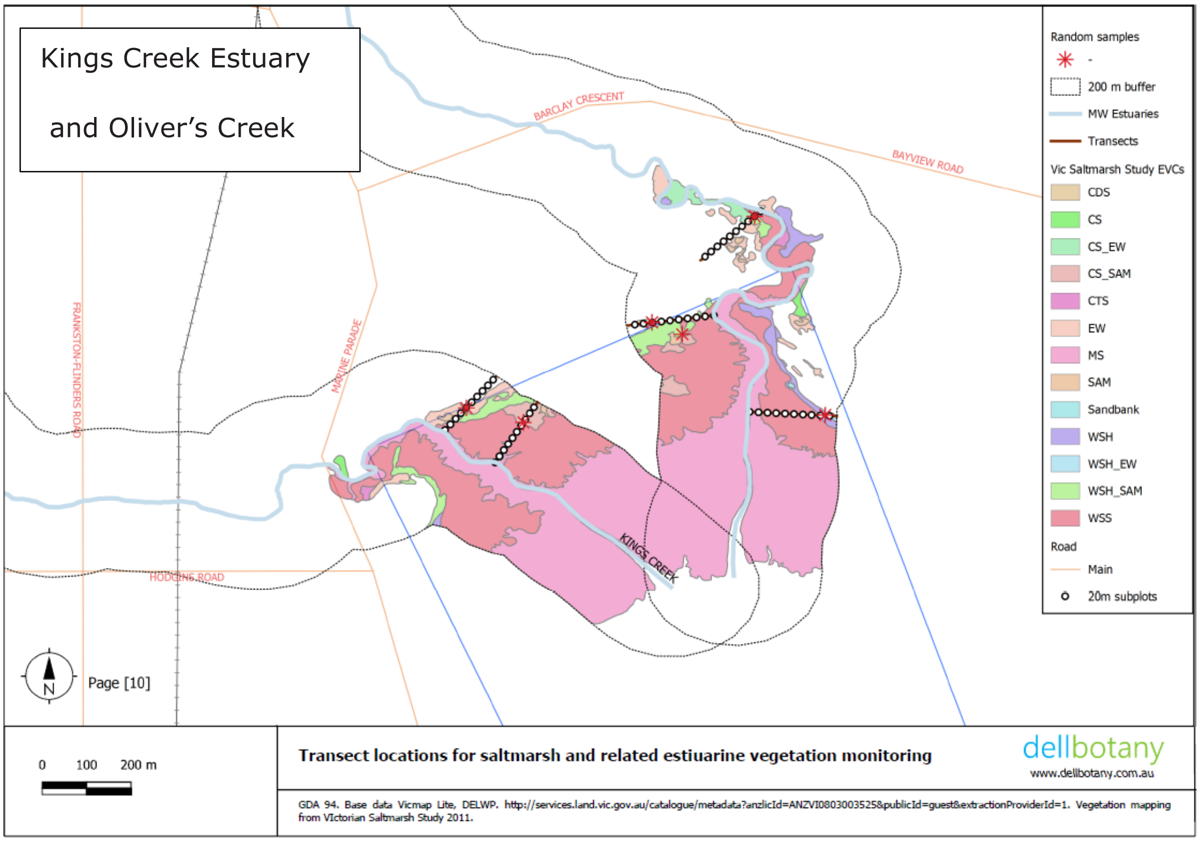
Kings Creek Estuary
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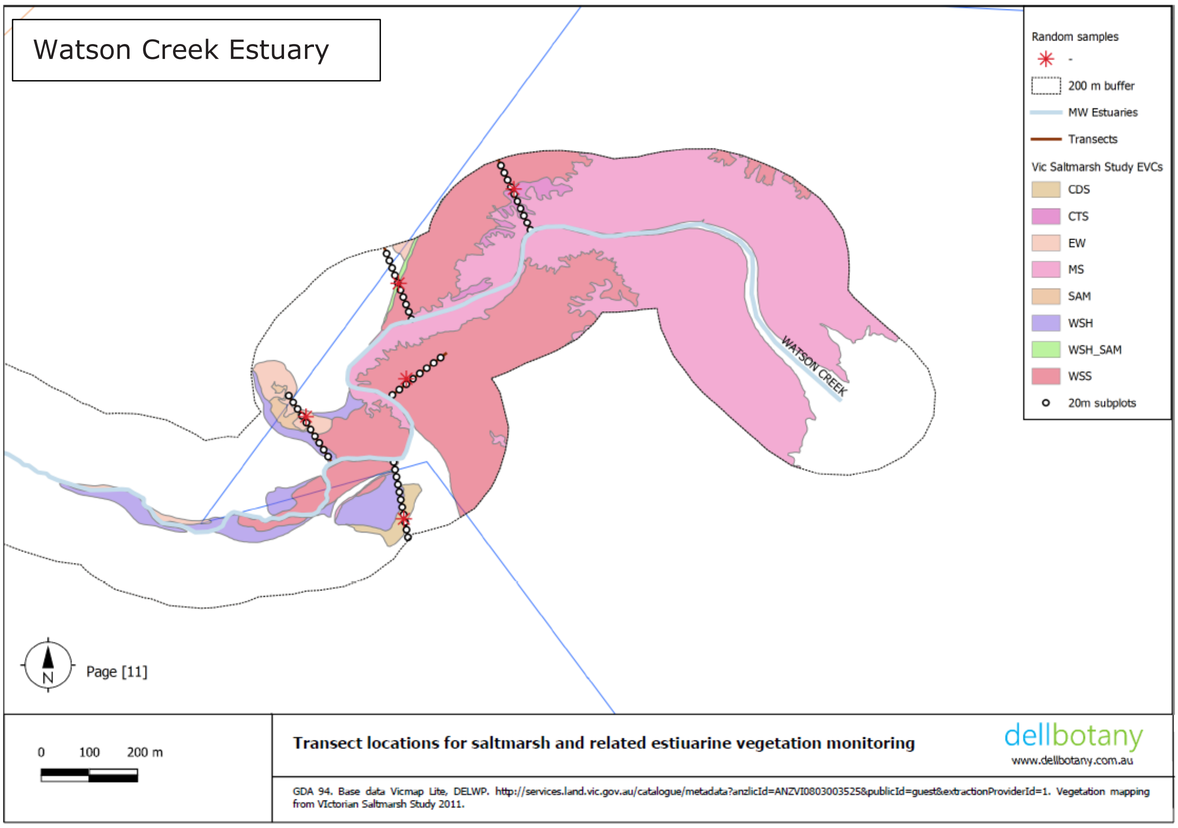
Watson Creek Estuary
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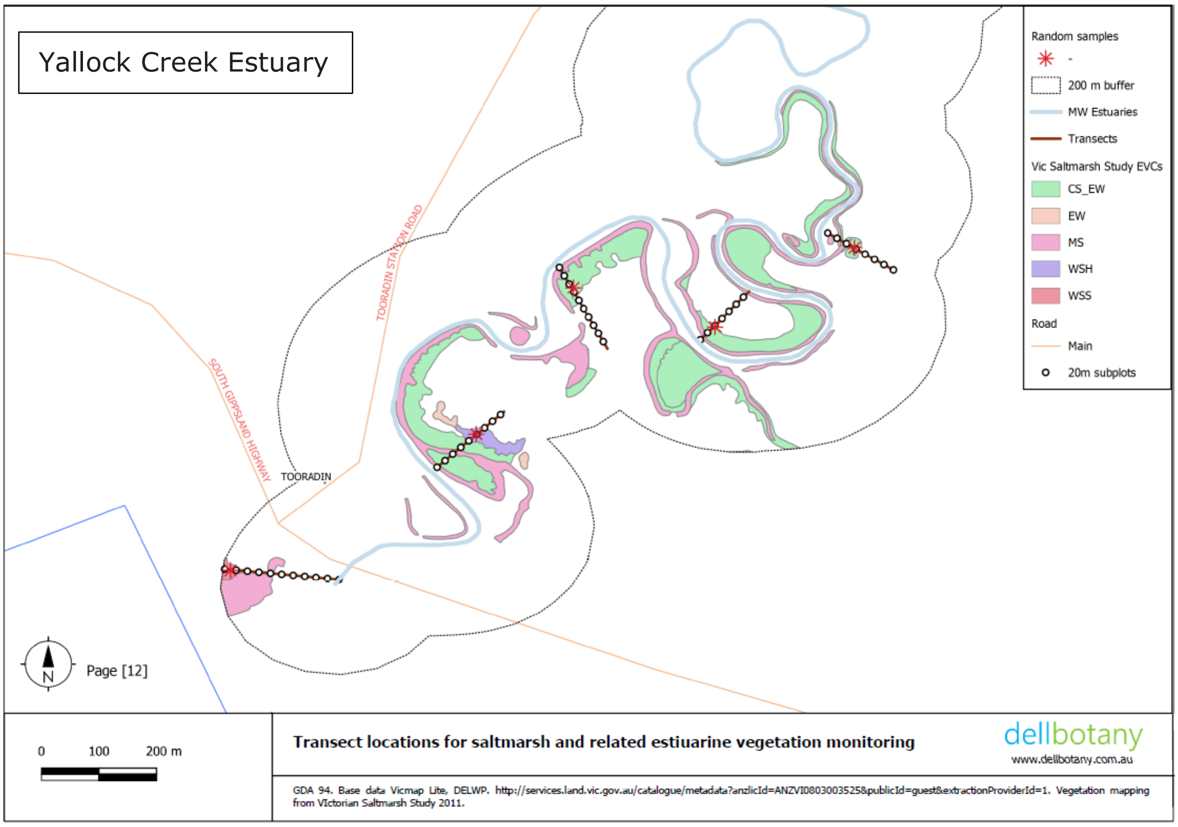
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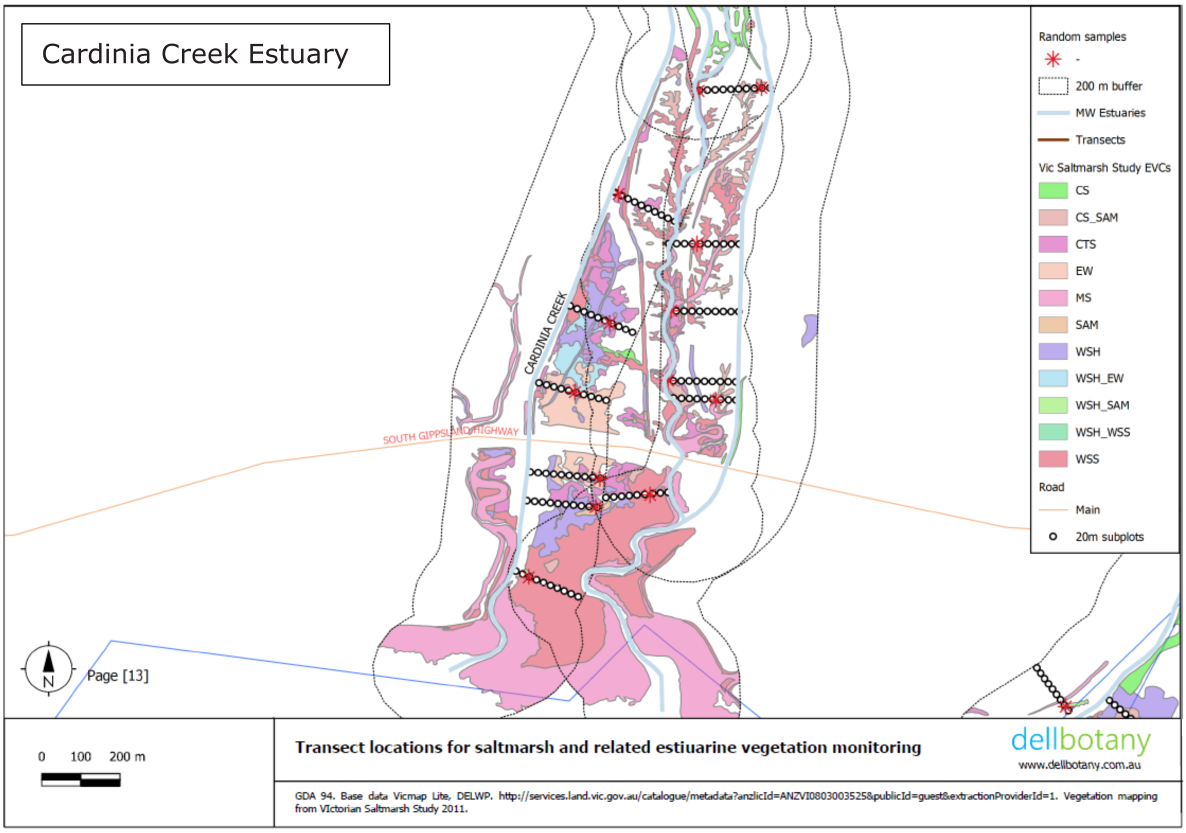

Cardinia Creek Estuary
CARDINIA CREEK
SOUTH GIPPSLAND HIGHWAY
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200 m buffer
MW Estuaries
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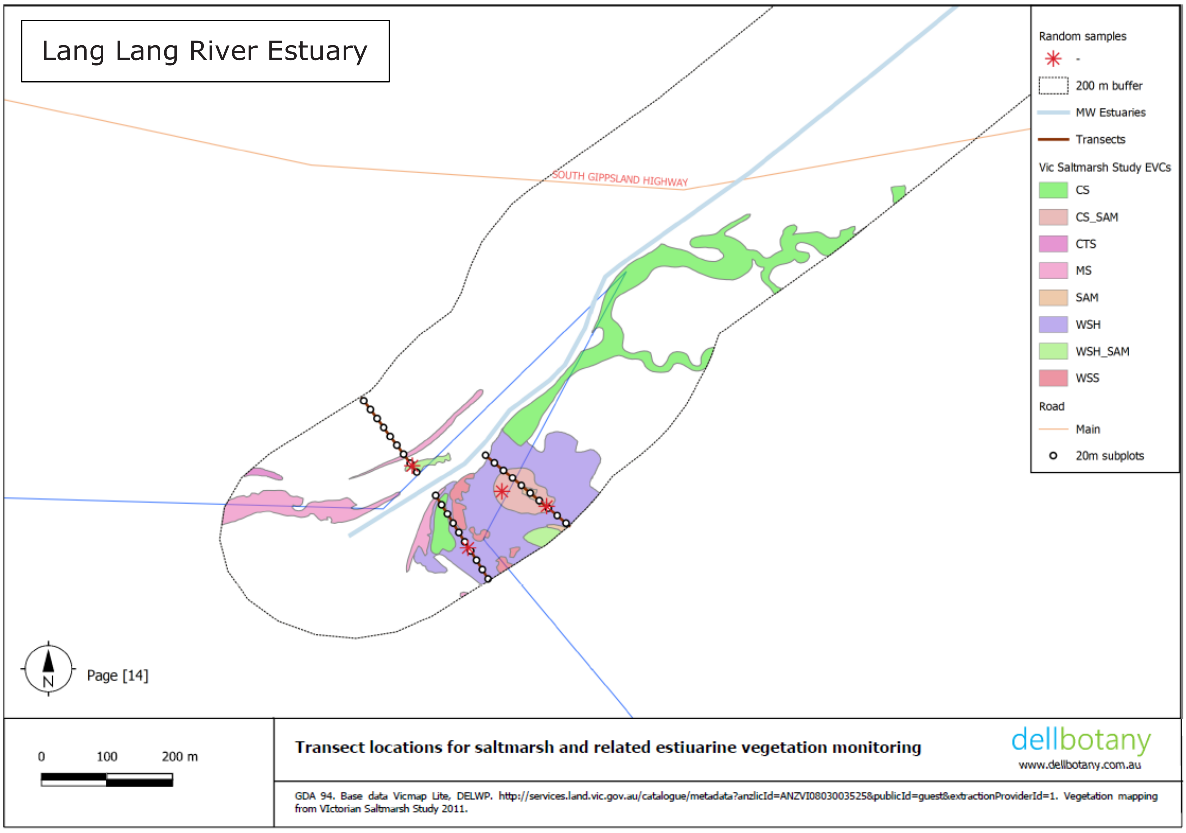

Lang Lang River Estuary
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Page [14]
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Random samples
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MW Estuaries
Transects
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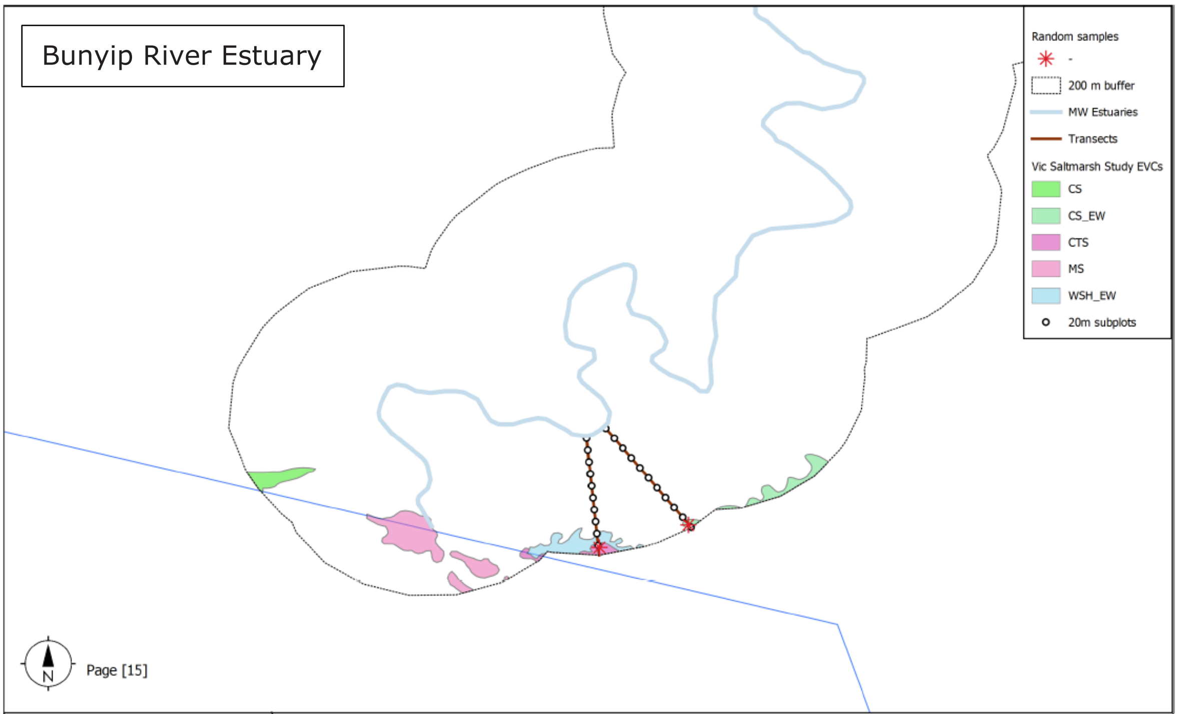

0 100 200 m

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GDA 94. Base data Vicmap Lite, DELWP. http://services.land.vic.gov.au/catalogue/metadata?anzlicId=ANZVI0803003525&publicId=guest&extractionProviderId=1. Vegetation mapping from Victorian Saltmarsh Study 2011.

0 100 200 m

Transect locations for saltmarsh and related estiuarine vegetation monitoring

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GDA 94. Base data Vicmap Lite, DELWP. http://services.land.vic.gov.au/catalogue/metadata?anzlicId=ANZVI0803003525&publicId=guest&extractionProviderId=1. Vegetation mapping from Victorian Saltmarsh Study 2011.

Appendix F: Estuary vegetation types

(taken from Dell, 2020b)

Ecological Vegetation Class	Broad Vegetation Type	Reference
Brackish Grassland (BG)	Grassland / Sedgeland / Rushland	DSE (2012)
Brackish Herbland (BH)	Grassland / Sedgeland / Rushland	DSE (2012)
Brackish Lignum Swamp (BLS)	Shrubland / Heathland	DSE (2012)
Brackish Wetland (BW)	Grassland / Sedgeland / Rushland	DSE (2012)
Coastal Dry Saltmarsh (CDS)	Shrubland / Heathland Herbland	Victorian Saltmarsh Study
Coastal Hypersaline Saltmarsh (CHS)	Shrubland / Heathland	Victorian Saltmarsh Study
Coastal Saline Grassland (CSG)	Grassland / Sedgeland / Rushland	Victorian Saltmarsh Study
Coastal Saltmarsh* (CS)	Shrubland / Heathland	DSE (2012)
Coastal Tussock Saltmarsh (CTS)	Grassland / Sedgeland / Rushland	Victorian Saltmarsh Study
Estuarine Flats Grassland (EFG)	Grassland / Sedgeland / Rushland	DSE (2012)
Estuarine Reedbed (ER)	Grassland / Sedgeland / Rushland	DSE (2012)
Estuarine Scrub (ES)	Shrubland / Heathland	DSE (2012)
Estuarine Wetland (EW)	Grassland / Sedgeland / Rushland	DSE (2012)
Mangrove Shrubland (MS)	Shrubland / Heathland	DSE (2012)
Saline Aquatic Meadow (SAM)	Herbland	DSE (2012)
Sea-grass Meadow (SM)	Herbland	DSE (2012)
Seasonally Inundated Sub-saline Herbland (SSH)	Herbland	DSE (2012)
Swamp Scrub (SS)	Shrubland / Heathland	DSE (2012)
Swampy Riparian Woodland (SRW)	Forest / Woodland	DSE (2012)
Wet Saltmarsh Herbland (WSH)	Herbland	Victorian Saltmarsh Study
Wet Saltmarsh Shrubland (WSS)	Shrubland / Heathland	Victorian Saltmarsh Study

*An aggregate of EVCs which have been classified further by the Victorian Saltmarsh Study (2011). Additional descriptions of relevant estuarine vegetation are found in DSE (2012)