Review and update of the ecological objectives and targets for the channel and floodplain priority environmental assets

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Review and Update of the Ecological Objectives and Targets for the Channel and Floodplain Priority Environmental Assets

Final Report

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Acknowledgement of Country

We acknowledge and respect the Traditional Custodians whose ancestral lands we live and work upon and we pay our respects to their Elders past and present.

We acknowledge and respect their deep spiritual connection and the relationship that Aboriginal and Torres Strait Islanders people have to Country.

We also pay our respects to the cultural authority of Aboriginal and Torres Strait Islander people and their nations in South Australia, as well as those across Australia.

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The planning and delivery of environmental water to the South Australian River Murray Channel Priority Environmental Asset (Channel PEA) and the South Australian River Murray Floodplain Priority Environmental Asset (Floodplain PEA) is informed by a set of Ecological Objectives and Ecological Targets. The existing objectives and targets were developed through separate, but collaborative processes in 2014 and 2015 respectively, and were subsequently consolidated into the *Long-Term Environmental Watering Plan for the South Australian River Murray Water Resource Plan Area* (SA River Murray LTWP) (DEWNR 2015). The plan was updated in November 2020 (DEW 2020), however the Ecological Objectives and Ecological Targets were not updated.

A key purpose of having clearly defined Environmental Water Requirements (EWRs), Ecological Objectives and Ecological Targets is to inform the annual planning, allocation and delivery of environmental water that contributes towards a healthy, functioning South Australian River Murray ecosystem. Substantial investments in monitoring and research on ecological responses to delivery of environmental water has occurred in the intervening decade since the targets were developed in 2014-15. The scope of this project was to review the existing Ecological Objectives and Ecological Targets and ascertain if: (i) they remain consistent with the current state of knowledge of the respective eco-hydrological attributes, and (ii) if gaps are identified, to provide recommendations on updates that would improve the management utility of the Ecological Objectives and Ecological Targets. It is anticipated that the revised information will be utilised by DEW in the forthcoming 2025 update of the SA River Murray LTWP.

This project only reviews the Ecological Objectives and Targets for the Channel and Floodplain PEA. The review and update of Ecological Objectives and Targets for the Coorong, Lower Lakes and Murray Mouth Priority Environmental Asset (DEW 2025) is out of scope and is being reviewed under a separate process.

Approach taken

The first step of this project was to consolidate all the existing Ecological Objectives and Targets utilised to plan and guide the delivery of environmental water within the South Australian reach of the River Murray. This includes not only the targets from the LTWP, but also targets in use within site-based management plans. The consolidated list was used to identify (i) targets in the 2020 version of the SA River Murray LTWP for which potential improvements had already been identified, and (ii) targets that are not currently contained in the SA River Murray LTWP that should be considered for inclusion.

A series of expert-elicitation small group workshops covering the key Ecological Target groups (e.g. native fish, floodplain trees, soil condition) was held with subsets of scientists/stakeholders with expertise in the relevant theme(s). Participants were tasked with reviewing the consolidated list and proposing updates to the Ecological Objectives and Ecological Targets for the Channel and Floodplain PEAs. After the initial workshop, follow up meetings were held to (i) clarify key points and (ii) in collaboration with each theme-based group, determine if the recommended changes to the Ecological Targets impact on their relationship with the EWRs and update the assessment of contribution of EWRs towards Ecological Targets.

Outcome

The 2020 version of the SA River Murray LTWP included different sets of Ecological Objectives and Ecological Targets for the Channel and the Floodplain Priority Environmental Assets. During the initial workshops run under this project, DEW representatives proposed, and it was agreed, that the project should develop a unified set of Ecological Objectives and Ecological Targets that encompass both the Channel and Floodplain PEA. This approach acknowledges (i) the continuity between the channel and floodplain, rather than treating the 40,000 ML/day flow band as a strict hydrological boundary between the two PEAs, and (ii) that biotic and ecological responses do not stop/start at the PEA boundary.

The workshop process generated 24 Ecological Objectives with 94 nested Ecological Targets. Initial feedback raised concerns about the management utility of the increased number of targets. Consequently, a target rationalisation process was undertaken. The refinement process generated 18 Ecological Objectives with 79 nested Ecological Targets that are recommended for inclusion in the 2025 review of the LTWP. This is a modest increase from the number of targets (69) in the 2020 version of the LTWP (see section 4.1). The increase reflects the increased state of knowledge of life history processes, demographics of target biota, ecological stressors, and the observed responses to delivery of environmental flows that has been generated over the intervening decade since the original targets were developed.

1 Project scope

1.1 Broad overview

The planning and delivery of environmental water to the South Australian River Murray Channel Priority Environmental Asset (Channel PEA) and the South Australian River Murray Floodplain Priority Environmental Asset (Floodplain PEA) is informed by a set of Ecological Objectives and Ecological Targets. The existing objectives and targets were developed through separate, but collaborative processes documented in Wallace *et al.* (2014b) and Kilsby and Steggles (2015) respectively, and were subsequently consolidated into the *Long-Term Environmental Watering Plan for the South Australian River Murray Water Resource Plan Area* (SA River Murray LTWP, hereafter referred to as LTWP) (DEWNR 2015). The plan was updated in November 2020 (DEW 2020), however the Ecological Objectives and Ecological Targets were not updated.

Substantial investments in monitoring and research on ecological responses to delivery of environmental water has occurred in the intervening decade since the 2015 release of the first version of the LTWP (DEWNR 2015). The scope of this project was to review the existing Ecological Objectives and Ecological Targets and ascertain if: (i) they remain consistent with the current state of knowledge of the respective eco-hydrological attributes, and (ii) if gaps are identified, to provide recommendations on updates that would improve the management utility of the objectives and targets. It is anticipated that the revised information will be utilised by DEW in the forthcoming 2025 update of the LTWP.

1.2 Key tasks

- Review and, where required, recommend amendments to the Ecological Objectives for the Floodplain and Channel PEAs
- Review and recommend amendments to the existing Ecological Targets, including improving their SMART-ness (see section 3.4) where practicable
- Develop and recommend additional Ecological Objectives or Ecological Targets that may be required
- Identify any existing Ecological Targets that may no longer be relevant, and provide a justification as to why
- Review, and where required, amend the tables provided in the preceding version of the LTWP (DEW 2020) that provide an assessment of expected contribution of full delivery of each environmental water requirement (EWR) for flows ranging from 10,000 to 80,000 $MLday^{-1}$.
- Produce a technical document that presents the methods and recommendations that will act as supporting information for the 2025 update of the LTWP.

2 About ecological objectives and ecological targets

2.1 Terminoligy

The terms "Objective" and "Target" are often used interchangeably by ecologists, managers, and stakeholders, which can create some confusion. Hence, the definitions within the SA River Murray LTWP have been retained but additional contextual information is provided.

Ecological Objectives provide a clear, plain language articulation for managers, scientists, stakeholders and the wider community of what the delivery of environmental water requirements (EWRs) are intended to achieve at each PEA.

Ecological Targets are nested within an ecological objective and there may be more than one target per objective. The targets specify a condition state, often described by a numerical value. Position (at any survey period) and trajectory (trend over a multi-year period) relative to the targets, allows a data driven assessment of (i) the need for water in any given water year, (ii) what watering actions are most appropriate at any given time, and (iii) progress towards achieving the Ecological Objectives.

The Ecological Targets developed via this project are based on best available knowledge captured through an expert elicitation process, and where it exists, published empirical data and conceptual models of what represents a sustainable, ecologically functional and resilient river system.

2.2 Utility and purpose

A key purpose of having clearly defined EWRs, Ecological Objectives and Ecological Targets is to inform the annual planning, allocation and delivery of environmental water that contributes towards a healthy, functioning South Australian River Murray ecosystem (DEW 2020). These Ecological Objectives and Targets have not been tested against what is achievable under the Basin Plan, nor what is currently or likely to be monitored in the future (DEW 2020).

It is important to note that recording condition scores that do not meet the Ecological Target in any given year, or sequence of years, is not an indication of failure. It is expected that the measured condition and trajectory of each attribute or process will be dynamic over time and space.

2.3 Ongoing review of targets

There is an expectation that the targets would be reviewed and updated on a 5-10 year cycle. If at that time, the monitoring data indicates that abundance is at or near either (i) historical (pre-regulation) or (ii) ecosystem carrying capacity, the target would be revised from "increase" to "maintain" the abundance of the biotic group or species.

3 Approach taken

3.1 Spatial scope and boundaries of the priority ecological assets

The South Australian River Murray Channel PEA is defined as the area of the river spanning longitudinally from the SA/NSW border downstream to Wellington, and laterally the area of river channel, anabranch creeks, wetlands and floodplain inundated at flows to South Australia (QSA) up to 40,000 $MLday^{-1}$. This incorporates a longitudinal distance of approximately 560 River kilometres and approximately 28,800 hectares. The Floodplain PEA spans the same longitudinal extent, but incorporates the area inundated at flows from 40,000 to 80,000 $MLday^{-1}$, incorporating approximately 54,300 hectares (DEWNR 2015).

This project only reviews the Ecological Objectives and Targets for the Channel and Floodplain PEA. The Coorong, Lower Lakes and Murray Mouth Priority Environmental Asset is out of scope and is being reviewed under a separate process.

3.2 Conceptual models

The review and refinement of Ecological Targets (section 4 and 5) and the evaluation of how EWRs contribute to these targets (section 7) depend extensively on existing conceptual models designed to guide management decisions and monitoring programs. These models are detailed in sources such as Bice et al. (2014), Wallace et al. (2014a, 2021), and the unpublished DEW (2016) SARFIIP conceptual models. For conciseness, the models are not reproduced here. Any relevant supporting information not covered in these sources is provided in section 8 of this document.

3.3 Cultural targets

Development and inclusion of cultural targets is beyond the scope of this current project.

3.4 SMART targets

The targets are structured within a SMART (specific, measurable, achievable, realistic, time bound) framework, noting that due to insufficient knowledge, not all targets meet all the components of the acronym.

3.5 Baseline conditions

The Basin Plan and Basin-Wide Environmental Watering Strategy (BWS) defines the baseline as follows:

"*Represents the Basin with the consumptive use and the rules and sharing arrangements as at June 2009*".

To establish Ecological Targets, a more adaptable timeline is used. In this context, the term "baseline" has more utility when referring to conditions documented between 2004 and 2015. This timeframe is particularly informative because it encompasses: (i) a period of significantly increased data collection, (ii) an extended, severe drought, and (iii) the time just before large-scale environmental water provisions were implemented.

3.6 Identification of relevant subject matter experts for collaborative phases

A series of discussions were held between June-August 2023 with relevant DEW staff, particularly those involved in planning and management of the PEAs and project staff from the Environmental Water Team to discuss and agree (i) the overarching methodology, (ii) objectives and target groupings, and (iii) the subject matter experts (River Murray scientists including DEW ecologists in ecological theme areas) to be consulted in the review of existing, and the development of new/refined objectives and targets.

3.7 Target identification and consolidation

The first step of this project was to consolidate the existing Ecological Objectives and Targets from:

- the SA River Murray LTWP (DEW 2020)
- management plans for Chowilla Floodplain (Wallace and Whittle 2014b),
- Pike and Katarapko Floodplain SARFIIP Endorsed Interim Ecological Objectives and Targets (DEW 2016),
- refined targets for fish condition monitoring at Pike and Katarapko (Fredberg and Bice 2021),
- research hypotheses relating to stratification, biofilms, open water productivity and propagule/particle suspension (Wallace 2021),
- Lock 7-9 weir pool manipulation strategy (Wallace et al. 2021) and
- Basin-Wide Environmental Watering Strategy expected outcomes (MDBA 2019).

The consolidated list (not presented here) was used to identify (i) targets in the SA River Murray LTWP (DEWNR 2015) for which potential improvements had already been identified, and (ii) targets that are not currently contained in the LTWP that should be considered for inclusion.

The LTWP (DEW 2020) included different sets of Ecological Objectives and Ecological Targets for the two assets. During the initial workshops run under this project, DEW representatives proposed, and it was agreed, that the project should develop a unified set of Ecological Objectives and Ecological Targets that encompass both the Channel and Floodplain PEA. This approach acknowledges (i) the hydrological continuity between the channel and floodplain, rather than treating the 40,000 ML/day flow band as a strict boundary between the two PEAs, and (ii) that biotic and ecological responses do not stop/start at the PEA boundary.

3.8 Workshop 1

An initial, "start-up" workshop was held on the 22nd September 2023 with the subject matter experts and environmental water (e-water) managers to ensure the context for the objective/target revision was understood, and that a consistent approach would be applied across all target groupings. The full attendee list, their organisation/employer and their relevant area of expertise are outlined in Table 3.1.

3.9 Subject matter specific workshops

A series of small group workshops covering the key Ecological Target groups (see Table 3.2 for target groups and participants) was held with subsets of scientists/stakeholders with expertise in the relevant theme(s), to review the consolidated list, and update the Ecological Objectives and Ecological Targets for the Channel and Floodplain PEAs. The review was undertaken by considering:

- the existing objectives and targets and their practical application in recent years e.g. utility in annual planning, SMART-ness, relevance
- objectives and targets in other environmental water management or monitoring plans (see sub-section 3.7)
- latest conceptual understanding of hydro-ecological relationships for key biota and functions
- results from monitoring and research programs
- expected environmental outcomes (EEOs) in the BWS and any outputs from work undertaken by MDBA to the update the EEOs
- any other relevant information

The first round of subject matter specific workshops was held during the period 26th October-7th November 2023 (see Table 3.2 for target groupings and participants). A second round of discussions (see Table 3.3 for target groupings and participants) was held to (i) clarify key points and (ii) in collaboration with each theme-based group, determine if the recommended changes to the Ecological Targets impact on their relationship with the EWRs and update the assessment of contribution of EWRs towards Ecological Targets.

Table 3.1. List of subject matter experts invited to workshop 1 (22nd September 2023). Members listed in *italics* did not attend

Name	Organisation	Role/expertise
Dr Eddie Banks	Flinders University	Hydrogeologist/soil scientist
Dr Chris Bice	SARDI Aquatic Sciences	Fish ecologist
Dr Qifeng Ye	SARDI Aquatic Sciences	Fish ecologist
Dr Brenton Zampatti	SARDI Aquatic Sciences	Fish ecologist
David Cheshire	DEW	Senior Scientific Officer
Dr Jason Nicol	SARDI Aquatic Sciences	Vegetation ecologist
Dr Susan Gehrig	Flora, Flow and Floodplains	Vegetation ecologist
Rupert Mathwin	Rupert Mathwin Ecology	Frog ecologist
Dr Luke Mosley	The University of Adelaide	Soil and water scientist
Dr Deborah Furst	*The University of Adelaide*	*Microinvertebrate ecologist*
Dr James Van Dyke	La Trobe University	Turtle ecologist
Tracey Steggles	DEW	Program Leader, River Murray Channel
Sarah Ryan	DEW	Senior Project Officer
Claudia Sabeeney	DEW	Project Officer, Environmental Water
Michelle Denny	DEW	Senior Floodplain Officer
Grace Hodder	DEW	Floodplain Ecologist
Dr Nathan Creeper	DEW	Project Manager, Weir Pool
Gareth Oerman	DEW	Senior Scientific Officer

Name	Organisation	Role/expertise
Richard Walsh	DEW	Floodplain Ecologist
Samantha Walters	DEW	Floodplain Ecologist
Dr Juliette Woods	DEW	Principal Groundwater Modeller
Luke Vial	DEW	Project Officer, The Living Murray
Jan Whittle	DEW	Program Leader, River and Floodplains
Rebecca Turner	DEW	Project Manager, Integrated Operations
Jody O'Connor	*DEW*	*Principal Advisor Restoration (Coorong)*
Dr Dan Rogers	*DEW*	*Principal Advisor, Biodiversity, Science and Knowledge*
Sam Hardy	Landscape SA	Wetland Ecologist
Kate Mason	Landscape SA	Principal Project Officer, Environmental Water
Dr Todd Wallace	The University of Adelaide	Floodplain and riverine ecologist

Table 3.2. List of subject matter experts and managers invited to first round of small group workshops. Members listed in *italics* did not attend

Grouping	Date	Invited participants
Hydrology/Hydraulics/ Ecosystem Processes	26th October 2023	Todd Wallace, Sarah Ryan, Tracey Steggles, Luke Mosley, Deborah Furst, Brenton Zampatti, Chris Bice, Qifeng Ye, Rebecca Turner, Nathan Creeper, Claudia Sabeeney, Charles Frost
Invertebrate Food resources/Productivity	26th October 2023	Todd Wallace, Sarah Ryan, Tracey Steggles, Claudia Sabeeney, Deborah Furst, Chris Bice, Rebecca Turner, Charles Frost
Long lived Vegetation	30th October 2023	Todd Wallace, Sarah Ryan, Tracey Steggles, Claudia Sabeeney, Susan Gehrig, Michelle Denny, Grace Hodder, Samantha Walters, Richard Walsh, Gareth Oerman, Charles Frost
Short lived vegetation	30th October 2023	Todd Wallace, Sarah Ryan, Tracey Steggles, Claudia Sabeeney, Susan Gehrig, Jason Nicol, Michelle Denny, Grace Hodder, Samantha Walters, Richard Walsh, Gareth Oerman, Ryan Lewis
Other Fauna	31st October 2023	Todd Wallace, Sarah Ryan, Tracey Steggles, Claudia Sabeeney, Casey O'Brien, Richard Walsh
Frogs	1st November 2023	Todd Wallace, Sarah Ryan, Tracey Steggles, Claudia Sabeeney, Rupert Mathwin, Kate

Grouping	Date	Invited participants
		Mason, Luke Vial, Rebecca Turner, Casey O'Brien, David Cheshire
Fish	1st November 2023	Todd Wallace, Sarah Ryan, Tracey Steggles, Claudia Sabeeney,Gareth Oerman, David Chesire, Brenton Zampatti, Chris Bice, Qifeng Ye, Rebecca Turner, Jan Whittle,
Soil and Groundwater	2nd November 2023	Todd Wallace, Sarah Ryan, Tracey Steggles, Claudia Sabeeney, Luke Mosley, Eddie Banks, Michelle Denny, Juliette Woods, Nathan Creeper
Birds	2nd November 2023	Todd Wallace, Sarah Ryan, Tracey Steggles, Claudia Sabeeney, Sam Hardy, Grace Hodder, Dan Rogers, Gareth Oerman, *Jody O'Conner*,
Turtles	6th November 2023	Todd Wallace, Sarah Ryan, Tracey Steggles, Claudia Sabeeney, James Van Dyke, Samantha Walters, Richard Walsh, David Chesire, Michelle Denny
Open Water Productivity	7th November 2023	Todd Wallace, Sarah Ryan, Tracey Steggles, Claudia Sabeeney, Luke Mosley, Rebecca Turner, Jan Whittle, Nathan Creeper, Ryan Lewis

Table 3.3. List of subject matter experts and managers invited to second round of small group workshops

Grouping	Date	Invited participants
Project Leads	21st November 2023	Todd Wallace, Sarah Ryan, Tracey Steggles,
Turtles	30th November 2023	Todd Wallace, James Van Dyke
Fish	1st December 2023	Todd Wallace, Qifeng Ye, Chris Bice, Brenton Zampatti
Short lived vegetation and soil salinity	1st December 2023	Todd Wallace, Jason Nicol. Susan Gehrig, Michelle Denny
Invertebrate productivity and ecosystem processes	4th December 2023	Todd Wallace, Deborah Furst
Birds	4th December 2023	Todd Wallace, Grace Hodder
Lignum and long lived vegetation	5th December 2023	Todd Wallace, Susan Gehrig
Frogs	5th December 2023	Todd Wallace, Rupert Mathwin
Soil and Groundwater	6th December 2023	Todd Wallace, Eddie Banks
Soil, water quality	8th December 2023	Todd Wallace, Luke Mosley

Grouping	Date	Invited participants
Project Leads	13th December 2023	Todd Wallace, Sarah Ryan, Tracey Steggles,
Key stakeholders	18th December 2023	Todd Wallace, Sarah Ryan, Tracey Steggles, Tony Herbert, Rebecca Turner, Nathan Creeper, Jan Whittle, Alison Stokes, Claudia Sabeeney
Terrestrial birds	19th January 2024	Todd Wallace, Tracey Steggles, Michelle Denny, Grace Hodder
Waterbirds	23rd January 2024	Todd Wallace, Tracey Steggles, Grace Hodder, Dan Rogers, Sam Hardy

4 Post workshop target refinement

4.1 Number of targets in the 2020 LTWP

The LTWP (DEW 2020) outlines 16 Ecological Objectives with 29 nested Ecological Targets for the Channel PEA and 21 Ecological Objectives with 40 nested Ecological Targets for the Floodplain PEA. However, several targets include co-nested reportable components. For example:

- *"During inundation periods, record an increase in the abundance and diversity of invertebrate food resources, nutrients, and DOC relative to those available during base flow,"*

  encompasses two reportable components: (i) invertebrates and (ii) nutrients and DOC.

- *"Population age structure of golden perch and silver perch includes YOY with sub-adults and adults in 8 years out of 10"*

  involves two distinct species with different life histories, each requiring separate reporting.

Separation of the co-nested target components reveals that the LTWP (DEW 2020) contains 32 targets for the Channel PEA, and 49 targets for the Floodplain PEA; a combined total of 81 reportable Ecological Targets. Considering only the unique targets, i.e. targets that were not repeated across both the Channel and Floodplain PEA, there were 62 unique reportable targets presented in the 2020 LTWP (DEW 2020).

4.2 Number of targets generated through the current review and refinement process

The workshop process described in section 3, generated 24 Ecological Objectives with 94 nested Ecological Targets. Initial feedback raised concerns about the management utility of the increased number of targets. Consequently, a target rationalisation process was undertaken. Considerations utilised in the rationalisation process were:

- Can the objective/target be consolidated with another and retain intent and reporting functionality?
- Is monitoring and reporting viable with existing standardised methods?
- Do the EWR contribution tables (see section 7) show that the attribute is markedly responsive to delivery of flow? If not, is this because of lack of a direct relationship, or lack of knowledge of the underlying relationship and/or other stressors?
- Is monitoring of the attribute considered to provide a high return on investment by improving the knowledge base that underpins management decisions?
- Will achievement of the Ecological Targets require major input(s) other than just delivery of environmental water e.g. predation and grazing control or restocking programs, which are generally undertaken at the site scale and would be difficult to implement at the landscape scale?

The refinement process generated 18 Ecological Objectives with 79 nested Ecological Targets that are recommended for inclusion in the 2025 review of the LTWP. The refined Ecological Objectives and Targets were circulated to the subject matter experts and relevant project managers in November-December 2024 for final review. An overview of the development and refinement process is presented in Table 5.1 (section 5). The final set of Objectives and Targets are presented in Table 6.1 (section 6).

An increase in the number of targets should not be unexpected, and reflects the increased state of knowledge of life history processes, demographics of target biota, ecological stressors, and the observed responses to delivery of environmental flows that has been generated over the intervening decade since the targets included in the LTWP (DEW 2020) were developed.

5 Summary tables

5.1 Ecological objectives and targets summary tables

Summary tables are presented in this section (Table 5.1). These provide an overview of the target development and rationalisation process and contain:

- the original Ecological Objective and Ecological Targets as provided in the LTWP (DEW 2020)
- the revised Ecological Objectives and Ecological Targets developed through the workshop process outlined in section 3
- Recommended updates for the Ecological Objective and Target(s)
- Rationale supporting the recommended updates
- availability of data that can be used to report on the targets
- information on key use of the targets
- information regarding further development of the targets
- Complementary actions that may support achievement of the objectives and targets.

The tables presented in the following pages contain target codes that precede the wording of the target. These identification codes were used to track iterations of draft targets during the workshop and subsequent review phases. Codes denoted as ( ) were used in the early development phases. Those denoted in [ ] were developed in later phases as objective groupings were refined, and are the final codes for the targets recommended for inclusion in the 2025 update of the Long Term Watering Plan. The early coding is retained here as it provides a means of backtracking through the iterative target development phases if deemed necessary.

Table 5.1. Overview of the target development and rationalisation process

Floodplain trees – River Red Gum		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	Throughout the length of the Channel asset (i.e. SA border to Wellington), establish and maintain a diverse native flood-dependent plant community in areas inundated by flows of 10,000–40,000 ML/day QSA	Maintain a viable, functioning River Red Gum population within the Floodplain PEA
SME workshop derived objective	Restore ecologically functional river red gum / black box/ river cooba woodlands	
	Maintain spatial extent of long-lived vegetation communities	
Recommended Update to Objective	Maintain spatial extent and restore ecologically functional River Red Gum woodlands.	
Rationale	Objective intent retained, but focus tightened to be specific to trees, as per 2020 objective for the Floodplain PEA. Separate objectives are presented for Black Box, River cooba, Lignum and understory vegetation. Separating the vegetation related objective into (i) tree species, (ii) lignum, and (iii) understory vegetation highlights that (A) whilst there is some overlap in sites, assessment locations for (i) tree condition, (ii) lignum, and (iii) understory vegetation, are generally not co-located, and (B) managing tree condition is a core input into the decision-making process regarding priority of delivery of environmental water. In addition to the Ecological Target, site-based management (Chowilla, Pike and Katarapko) utilises a Management Threshold for tree condition that guides the prioritisation process. Although implied within the original objective for the Channel PEA, no metrics for maintaining spatial extent or limiting tree death were presented in the Objective within the 2020 version of the LTWP. Addressing this was seen as a key improvement as existing data highlights that there are major differences in condition related to flood return frequency and duration of inundation. Note also that data from mixed woodland communities demonstrates marked differences in condition may be expected between tree species within the same location.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	In standardised transects spanning the elevation gradient in the target zone*, 70% of river red gums have a Tree Condition Index score ≥ 10. **The target zone is the area inundated by flows of 10,000-40,000 ML/day (under normal River operations)*	In standardised transects that span the Floodplain PEA elevation gradient and existing spatial distribution, >70% of all trees have a Tree Condition Index Score (TCI) ≥10
	A sustainable demographic* is established to match the modelled profile for a viable River Red Gum population in existing communities spanning the elevation gradient in the	A sustainable demographic* that matches the modelled profile for a viable population is established within existing communities across the floodplain elevation gradient

	target zone **Sustainable demographic is described in (Wallace, et al., 2014a)*	**Sustainable demographic is described in (Wallace, et al., 2014a)*
SME workshop derived targets	(TC1) [TREE_1]: In woodlands adjacent permanent water ≥90% of viable River Red Gum will have a Tree Condition Index Score ≥10	
	(TC2) [TREE_2]: In floodplain woodlands, ≥ 90% of viable River Red Gum will have a Tree Condition Index Score ≥10	
	(WV1) [TREE_3]: Effective regeneration of River Red Gum woodlands at least 1 in 10 years, as evidenced by >85 % of assessment areas containing saplings and/or sub-adult trees (DBH <10cm) comprising >30% of the population	
	(WV3) [TREE_4]: The rate of loss (die back to a TCI = 0) of mature River Red Gums will not exceed 0.15% per year	
	(WV5) No net contraction in spatial extent (ha) of river red gum woodland from 2002 baseline	
Recommended Update to targets	Based on post workshop feedback provided by DEW staff, it was agreed to merge targets (TC1) and (TC2), and add text referencing transects i.e. for (TC1) [TREE_1] the target should be *"In standardised transects spanning the elevation gradient, ≥90% of viable River Red Gum will have a Tree Condition Index Score ≥10"*	
	Adopt SME derived targets (WV1) and (WV3).	
	Based on post-workshop discussions with SME, it was decided that (WV5) could be removed. Whilst this represents a high value target, mapping spatial contraction would require an agreed classification system to define classes based on various factors including tree density and size classes plus understory within assessment areas. Recommend this target is withheld until mapping issue is resolved.	
Rationale	Assessments are undertaken within standardised transects that span the existing elevation gradient incorporating both the Channel and Floodplain PEA. Analysis of data sets needs to factor in which PEA the transect lies within and could include assessment of distance from permanent water as per the SME derived targets TC1 and TC2. For River Red Gums, adjacent is taken to mean within 50m of permanent water. Condition assessment is for trees with DBH >10 cm that support live foliage; referred to as "viable" trees. Viable trees are deemed to be those receiving TCI scores ≥ 2; a TCI score of 0 denotes no foliage is present (tree is presumed to be dead or very near to the critical point of loss), and a TCI score of 1 cannot be generated via the standardised methodology (Souter *et al.* 2010a). The inclusion of "viable" within the target is in response to observations that many of the existing transects in use at Chowilla (Wallace 2023a), Pike (Wallace 2023c) and Katarapko (Wallace 2023b) include relatively high numbers of dead/non-viable trees, such that in some cases, the original metric of <u>70% of all trees</u> is not achievable. In many cases, the percentage of dead/non-viable trees increased during the Millenium drought, and there has been some ongoing loss in the intervening period between 2020-11 and current. Altering the target to apply to viable trees, and including a loss component, means the percentage component of the target can be achieved whilst also accounting for tree loss. The target metric was increased from 70% of viable trees to 90% of trees based on multi-	

	year data sets (Wallace 2024b) demonstrating that in areas that have received environmental water at an appropriate regime, 90% is readily achieved. It is also pertinent to note that with a metric of 70% the population may remain in precarious condition state, as 70% of viable trees having a Tree Condition Index Score ≥10 allows for up to 30% of trees to be in a poor condition state where death is possible during dry years (documented in supplementary information). Note that if only the condition of viable trees is reported, in cases where loss (death) of these stressed trees occurs, it is possible for the perceived condition of the assessment area to improve even though the population is in decline. Therefore inclusion of [TREE_4] is an important addition, and if [TREE_1] is met but [TREE_4] is not met, this should be considered a red flag. The existing SA River Murray LTWP presented the same target metrics for both PEAs with minor differences in wording. Wording should be standardised across both PEAs. Whilst the percentage of trees adjacent to permanent water is small relative to the total population, it is expected that those trees would be in better condition due to the influence of pulse flows in recharging lower salinity lenses (LSL) within near bank losing reaches maintaining soil water availability conducive to tree growth/survival during inter-flood periods. It is also expected that there will be differences in tree condition based on inundation return intervals between low and high elevation sections of the floodplain. This expectation is supported by data from existing monitoring programs. Functional linkage with LSL aligns target for tree condition with soil and groundwater targets. The population demographic target was replaced with a regeneration metric. This is because it is considered that the "inverse J curve model" (which requires regular recruitment) originally used to define a sustainable demographic (per George *et al.* 2005) is not considered appropriate in the lower Murray, where patchy and episodic recruitment is considered by the SME team to be expected and desirable. The proposed regeneration metrics are expert opinion of what might be required for a stand to be considered sustainable over time frames meaningful to long-lived vegetation, and take into account an urgent need for regeneration to off-set the catastrophic loss observed during the millenium drought. In areas that have not experienced such loss, much lower return frequencies may be more appropriate. Including percentage of assessment areas spanning the elevation gradient within the metric is an attempt to offset the probability of high rates of recruitment in the lower elevation bands/higher flood return intervals compared to very low rates of recruitment in the higher elevation bands/low flood return interval areas. Rate of loss is based off observed whole of floodplain rates of loss from Chowilla (Wallace 2024b), Pike (Wallace 2024d) and Katarapko (Wallace 2024c) and a recognition that there must be some "natural loss" rate associated with senescence of old trees and natural thinning of juveniles/young adults.
Existing data	Yes. There are long-term data sets from each of the managed floodplains (Chowilla, Pike and Katarapko) with some data available for other managed sites. There is a lack of data outside of managed areas.
Key use of targets	Major determinant of condition and trajectory of a key-stone species that is considered a central objective of environmental water delivery. In areas where EWRs are met and metrics for soil water availability are met, nearly all viable trees can be expected to be in good to excellent condition (i.e. TCI > 10).

	The presence of saplings/juveniles in water stressed floodplain areas and the ability to (i) benefit those trees, or (ii) place them at risk via overtopping, is a key consideration in delivery of environmental water. Ability to assess regeneration is a key component of being able to assess progress towards habitat recovery to counter the extensive loss incurred through the millenium drought. If EWRs are met, over a 10-year period there would be 3+ opportunities to facilitate effective regeneration of seedlings through to successful establishment of RRG saplings and sub-adults.
Further development	Resolve outstanding issues associated with mapping vegetation types. This includes developing an agreed classification system to define vegetation classes based on various factors including tree density and size classes plus understory within assessment areas.
Complementary actions	Limiting the cumulative impact of grazers on survival of germinants and seedlings may be a key component of increasing the success of recruitment events.

Floodplain trees – Black Box		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	N/A	Maintain a viable, functioning Black Box population within the Floodplain PEA.
SME workshop derived objective	Restore ecologically functional river red gum / black box/ river cooba woodlands	
	Maintain spatial extent of long-lived vegetation communities	
Recommended Update to Objective	Maintain spatial extent and restore ecologically functional Black Box woodlands.	
Rationale	Objective intent retained, but focus tightened to be specific to trees, as per 2020 objective for the Floodplain PEA. Separate objectives are presented for Black Box, River cooba, Lignum and understory vegetation. Separating the vegetation related objective into (i) tree species, (ii) lignum, and (iii) understory vegetation highlights that (A) whilst there is some overlap in sites, assessment locations for (i) tree condition, (ii) lignum, and (iii) understory vegetation, are generally not co-located, and (B) managing tree condition is a core input into the decision-making process regarding priority of delivery of environmental water. In addition to the Ecological Target, site-based management (Chowilla, Pike and Katarapko) utilises a Management Threshold for tree condition that guides the prioritisation process. Although implied within the original objective for the Channel PEA, no metrics for maintaining spatial extent or limiting tree death were presented in objective within the 2020 version of the LTWP. Addressing this was seen as a key improvement as existing data highlights that there are major differences in condition related to flood return frequency and duration of inundation. Note also that data from mixed woodland communities demonstrates marked differences in condition may be expected between tree species within the same location.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	N/A	In standardised transects that span the Floodplain PEA elevation gradient and existing spatial distribution, >70% of all trees have a TCI ≥10
		A sustainable demographic that matches the modelled profile for a viable population is established within existing communities across the floodplain elevation gradient (Floodplain PEA)
SME workshop derived targets	(TC3) [TREE_5]: In woodland adjacent permanent water ≥90% of viable Black Box will have a Tree Condition Index Score ≥10	
	(TC4) [TREE_6]: In floodplain woodlands that span the elevation gradient, ≥90% of viable Black Box will have a Tree Condition Index Score ≥10	

	(WV2) [TREE_7]: Effective regeneration of Black Box woodlands at least 1 in 20 years, as evidenced by >75 % of assessment areas containing saplings (size) and/or sub-adult trees (DBH <10cm) comprising >30% of the population
	(WV4) [TREE_8]: The rate of loss (die back to a TCI = 0) of mature Black Box will not exceed will not exceed 0.15% per year
	(WV6) No net contraction in spatial extent (ha) of black box woodland from 2002 baseline
Recommended Update to targets	Based on post workshop feedback provided by DEW staff, it was agreed to merge targets (TC3) and (TC4), and add text referencing transects i.e. the target should be *"In standardised transects spanning the elevation gradient, ≥90% of viable Black Box will have a Tree Condition Index Score ≥10"*
	Adopt SME derived targets (WV2) and (WV4).
	Based on post-workshop discussions with SME, it was decided that (WV6) could be removed. Whilst this represents a high value target, mapping contraction would require an agreed classification system to define classes based on various factors including tree density and size classes plus understory within assessment areas. Recommend this target is withheld until mapping issue is resolved.
Rationale	Assessments are undertaken within standardised transects that span the existing elevation gradient incorporating both the Channel and Floodplain PEA. Analysis of data sets needs to factor in which PEA the transect lies within and could include assessment of distance from permanent water as per the SME derived targets TC1 and TC2. For Black Box, adjacent is taken to mean within 100m of permanent water. The metric for River Red Gum (50m) is less than that of Black Box (100m) due to the differing ability to grow in low soil water potential conditions. Condition assessment is for trees with DBH >10 cm that support live foliage; referred to as "viable" trees. Viable trees are deemed to be those receiving TCI scores ≥ 2; a TCI score of 0 denotes no foliage is present (tree is presumed to be dead or very near to the critical point of loss), and a TCI score of 1 cannot be generated via the standardised methodology (Souter *et al.* 2010a). The inclusion of "viable" within the target is in response to observations that many of the existing transects in use at Chowilla (Wallace 2023a), Pike (Wallace 2023c) and Katarapko (Wallace 2023b) include relatively high numbers of dead/non-viable trees, such that in some cases, the original metric of <u>70% of all trees</u> is not achievable. In many cases, the percentage of dead/non-viable trees increased during the Millenium drought, and there has been some ongoing loss in the intervening period between 2020-11 and current. Altering the target to apply to viable trees, and including a loss component, means the percentage component of the target can be achieved whilst also accounting for tree loss. The target metric was increased from 70% of viable trees to 90% of trees based on multi-year data sets (Wallace 2024b) demonstrating that in areas that have received environmental water at an appropriate regime, 90% is readily achieved. It is also pertinent to note that with a metric of 70% the population may remain in precarious condition state, as 70% of viable trees having a Tree Condition Index Score ≥10 allows for up to 30% of trees to be in a poor condition state where death is possible during dry years (documented in supplementary information). Note that if only (TC3) is reported, in cases where loss (death) of these stressed trees occurs, it is possible for the perceived condition of the assessment area to

	improve even though the population is in decline. Therefore inclusion of [TREE_8] is an important addition, and if TC3 is met but [TREE_8] is not met, this should be considered a red flag. The 2020 SA River Murray LTWP presented the same target metrics for both PEAs with minor differences in wording. Wording should be standardised across both PEAs. Whilst the percentage of trees adjacent permanent water is small relative to the total population, it is expected that those trees would be in better condition due to the influence of pulse flows in recharging lower salinity lenses (LSL) within near bank losing reaches maintaining soil water availability conducive to tree growth/survival during inter-flood periods. It is also expected that there will be differences in tree condition based on inundation return intervals between low and high elevation sections of the floodplain. This expectation is supported by data from existing monitoring programs. Functional linkage with LSL aligns target for tree condition with soil and groundwater targets. The population demographic target was replaced with a regeneration metric. This is because it is considered that the “inverse J curve model” (which requires regular recruitment) originally used to define a sustainable demographic (per George *et al.* 2005) is not considered appropriate in the lower Murray, where patchy and episodic recruitment is considered by the SME team to be expected and desirable. The proposed regeneration metrics are expert opinion of what might be required for a stand to be considered sustainable over time frames meaningful to long-lived vegetation, and take into account an urgent need for regeneration to off-set the catastrophic loss observed during the millenium drought. In areas that have not experienced such loss, much lower return frequencies may be more appropriate. Including percentage of assessment areas spanning the elevation gradient within the metric is an attempt to offset the probability of high rates of recruitment in the lower elevation bands/higher flood return intervals compared to very low rates of recruitment in the higher elevation bands/low flood return interval areas. Rate of loss is based off observed whole of floodplain rates of loss from Chowilla (Wallace 2024b), Pike (Wallace 2024d) and Katarapko (Wallace 2024c) and a recognition that there must be some “natural loss” rate associated with senescence of old trees and natural thinning of juveniles/young adults.
Existing data	Yes. There are long-term data sets from each of the managed floodplains (Chowilla, Pike and Katarapko) with some data available for other managed sites. There is a lack of data outside of managed areas.
Key use of targets	Major determinant of condition and trajectory of a key-stone species that is considered a central objective of environmental water delivery. In areas where EWRs are met and metrics for soil water availability are met, nearly all viable trees can be expected to be in good to excellent condition (i.e. TCI > 10). The presence of saplings/juveniles in water stressed floodplain areas and the ability to (i) benefit those trees, or (ii) place them at risk via overtopping, is a key consideration in delivery of environmental water. Ability to assess regeneration is a key component of being able to assess progress towards habitat recovery to counter the extensive loss incurred through the millenium drought.

	If EWRs are met, over a 20-year period there would be 3+ opportunities to facilitate effective regeneration of seedlings through to successful establishment of BB saplings and sub-adults.
Further development	Resolve outstanding issues associated with mapping vegetation types. This includes developing an agreed classification system to define vegetation classes based on various factors including tree density and size classes plus understory within assessment areas.
Complementary actions	Limiting the cumulative impact of grazers on survival of germinants and seedlings may be a key component of increasing the success of recruitment events.

Floodplain trees – River Cooba		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	N/A	Maintain a viable, functioning River Cooba population within the Floodplain PEA.
SME workshop derived objective	Restore ecologically functional river red gum / black box/ river cooba woodlands	
	Maintain spatial extent of long-lived vegetation communities	
Recommended Update to Objective	Maintain spatial extent and restore ecologically functional River Cooba woodlands.	
Rationale	Objective intent retained, but focus tightened to be specific to trees, as per 2020 objective for the Floodplain PEA. Separate objectives are presented for Black Box, River cooba, Lignum and understory vegetation. Separating the vegetation related objective into (i) tree species, (ii) lignum, and (iii) understory vegetation highlights that (A) whilst there is some overlap in sites, assessment locations for (i) tree condition, (ii) lignum, and (iii) understory vegetation, are generally not co-located, and (B) managing tree condition is a core input into the decision-making process regarding priority of delivery of environmental water. In addition to the Ecological Target, site-based management (Chowilla, Pike and Katarapko) utilises a Management Threshold for tree condition that guides the prioritisation process. River cooba was excluded from the 2020 LTWP channel objectives due to the very low percentage of River cooba within the area inundated by flows of <40,000 $MLday^{-1}$. However, whilst the percentage of trees adjacent permanent water is small relative to the total population, it is expected that those trees would be in better condition due to (i) the influence of flows <40,000 $MLday^{-1}$ in recharging lower salinity lenses (LSL) within near bank losing reaches maintaining soil water availability conducive to tree growth/survival during inter-flood periods, and (ii) expected differences in tree condition based on inundation return intervals between low and high elevation sections of the floodplain. Functional linkage with LSL aligns target for tree condition with soil and groundwater targets. Although implied within the original objective for the Channel PEA, no metrics for maintaining spatial extent or limiting tree death were presented in the objective within the 2020 version of the LTWP. Addressing this was seen as a key improvement as existing data highlights that there are major differences in condition related to flood return frequency and duration of inundation. Note also that data from mixed woodland communities demonstrates marked differences in condition may be expected between tree species within the same location. In addition, data from Chowilla, Pike and Katarapko demonstrate that River cooba woodlands that are infrequently inundated continue to be in relatively poor condition	
Ecological targets	**Channel PEA**	**Floodplain PEA**
	N/A	In standardised transects that span the Floodplain PEA elevation gradient and

Existing SA River Murray LTWP 2020 Targets		existing spatial distribution, >70% of all trees have a TCI ≥10
		A sustainable demographic that matches the modelled profile for a viable population is established within existing communities across the floodplain elevation gradient.
SME workshop derived targets	(TC5) [TREE_9]: In woodlands adjacent permanent water ≥90% of viable river cooba will have a Tree Condition Index Score ≥10	
	(TC6) [TREE_10]: In floodplain woodlands, ≥90% of viable river cooba will have a Tree Condition Index Score ≥10	
Recommended Update to targets	Based on post workshop feedback provided by DEW staff, it was agreed to merge targets (TC5) and (TC6), and add text referencing transects i.e. the target should be "*In standardised transects spanning the elevation gradient, ≥90% of viable River Cooba will have a Tree Condition Index Score ≥10*"	
Rationale	Assessments are undertaken within standardised transects that span the existing elevation gradient incorporating both the Channel and Floodplain PEA. Analysis of data sets needs to factor in which PEA the transect lies within and could include assessment of distance from permanent water as per the SME derived targets TC1 and TC2. For River Cooba, adjacent is taken to mean within 100m of permanent water. Condition assessment is for trees with DBH >10 cm that support live foliage; referred to as "viable" trees. Viable trees are deemed to be those receiving TCI scores ≥ 2; a TCI score of 0 denotes no foliage is present (tree is presumed to be dead or very near to the critical point of loss), and a TCI score of 1 cannot be generated via the standardised methodology (Souter *et al.* 2010a). The inclusion of "viable" within the target is in response to observations that many of the existing transects in use at Chowilla (Wallace 2023a), Pike (Wallace 2023c) and Katarapko (Wallace 2023b) include relatively high numbers of dead/non-viable trees, such that in some cases, the original metric of <u>70% of all trees</u> is not achievable. In many cases, the percentage of dead/non-viable trees increased during the Millenium drought, and there has been some ongoing loss in the intervening period between 2020-11 and current. Altering the target to apply to viable trees, and including a loss component, means the percentage component of the target can be achieved whilst also accounting for tree loss. The target metric was increased from 70% of viable trees to 90% of trees based on multi-year data sets (Wallace 2024b) demonstrating that in areas that have received environmental water at an appropriate regime, 90% is readily achieved. It is also pertinent to note that with a metric of 70% the population may remain in precarious condition state, as 70% of viable trees having a Tree Condition Index Score ≥10 allows for up to 30% of trees to be in a poor condition state where death is possible during dry years (documented in supplementary information). No target for loss, or for spatial extent was developed during the SME workshop process. Clonal reproduction of River Cooba is a complicating factor in assessing contraction/expansion of stands that has not yet been resolved; see "Further development".	

Existing data	Yes. There are long-term data sets from each of the managed floodplains (Chowilla, Pike and Katarapko) with some data available for other managed sites. There is a lack of data outside of managed areas.
Key use of targets	Major determinant of condition and trajectory of a key-stone species that is considered a central objective of environmental water delivery. In areas where EWRs are met and metrics for soil water availability are met, nearly all viable trees can be expected to be in good to excellent condition (i.e. TCI > 10).
Further development	Target for population demographic not recommended to be continued at this time. Sexual and asexual (clonal) reproduction by this species complicates ability to assess demographics, and there is distinct lack of certainty on what represents a sustainable demographic. Consideration also needs to be given to developing targets for acceptable rates of loss/senescence.
Complementary actions	N/A

Lignum Shrublands		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	N/A	Maintain a viable, functioning Lignum population within the Floodplain PEA.
SME workshop derived objective	Restore ecologically functional Lignum shrublands	
	Maintain spatial extent of long-lived vegetation communities	
Recommended Update to Objective	Maintain spatial extent and restore ecologically functional Lignum shrublands.	
Rationale	Although implied within the 2020 LTWP objective and target, no target metrics for maintaining spatial extent were presented. The two objectives developed in the SME workshop process can be consolidated.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	N/A	In standardised transects that span the Floodplain elevation gradient and existing spatial distribution, ≥70% of Lignum plants have a Lignum Condition Score (LCI) ≥6 for colour
SME workshop derived targets	(LC1) [LIGN_1]: 30% of lignum sites receive condition values indicative of good condition at least once every 2 years	
	(LC2) [LIGN_2]: 60% of lignum sites receive condition values indicative of good condition at least once every 3 years	
	(LC3) [LIGN_3]: 80% of lignum sites receive condition values indicative of good condition at least once every 4 years	
	(WV7) No net contraction in spatial extent (ha) of lignum shrubland from 2002 baseline	
Recommended Update to targets	Adopt (LC1), (LC2) and (LC3).	
	Based on post-workshop discussions with SME, it was decided that (WV7) could be removed. Whilst this represents a high value target, mapping contraction would require an agreed classification system to define classes based on various factors including tree density and size classes plus understory within assessment areas. Recommend this target is withheld until mapping issue is resolved.	
	Include new target: [LIGN_4]: Percentage of dead (non-viable plants) within assessment areas decreases.	
Rationale	In the 2020 LTWP, lignum was not included in the Channel PEA. The proposed Target (and Objective) now applies to both PEA's. Whilst the percentage of lignum within the channel PEA is small relative to the total population, lignum is a key ecological feature of shedding and retaining wetland areas within both PEA's. A range of condition metrics [LIGN_1-3] based on flood return intervals are provided to reflect expected differences in lignum condition based on inundation return intervals between low and high elevation sections of the floodplain.	

	[LIGN_4] added to (i) address failure of SME workshop derived targets to address loss, and (ii) ensure loss and regeneration is assessed with recommended change to determination of "good" condition based on condition of viable plants. Existing data shows high percentage of dead plants within some assessment locations with a large proportion of loss assumed to have occurred during the millennium drought. High percentage of dead plants negatively impacts ecological function of lignum shrublands. Progressive regeneration via sexual or asexual reproduction facilitated via delivery of environmental water should reduce the percentage of non-viable plants within assessment areas as new plants establish and plant density (number of plants per square meter) increases. Note that ad-hoc observations from the 2010-11 flood and survey data post the 2022-23 flood show that excessive duration of inundation can cause extensive die-off of lignum in some low elevation lignum shrublands. Stable percentage rates would suggest either (i) regeneration is not occurring, or (ii) regeneration is being offset by concomitant loss.
Existing data	Yes. There is a network of monitoring sites. Assessment frequency varies between sites. Distribution is biased towards managed floodplain/wetland sites.
Key use of targets	Major determinant of condition and trajectory of a key-stone species that is considered a central objective of environmental water delivery.
Further development	Metric of "good condition" for an individual plant taken to be LCI ≥8 as agreed at small group workshop held 15th August 2024. Preliminary (unpublished at the time of this report) review of data from Chowilla and Pike Floodplain undertaken in September 2024 suggests that a target metric considered to be representative of good condition assessment location may be "≥90% of <u>viable</u> plants have a Lignum Condition Score (LCI) ≥8". Target metric requires further review to determine appropriate percentage of plants. The issue of percentage of dead plants within an assessment area also needs further consideration i.e. if 80% of plants in an assessment area are dead, but the viable plants are in "good" condition, the site may not be able to be considered "ecologically functional". Resolution of this issue will require clarification of what "ecologically functional" means; which is beyond the scope of this current work. However, if the target metric includes all (live and dead plants) the ability of an assessment area to meet the target in the short-term will be dependent on extent of plant loss over recent decades. Ability to meet the target going forward will be dependent on recruitment (sexual reproduction) and expansion (clonal reproduction). Resolve outstanding issues associated with mapping vegetation types. This includes developing an agreed classification system to define vegetation classes based on various factors including tree density and size classes plus understory within assessment areas.
Complementary actions	N/A

Non-woody vegetation – Permanently inundated channels and pool connected wetlands		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	Throughout the length of the Channel asset (i.e. SA border to Wellington), establish and maintain a diverse native flood-dependent plant community in areas inundated by flows of 10,000–40,000 ML/day QSA (Channel PEA)	N/A.
SME workshop derived objective	Establish ecologically functional native understorey vegetation community	
Recommended Update to Objective	Establish ecologically functional native understorey vegetation community in permanently inundated habitats.	
Rationale	Intent of Objective and Target retained, but wording refined from generic statement to focus specifically on target vegetation community. Change is based on recommendations from subject matter experts that refinements for non-woody vegetation should focus on expectations for different habitats/flow bands e.g. permanently inundated, frequently inundated.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	Species from the Plant Functional Group 'flood-dependent/responsive' occur in 70% of quadrats spanning the elevation gradient in the target zone at least once every 3 years.	N/A
SME workshop derived targets	(PC1) [UVEG_1]: In permanently inundated channels and pool connected wetlands, a minimum of 90% of survey cells located on the bed, bank toe, slope and crest are either inundated or contain native flood-dependent and/or amphibious taxa at least once every 2 years	
	(PC2) [UVEG_2]: In permanently inundated channels and pool connected wetlands, survey cells will have species richness of native flood-dependent, amphibious and aquatic plants ≥ 60 at least once every 2 years	
Recommended Update to targets	Adopt SME workshop derived targets (PC1) and (PC2)	
Rationale	Target split to include both presence/absence and species diversity, to highlight that presence of flood-dependent, amphibious and aquatic plants in sites that have been recently inundated is a core expectation in successional patterns associated with wetting and drying cycles. Split is also consistent with recommended change to 2020 version of targets for the Floodplain PEA (see later tables) in which presence/absence and species diversity were originally presented within a combined target. Functional habitat should have capacity to respond to inundation and produce a diverse response, with successional change driving high diversity and providing a wide range of food resources and habitat for biota with contrasting needs.	

Existing data	Yes. There is a network of monitoring sites that are assessed on a quasi-annual basis.
Key use of targets	Assessment of achievement of core expectation of reinstating successional patterns associated with wetting and drying cycles. Understory vegetation is a key component of habitat and provides food resources to both aquatic and woodland fauna.
Further development	N/A
Complementary actions	N/A

Non-woody vegetation – Frequently inundated temporary wetlands and shedding floodplain		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	Throughout the length of the Channel asset (i.e. SA border to Wellington), establish and maintain a diverse native flood-dependent plant community in areas inundated by flows of 10,000–40,000 ML/day QSA	N/A.
SME workshop derived objective	Establish ecologically functional native understorey vegetation community	
Recommended Update to Objective	Establish ecologically functional native understorey vegetation community in frequently inundated habitats.	
Rationale	Intent of Objective and Target retained, but wording refined from generic statement to focus specifically on target vegetation community. Change is based on recommendations from subject matter experts that refinements for non-woody vegetation should focus on expectations for different habitats/flow bands e.g. permanently inundated, frequently inundated.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	Native macrophytes from the emergent, amphibious and flood-dependent functional groups occur in 70% of quadrats spanning the elevation gradient in the target zone at least once every 3 years.	N/A
SME workshop derived targets	(TW1) [UVEG_3]: In temporary wetlands inundated at flows ≤40,000 $MLday^{-1}$, a minimum of 70% of survey cells located on the bed, bank toe, slope and crest are either inundated or contain native flood-dependent and/or amphibious taxa at least once every 2 years	
	(TW2) [UVEG_4]: In temporary wetlands inundated at flows ≤40,000 $MLday^{-1}$, survey cells will have species richness of native flood-dependent, amphibious and aquatic plants ≥ 80 at least once every 2 years	
	(SF1) [UVEG_5]: The shedding floodplain inundated at flows ≤40,000 $MLday^{-1}$ has a minimum of 70% of survey cells either inundated or containing native flood-dependent and/or amphibious taxa at least once every 2 years	
	(SF2) [UVEG_6]: The shedding floodplain inundated at flows ≤40,000 $MLday^{-1}$ survey cells will have species richness of native flood-dependent, amphibious and aquatic plants ≥ 80 at least once every 2 years	
Recommended Update to targets	Adopt SME workshop derived targets	
Rationale	Separating (a) temporary wetlands and (b) shedding floodplains, highlights that there is a different expected outcome in these contrasting habitats. Split is also consistent with recommended change to 2020 version of targets for the	

	Floodplain PEA (see later tables) in which presence/absence and species diversity were originally presented within a combined target. Functional habitat should have capacity to respond to inundation and produce a diverse response, with successional change driving high diversity and providing a wide range of food resources and habitat for biota with contrasting needs. Expected frequency of achievement increased from 3 to 2 years. Recommended target metrics align with those utilised at the three major floodplains.
Existing data	Yes. There is a large network of monitoring sites that are assessed on a quasi-annual basis. Distribution is biased towards managed floodplain/wetland sites.
Key use of targets	Assessment of achievement of core expectation of reinstating successional patterns associated with wetting and drying cycles. Understory vegetation is a key component of habitat and provides food resources to both aquatic and woodland fauna.
Further development	N/A
Complementary actions	Managing total (domestic, feral and native) grazing pressure, combined with weed management are complementary actions that can be expected to influence ability to achieve metrics and provide functional habitat. Data from existing grazing exclosures provides clear evident of negative impacts of grazing pressure.

Non-woody vegetation – Infrequently inundated temporary wetlands		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	N/A	Establish and maintain diverse water dependent vegetation within aquatic zones across the Floodplain PEA.
SME workshop derived objective	Establish ecologically functional native understorey vegetation community	
Recommended Update to Objective	Establish ecologically functional native understorey vegetation community in infrequently inundated temporary wetlands.	
Rationale	Intent of Objective retained, but wording refined from generic statement to focus specifically on target vegetation community. Change is based on recommendations from subject matter experts that refinements for non-woody vegetation should focus on expectations for different habitats/flow bands e.g. permanently inundated, frequently inundated.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	N/A	In aquatic zones, a minimum of 40% of cells either inundated or dry containing inundation-dependent or amphibious plant taxa once every two years on average with maximum interval no greater than 4 years. Native water dependent species richness >30 across the Floodplain PEA.
		In aquatic zones, a minimum of 80% of cells either inundated or dry containing native flood dependent or amphibious plant taxa once every four years on average with maximum interval no greater than 6 years Native water dependent species richness >50 across the Floodplain PEA.
SME workshop derived targets	(TW3) [UVEG_7]: In temporary wetlands inundated at flows >40,000 $MLday^{-1}$, a minimum of 40% of survey cells located on the bed, bank toe, slope and crest are either inundated or contain native flood-dependent and/or amphibious taxa once every 2 years on average with maximum interval ≤4 years.	
	(TW5) [UVEG_8]: In temporary wetlands inundated at flows >40,000 $MLday^{-1}$, survey cells located on the bed, bank toe, slope and crest will have species richness of native flood-dependent, amphibious and aquatic plants ≥40 once every 2 years on average with maximum interval ≤ 4 years.	
	(TW4) [UVEG_9]: In temporary wetlands inundated at flows >40,000 $MLday^{-1}$, a minimum of 80% of survey cells located on the bed, bank toe, slope and crest are either inundated or contain native flood-dependent and/or amphibious taxa once every 4 years on average with maximum interval ≤ 6 years.	

	(TW6) [UVEG_10]: In temporary wetlands inundated at flows >40,000 MLday^{-1}, survey cells located on the bed, bank toe, slope and crest will have species richness of native flood-dependent, amphibious and aquatic plants ≥60 once every 4 years on average with maximum interval ≤ 6 years.
Recommended Update to targets	Adopt SME workshop derived targets
Rationale	Presenting separate targets for frequently and infrequently inundated areas highlights that there is a different expected outcome in these contrasting habitats. Presence/absence and species diversity were originally presented within a combined target, now presented separately. Functional habitat should have capacity to respond to inundation and produce a diverse response, with successional change driving high diversity and providing a wide range of food resources and habitat for biota with contrasting needs. It's noted that target metrics align with those utilised at the three major floodplains.
Existing data	Yes. There is a large network of monitoring sites that are assessed on a quasi-annual basis. Distribution is biased towards managed wetland sites.
Key use of targets	Assessment of achievement of core expectation of reinstating successional patterns associated with wetting and drying cycles. Understory vegetation is a key component of habitat and provides food resources to both aquatic and woodland fauna.
Further development	N/A
Complementary actions	Managing total (domestic, feral and native) grazing pressure, combined with weed management are complementary actions that can be expected to influence ability to achieve metrics and provide functional habitat. Data from existing grazing exclosures provides clear evident of negative impacts of grazing pressure.

Non-woody vegetation – Infrequently inundated shedding floodplain		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	N/A	Establish and maintain diverse native vegetation comprising native flood dependent and amphibious species within the shedding floodplain zones across the Floodplain PEA
SME workshop derived objective	Establish ecologically functional native understorey vegetation community	
Recommended Update to Objective	Establish ecologically functional native understorey vegetation community 0n infrequently inundated shedding floodplain areas.	
Rationale	Intent of Objective retained, but wording refined to focus specifically on infrequently inundated shedding zones, generating a separation based on duration and frequency of inundation. Change is based on recommendations from subject matter experts that refinements for non-woody vegetation should focus on expectations for different habitats/flow bands e.g. permanently inundated, frequently inundated.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	N/A	In shedding floodplain zones, a minimum of 20% of cells containing native flood dependent or amphibious plant taxa once every three years on average with maximum interval no greater than 5 years. Native flood dependent and amphibious species richness >20 across the Floodplain PEA.
		In shedding floodplain zones, a minimum of 40% of cells containing native flood dependent or amphibious plant taxa once every five years on average with maximum interval no greater than 7 years. Native flood dependent and amphibious species richness >30 across the Floodplain PEA.
		In shedding floodplain zones, a minimum of 65% of cells containing native flood dependent or amphibious plant taxa once every seven years on average with maximum interval no greater than 10 years. Native flood dependent and amphibious species richness >50 across the Floodplain PEA.

SME workshop derived targets	(SF3) [UVEG_11]: The shedding floodplain inundated at flows >40,000 $MLday^{-1}$ has a minimum of 20% of survey cells that are either inundated or contain native flood-dependent and/or amphibious taxa once every 3 years on average with maximum interval ≤5 years.
	(SF6) [UVEG_12]: On the shedding floodplain inundated at flows >40,000 $MLday^{-1}$, survey cells will have species richness of native flood-dependent, amphibious and aquatic plants ≥ 50 once every 3 years on average with maximum interval ≤ 5 years.
	(SF4) [UVEG_13]: The shedding floodplain inundated at flows >40,000 $MLday^{-1}$ has a minimum of 40% of survey cells that are either inundated or contain native flood-dependent and/or amphibious taxa once every 5 years on average with maximum interval ≤7 years.
	(SF7) [UVEG_14]: On the shedding floodplain inundated at flows >40,000 $MLday^{-1}$, survey cells will have species richness of native flood-dependent, amphibious and aquatic plants ≥ 75 once every 5 years on average with maximum interval ≤ 7 years.
	(SF5) [UVEG_15]: The shedding floodplain inundated at flows >40,000 $MLday^{-1}$ has a minimum of 70% of survey cells that are either inundated or contain native flood-dependent and/or amphibious taxa once every 7 years on average with maximum interval ≤10 years.
	(SF8) [UVEG_16]: On the shedding floodplain inundated at flows >40,000 $MLday^{-1}$, survey cells will have species richness of native flood-dependent, amphibious and aquatic plants ≥ 100 once every 7 years on average with maximum interval ≤ 10 years.
Recommended Update to targets	Adopt SME workshop derived targets
Rationale	Presenting separate targets for frequently and infrequently inundated areas highlights that there is a different expected outcome in these contrasting habitats. Presence/absence and species diversity were originally presented within a combined target, now presented separately. Functional habitat should have capacity to respond to inundation and produce a diverse response, with successional change driving high diversity and providing a wide range of food resources and habitat for biota with contrasting needs. Recommended target metrics align with those utilised at the three major floodplains. Species richness metric has been increased based on long-term data from 3 managed floodplains.
Existing data	Yes. There is a large network of monitoring sites that are assessed on a quasi-annual basis. Distribution is biased towards managed floodplains.
Key use of targets	Assessment of achievement of core expectation of reinstating successional patterns associated with wetting and drying cycles. Understory vegetation is a key component of habitat and provides food resources to both aquatic and woodland fauna.
Further development	N/A

Complementary actions	Managing total (domestic, feral and native) grazing pressure, combined with weed management are complementary actions that can be expected to influence ability to achieve metrics and provide functional habitat. Data from existing grazing exclosures provides clear evident of negative impacts of grazing pressure.

Groundwater		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	Throughout the length of the Channel asset (i.e. SA border to Wellington), establish and maintain groundwater and soil moisture conditions conducive to improving riparian vegetation.	Establish groundwater conditions conducive to maintaining diverse native vegetation across the Floodplain PEA.
SME workshop derived objective	Establish and maintain groundwater conditions conducive to supporting diverse ecologically functional native vegetation.	
	Changes in groundwater (A) depth below ground level and (B) salinity, do not increase the rate of salt accumulation in soils .	
Recommended Update to Objective	Establish and maintain groundwater conditions conducive to supporting diverse ecologically functional native vegetation.	
	Changes in depth to groundwater do not increase the rate of salt accumulation in soils .	
Rationale	The recommended objective "*Establish and maintain groundwater conditions conducive to supporting diverse, ecologically functional native vegetation*" preserves the intent of the 2020 LTWP objectives and targets. However, it separates the groundwater and soil condition objectives into individual reportable components. The recommended objective "*Changes in depth to groundwater do not increase the rate of salt accumulation in soils*" may be adequately encompassed within the first objective. Nevertheless, as currently framed, it emphasises a key risk associated with environmental water delivery. The inclusion of "salinity" in the SME-derived version of this objective addressed the risk of managed inundations disturbing existing low-salinity groundwater lenses (see Wallace 2019b for a description of this risk). Currently, the risk of low salinity lens disturbance remains theoretical with no empirical evidence of its occurrence. In contrast, shallow depth to saline groundwater is widely recognised as one of, if not the most significant factor, in the declining condition of floodplain vegetation in the lower Murray. The high salinity of groundwater underlying most of the lower Murray floodplain means that it is not utilisable as a water source for many floodplain vegetation types including floodplain trees, shrubs and most of the understory vegetation species. Construction and routine operation of the main channel weirs is considered to have substantially reduced the depth to groundwater, facilitating marked increases in the rate of evaporation of groundwater and the accumulation of salt in floodplain soils. In addition, river regulation and extraction of water for consumptive use has reduced the frequency and duration of floods that emplace low salinity water into the soil profile. The combination of reduced depth to shallow groundwater and reduced frequency and duration of flooding ensures that upward flux of saline groundwater into the dry surface layer exceeds downward fluxes of low salinity water from flooding. As a result, high soil salinity and low (strongly negative) soil water potential are major barriers to achieving the stated objective of "*supporting diverse, ecologically functional native vegetation*". In order to achieve net benefit, downward fluxes of low salinity water from delivery of environmental water and unregulated flooding	

needs to exceed the upward flux of saline groundwater during inter-flood dry periods.

With regard to delivery of environmental water, fringe degradation may occur in areas where depth to saline groundwater decreases in the absence of inundation (Wallace and Whittle 2014a; Wallace *et al.* 2024). In addition, in areas where environmental water delivery does generate inundation, reduced depth to groundwater experienced post-flood may exacerbate salt accumulation if the reduced depth to groundwater either (i) activates evaporation by causing the top of the capillary driven zone to overlap with the evaporation zone, or (ii) accelerates evaporation and salt buildup in the dry surface layer, by driving the capillary driven zone further into the evaporation zone. See Wallace *et al.* (2024) for a description of the key processes driving salt accumulation in floodplain soils. Any concomitant increase in groundwater salinity would be expected to accelerate salt accumulation.

In addition to reduced depth to groundwater, stable water levels generated via routine operation of the weirs and prolonged periods of low/stable flows limits the potential for near bank and vertical recharge of groundwater. Existing field data on tree and soil condition combined with conceptual models suggest that frequent delivery of pulse flows in the 20,000 + range are critical to support near bank recharge. The shape of the hydrograph is likely to have strong influence on outcomes; a long slow rise is likely to be less desirable than a relatively quick rise due to groundwater-surface water equilibrating over short time periods. On the broader floodplain, sustained periods of inundation will support downwards infiltration of comparatively low salinity surface water into the soil profile. The capacity of infiltrated surface water to connect with and induce groundwater recharge and drive a measurable improvement in groundwater salinity is highly site dependent, with the rate of vertical recharge dependent on localised variability in soil hydraulic conductivity and depth to groundwater.

Ecological targets	Channel PEA	Floodplain PEA
Existing SA River Murray LTWP 2020 Targets	Establish and maintain freshwater lenses in near-bank recharge zones.	Establish and maintain freshwater lenses in near-bank recharge zones.
SME workshop derived targets	(GS1) Where the watertable resides within the extinction depth for evaporation groundwater salinity in the top one metre of the saturated zone is within the range utilisable as a water source for river red gum (≤ 5,000 μScm^{-1}) and black box (≤ 8,000 μScm^{-1})	
	(GS2): The three year rolling mean of groundwater salinity in the top one metre of the saturated zone does not increase by more than 10% from baseline condition	
	(GS4): Where groundwater salinity exceeds the range utilisable as a water source for trees, the three-year mean depth below ground level does not decrease by more than 10% relative to the baseline	
Recommended Update to targets	(GS1a) [GWTR_1] Where the watertable resides within the active rooting depth, groundwater salinity in the top one metre of the saturated zone is within the range utilisable as a water source for river red gum (≤ 5,000 μScm^{-1})	

	(GS1b) [GWTR_2] Where the watertable resides within the active rooting depth, groundwater salinity in the top one metre of the saturated zone is within the range utilisable as a water source for black box (≤ 8,000 μScm^{-1})
	(GS4a) [GWTR_3] Where groundwater salinity in the top 1 metre of the saturated zone exceeds the range utilisable as a water source for trees, depth to groundwater returns to pre-watering baseline values during inter-flood periods
Rationale	The target (GS1) (SME workshop notes 18/12/2024) was split to GS1a and GS1b (summary tables 15th January 2024) to highlight the different metrics for each tree species. Based on feedback received from SME (MD February 2024), draft report version 4.0 wording for (GS1a/b) was changed from "Where the watertable resides within the extinction depth for evaporation groundwater" to "Where the watertable resides within the active rooting depth, groundwater salinity in the top one metre of the saturated zone is within the range utilisable as a water source…". The potential rooting depth of River Red Gum and Black Box is taken to be 9 m (Denny *et al.* 2016). Given that the rooting zone exceeds the depth of groundwater across most of the floodplain, the first component of the target (*Where the watertable resides within the active rooting depth*) may be redundant. The SME derived target (GS2) was removed based on advice from MD that targets (GS1a) and (GS1b) make GS2 redundant by providing a baseline and reference point against which to assess and report changes in groundwater salinity. In the SME workshops (2003), objective (GS4) "*Where groundwater salinity exceeds the range utilisable as a water source for trees, the three-year mean depth below ground level does not decrease by more than 10% relative to the baseline*" was developed. During the workshop process that objective was categorised as an ancillary objective as it was perceived that delivery of EWR's was more likely to reduce depth to GW than to improve conditions i.e. contribute to achieving the target. Based on feedback from MD in February 2024 (draft report version 4.0), a decision was made to reinstate the target, as reduced depth to groundwater is considered a key threat (see preceding text related to proposed objective and sub-sections on Soil Condition – soil salinity). Based on further feedback (draft version 11.2 November 2024), the target was modified to that recommended here. Problematic evapoconcentration of groundwater occurs where the top of the capillary driven zone interacts with or overlaps the evaporation depth for prolonged periods of time. Evaporation rates will be highest immediately post flood when the surface layer has high moisture content and depth to groundwater is shallow. Evaporation rates will progressively decrease as a dry surface layer develops and depth to groundwater increases during the "mid-" and "late- recession" phases. Given the relatively shallow (e.g. 2.5-4.5 m) depth to groundwater across much of the floodplain during inter-flood periods, it is expected that some level of evaporation occurs in most areas, for most of the time. Establishing conditions in which rates of salt accumulation from evaporation of groundwater are slow enough to be easily offset by intermittent inundations, is critical to limiting the ecological impacts of long-term salt accumulation. In this context, ensuring that (i) floods are frequent enough to emplace sufficient low salinity water into the soil profile to maintain soil water potential in the range

	conducive to growth and maintenance of vegetation, and (ii) inter-flood dry periods are long enough for depth to groundwater to recede to pre-flood baseline values, and hence avoid a sustained decrease in depth to groundwater and net increase in salt accumulation, will be vital to achieving the ecological objective. How long (in months) the higher rates of evaporation associated with mid- and late- recession conditions are tolerable, and how long pre-flood baseline conditions should be attained before another flood event is delivered, are critical knowledge gaps (see section on further development).
Existing data	Outside of the managed floodplains (Chowilla, Pike and Katarapko) there is relatively limited data available on groundwater conditions to enable reporting. Within the managed floodplains, a relatively high proportion of monitoring wells have salinity profiling undertaken (24 of 52 at Katarapko, and 51 of 79 at Pike). At those locations, groundwater conditions are monitored 3 times annually and reported on in detail. The data sets from the soil monitoring programs at the three major floodplains (Chowilla, Pike and Katarapko) show examples of strong salinity spikes at 1.0-1.5 m, and some cases precipitation of salts into crystalline forms is evident within soil pores indicating that salt concentrations have exceeded the solubility limit (Wallace *et al.* 2024). Data on vertical profiles of soil moisture content and soil salinity from the existing soil monitoring programs at Chowilla, Pike and Katarapko provide insight into the thickness of the capillary driven zone and the evaporation zone. However, changes in depth to groundwater is a more readily measured variable, especially over a large number of sites and at high frequency (e.g. multiple times per year).
Key use of targets	The targets seek to (A) provide a benchmark condition for groundwater salinity against which changes (positive and negative) can be assessed, and (B) ensure that negative outcomes are not induced by (i) short inter-flood periods that result in net decrease in depth to groundwater.
Further development	With regard to the target related to monitoring reductions in depth to groundwater, the option presented as the recommended update (GS4a, [GWTR_3]) requires establishing (i) a benchmark period from which changes in depth to groundwater are assessed, and (ii) a minimum time period for how long the baseline should be achieved between flood events. As this outcome is dependent on the duration of interflood periods, not delivery of environmental water, it is not assessed in section 7. There is a lack of relevant studies on evaporation of saline groundwater through floodplain soils. However, early studies (Gardner and Fireman 1958) indicate that evaporation rates increase exponentially once depth to water is less than 2m below the soil surface. Note that in the context of evaporation of groundwater and evapoconcentration of salt in the unsaturated zone, the top of the capillary driven zone is functionally equivalent to depth to groundwater (Wallace et al., 2024). The depth to groundwater at which there is effective separation between the evaporation depth and the top of the capillary driven zone is currently a knowledge gap but is expected to be site specific due to localised variability in the soil types and their ability to support capillary rise. This is because clay type soils support capillary rise from much greater depths than sand type soils (i.e.

	metres v's fractions of a metre respectively). As a preliminary hypothesis, a critical depth to groundwater of 4 metres in areas with medium-clay type soils, and 3 metres in areas with sandy-clay or sandy-loam type soils may represent useful benchmark values, as they allow for an assumed evaporation zone of 2 metres and a capillary driven zone of up to 2 metres in clay soils and 1 metre in sandy-clay or sandy-loam type soils. Results presented by Jolly *et al.* (1993) and preliminary analysis of data from the annual soil monitoring programs at Chowilla, Pike and Katarapko appear to support this suggestion, but further investigation is required. Groundwater salinity and frequency and duration of inundation influence these depths, with longer inter-flood periods and increasing groundwater salinity reducing the critical depth. The target for groundwater salinity may be able to be modified pending additional research. The stated metric is "ideal" conditions that represent a Low Salinity Lens that trees can use as a water source during prolonged inter-flood dry periods and maintain good condition. At the localised scale, maintaining/improving areas with lower salinity lens, where groundwater salinity is not ideal, but still provides a water source that can be used by trees during short inter-flood dry periods without incurring rapid loss of tree condition (see Table 8.5 in section 8.6 for salinity values) as occurs in areas with higher groundwater salinity, may be expected to be beneficial (see conceptual model in Wallace *et al.* 2024). Further research to improve understanding of realistic expectations of the positive and negative impacts of managed delivery of environmental water on groundwater conditions both inside, and outside of lower salinity lenses is required.
Complementary actions	Expansion/refinement of monitoring well network.

Soil Condition – soil water potential		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	Throughout the length of the Channel asset (i.e. SA border to Wellington), establish and maintain groundwater and soil moisture conditions conducive to improving riparian vegetation	Establish soil conditions conducive to maintaining diverse native vegetation across the Floodplain PEA
SME workshop derived objective	Establish soil conditions conducive to supporting diverse ecologically functional native vegetation	
Recommended Update to Objective	Adopt SME derived objective	
Rationale	Recommended change retains intent of original objective. Separation of groundwater and soil recognises that each component requires specific attention and receives different approaches to monitoring.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	Maintain soil water availability, measured as soil water potential > -1.5 MPa at soil depth 20–50 cm, to sustain recruitment of long-lived vegetation across the elevation gradient in the target zone.	Maintain soil water availability, measured as soil water potential at soil depth 20-50cm, greater than -1.5 MPa in order to sustain the recruitment of long-lived vegetation.
SME workshop derived targets	(SC1) [SOIL_1]: In River Red Gum woodlands, at least one depth interval between 0.2 m and the water table has soil water potential ≥ -1.0 MPa	
	(SC2) [SOIL_2]: In Black Box woodlands, at least one depth interval between 0.2 m and the water table has soil water potential ≥ -2.0 MPa	
	(SC3) [SOIL_3]: In lignum shrublands, at least one depth interval between 0.2 m and the water table has soil water potential ≥ -2.0 MPa	
	(SC4a) Soil water potential at 0.2-0.5 m depth is ≥ -1.0 MPa for at least 120 days post inundation to support plant establishment and growth at least once every 2 years (Channel PEA)	
	(SC4b) Soil water potential at 0.2-0.5 m depth is ≥ -1.0 MPa for at least 120 days post inundation to support plant establishment and growth at least once every 5 years (Floodplain PEA)	
Recommended Update to targets	Adopt (SC1), (SC2) and (SC3)	
	(SC4a) and (SC4b) are not recommended for inclusion at this time	
Rationale	Targets (SC4a) and (SC4b) are related to for supporting plant establishment and growth. Based on review of existing data sets collected following the 2022-23 flood (e.g. Wallace 2024a), it is highly unlikely that the 120 day duration is achievable across most of the floodplain, and hence may not be appropriate. Recommend this target is withheld until further research is undertaken. It is	

	assumed that if targets (SC1-3) are met, that the conditions in these additional targets (SC4a and SC4b) would also be met. Wording changed from “soil water availability” to “soil water potential” to use correct terminology. Soil water potential is a measurement of the biological availability of water held within the unsaturated zone. Values for soil water potential include matric potential (suction due to attraction of water by the soil matrix), osmotic potential due to energy effects of solutes (e.g. salt) in water and the pressure potential (typically zero in unsaturated soils) (Wallace 2023c). Existing data sets from Chowilla, Pike and Katarapko demonstrates that the original recruitment focused target is not achievable, as soil water potential within the 20-50 cm depth interval is only maintained in the target range for a short period (weeks-months) during the drying phase due to evaporative processes (e.g. Wallace 2023c). Focus has been shifted to maintaining at least one depth interval with biologically available water to support maintenance of good condition as it is recognised soil conditions are not conducive to active growth of long-lived vegetation during extended dry periods. Soil water potential metrics are based on regional research and multi-year monitoring programs at Chowilla, Pike and Katarapko floodplains.
Existing data	Yes. There is a quasi-annual monitoring program at each of the major floodplains. Data from locations outside of these areas is limited.
Key use of targets	Delivery of environmental water has potential to emplace low salinity water into the soil profile, and flush salt either out of, or deeper into the soil profile (Wallace *et al.* 2024). Emplacing sufficient low salinity water into the unsaturated zone to support active growth of vegetation is a core objective of environmental flows. However, soil salinity may remain high, and soil water availability may remain low in areas where (i) inundation does not occur, or (ii) where inundation is only partially effective in improving soil conditions. Measurement of soil water potential is used as (i) a predictive tool for prioritising delivery of environmental water and (ii) a diagnostic tool to investigate why expected outcomes are not achieved. Data can be used to determine if follow-up delivery of environmental water is required due to ongoing low soil water potential, or if soil water potential is adequate and trees need more time to actively grow and recover. Physiological/ morphological water stress is substantially more likely if stated metrics are not met.
Further development	Undertake research to determine duration post flooding that high soil water potential conditions are required to support plant establishment. Current sampling programs provide quasi-annual sampling with limited sampling undertaken at higher frequencies. Additional research on the rate of decline of soil water potential post inundation is required to improve understanding of inundation return intervals required to (i) achieve post-drought recovery via active growth of long-lived vegetation and (ii) maintenance of good condition.
Complementary actions	N/A

Soil Condition – soil salinity		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	Throughout the length of the Channel asset (i.e. SA border to Wellington), establish and maintain groundwater and soil moisture conditions conducive to improving riparian vegetation (Channel PEA)	Establish soil conditions conducive to maintaining diverse native vegetation across the Floodplain PEA
SME workshop derived objective	Establish soil conditions conducive to supporting diverse ecologically functional native vegetation	
Recommended Update to Objective	Adopt SME derived objective	
Rationale	Recommended change retains intent of original objective. Separation of groundwater and soil recognises that each component requires specific attention and receives different approaches to monitoring.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	Reduce soil salinity (measured as EC 1:5) to <5000 µS/cm to prevent shifts in understorey plant communities to salt-tolerant functional groups across the elevation gradient in the target zone.	Reduce soil salinity (EC 1:5) to below 5,000 µS/cm to prevent permanent shifts in understorey plant communities to salt tolerant functional groups.
SME workshop derived targets	(SC5) [SOIL_4] Soil salinity (EC 1:5) is <2,700 µScm^{-1} (extremely saline) in the 0.2-0.5 m depth interval	
	(SC6a) [SOIL_5] Soil salinity (EC 1:5) is <1,300 µScm^{-1} (non-moderately saline) in the 0.2-0.5 m depth interval at least once every 2 years in the Channel PEA	
	(SC6b) [SOIL_6] Soil salinity (EC 1:5) is <1,300 µScm^{-1} (non-moderately saline) in the 0.2-0.5 m depth interval at least once every 5 years in the Floodplain PEA	
Recommended Update to targets	Recommend adoption of SME workshop derived targets.	
	In targets (SC6a and SCb), the term "non-moderately saline" denotes salinity between non-saline and (<300 µScm^{-1}) and moderately saline (0.7-1.3 µScm^{-1}) (classification per http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/water_spotting_soil_salting#sc). For the sake of simplicity the text (non-moderately saline) could be removed.	
Rationale	Existing data sets from Chowilla, Pike and Katarapko demonstrate that the metric stated in the 2020 LTWP (<5000 µS/cm) was set too high i.e. it was not reached in wetland areas with shallow depth to saline groundwater with a vegetation community dominated by salt tolerant vegetation. The threshold had subsequently been lowered to 3,000 µS/cm for other site-specific monitoring/management plans within the lower Murray River. Noting the lack of data on salinity tolerances of floodplain understory vegetation, it is recommended that the target is lowered to <2,700 µScm^{-1} to be consistent with classification threshold of " extremely saline" used in the existing soil monitoring	

	programs at Chowilla, Pike and Katarapko (e.g. Wallace 2022). However, it must be noted that the classification of 2,700 μScm^{-1} as "extremely saline" is derived from agricultural literature, which may not equate to "extremely saline" for floodplains in the lower Murray system. Target (SC5) seeks to ensure that soil salinity within the shallow unsaturated zone does not become extremely saline and exceed the tolerance of most flood dependent and amphibious plant species. Lower soil salinities (e.g. <1.300 μScm^{-1}) may be periodically required to facilitate establishment and growth of plant species that prefer non-saline to low-saline conditions. Preliminary targets (SC6a) and (SC6b) were developed with this in mind. However, as per the "extremely saline" metric, the lower salinity metric (<1.300 μScm^{-1}) may need to be investigated further to define values that are specific to floodplains in the lower Murray.
Existing data	Yes. There is a quasi-annual monitoring program at each of the major floodplains that reports on this metric. Data from locations outside of these areas is limited but could be collected.
Key use of targets	Capillary rise draws groundwater, and the dissolved salts contained in the groundwater, from the top of the water table (the saturated zone) into the unsaturated zone. When the capillary fringe extends to the surface, vaporization and salt crusting occurs at the soil surface. Where the capillary fringe does not extend to the surface, but overlaps the evaporation depth, direct evaporative flux through the unsaturated zone can cause salt to be left behind and accumulate towards/at the top of the capillary fringe leading to soil salinisation (Shokri-Kuehni *et al.* 2020). The data sets from the soil monitoring programs at the three major floodplains (Chowilla, Pike and Katarapko) show examples of strong salinity spikes at 1.0-1.5 m, and some cases precipitation of salts into crystalline forms is evident within soil pores indicating that salt concentrations have exceeded the solubility limit (Wallace *et al.* 2024). Emplacing sufficient low salinity water into the unsaturated zone to reduce/offset salt accumulated in the unsaturated zone is a core objective of environmental flows. Existing data suggests (i) that some sites experience very marked reductions in soil salinity, whilst others have modest or no reduction, and (ii) decreased depth to groundwater can functionally increase soil salinity due to presence of saline groundwater in the soil pores. Salt may be more likely to be moved down the profile into the saturated zone as the wetting front moves down the profile with vertical infiltration than exported out of the soil profile (e.g. Wallace 2022).
Further development	Annual reporting (e.g. Wallace 2022) has identified a discrepancy between metric used to define soil as "extremely saline (2,700 µS/cm) and the stated target metric which is derived from agricultural based literature and may be too low for River Murray floodplain settings. Further investigation is required to improve certainty on salinity thresholds relevant to floodplain understory vegetation. Metric may need to be adjusted when data on salinity tolerances of floodplain understory vegetation becomes available. The recommended targets are specifically related to supporting understory vegetation and survival/establishment of germinants of floodplain trees. They are not related more broadly to soil salinity values in the deeper parts of the profile.

	Development of additional targets that have a focus on the deeper parts of the soil profile should be a priority.
Complementary actions	N/A

Soil Condition – soil organic carbon		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	Throughout the length of the Channel asset (i.e. SA border to Wellington), establish and maintain groundwater and soil moisture conditions conducive to improving riparian vegetation.	Establish soil conditions conducive to maintaining diverse native vegetation across the Floodplain PEA
SME workshop derived objective	Establish soil conditions conducive to supporting diverse ecologically functional native vegetation	
Recommended Update to Objective	Adopt SME derived objective	
Rationale	Same objective utilised for soil water potential, soil salinity and soil organic carbon.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	N/A	N/A
SME workshop derived targets	(SC7) Soil total organic carbon % (TOC) in the 0.0-0.2 depth interval is ≥ 0.7 in grassland/shrubland areas	
	(SC8) Soil total organic carbon % (TOC) in the 0.0-0.2 depth interval is ≥ 1.5 in River Red Gum woodlands	
	(SC9) Soil total organic carbon % (TOC) in the 0.0-0.2 depth interval is ≥ 0.6 in Black Box woodlands	
Recommended Update to targets	No target recommended. Recommend further investigation of floodplain soil specific metrics prior to adoption of SME workshop derived targets.	
Rationale	No target for soil organic carbon was provided in the 2015 or 2020 version of the LTWP. Soil organic carbon should be considered for inclusion, as soil organic carbon is widely regarded a key indicator of soil health, and increasing soil organic carbon is typically considered a Key Performance Indicator of soil remediation and Climate Change mitigation projects. Areas supporting structurally diverse vegetation including woody plants should have comparatively high values of soil organic carbon. Outcome is a "downstream" cascade effect. If vegetation targets are met it is probable that soil organic carbon metric is met. SME derived metrics are based on existing agriculture/forestry literature. Targeted investigation of metrics that are relevant to floodplain vegetation communities is recommended. Once resolved, this target can replace the 2020 target for soil sodicity.	
Existing data	No, but data could be generated by adding TOC analysis to soil samples already collected via existing soil condition monitoring programs.	
Key use of targets	Provides an indication of the influence of achieving target metrics for long lived vegetation (trees and lignum) and understory on soil health.	

Further development	Total Organic Carbon (TOC) metrics that are specific to floodplain vegetation communities (red gum, black box, grassland and lignum shrubland areas) need to be developed.
Complementary actions	N/A

Soil Condition – soil sodicity		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	Throughout the length of the Channel asset (i.e. SA border to Wellington), establish and maintain groundwater and soil moisture conditions conducive to improving riparian vegetation.	Establish soil conditions conducive to maintaining diverse native vegetation across the Floodplain PEA
SME workshop derived objective	Establish soil conditions conducive to supporting diverse ecologically functional native vegetation	
Recommended Update to Objective	Adopt SME derived objective	
Rationale	Same objective utilised for soil water potential, soil salinity and soil organic carbon.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	N/A	Maintain soil sodicity below the exchangeable sodium percent (ESP) value of 15 (highly sodic)
Recommended Update to targets	No target recommended	
Rationale	Target not to be continued. Metric unlikely to respond positively to inundation. SME had suggested that soils may have been sodic prior to river regulation. Achieving a positive trajectory is highly likely to require site based management actions.	
Existing data	Limited data from Pike floodplain (Wallace and Rengasamy 2011)	
Key use of targets	N/A	
Further development	N/A	
Complementary actions	N/A	

Woodland dependent fauna – Reptiles and mammals		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	N/A	Provide habitat conducive to supporting communities of native woodland birds, reptiles and mammals across the Floodplain PEA
SME workshop derived objective	Restore resilient populations of native semi-aquatic and terrestrial reptiles and mammals	
Recommended Update to Objective	Restore resilient populations of native semi-aquatic and terrestrial reptiles, mammals and birds	
Rationale	Terrestrial birds added to SME derived objective. Focus of original objective was to provide habitat for fauna (which is one of the overarching objectives of ecosystem management) with a "build it and they will come" assumption. Assessing habitat occupation by fauna that are primarily dependent on, or intensively utilises riparian/floodplain habitat provides a direct measure of success, and therefore should be considered for inclusion.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	N/A	Each of the reptile species known to utilise similar floodplain/woodland habitats in the region will be recorded at 50% sites across the Floodplain PEA in any three-year period.
		Each of the native mammal species known to utilise similar floodplain/woodland habitats in the region will be recorded at 50% sites across the Floodplain PEA in any three year period.
SME workshop derived targets	(OF1) [WDFN_3] Each of the terrestrial reptile species that routinely use the littoral and/or floodplain zones for foraging and/or nesting are recorded across ≥50% of sites within their known distribution at least once every two years	
	(OF2) [WDFN_4] Each of the terrestrial mammal species that routinely use the littoral and/or floodplain zones for foraging and/or nesting are recorded across ≥50% of sites within their known distribution at least once every two years	
	(OF3) Each of the 14 bat species known to occur within the asset will be detected across ≥ 75% of sites within their known distribution at least once every two years	
Recommended Update to targets	Adopt (OF1) with minor changes: Each of the terrestrial reptile species that use the littoral and/or floodplain zones are recorded across ≥50% of sites within their known distribution at least once every two years	
	Adopt (OF2) with minor changes: Each of the terrestrial mammal species that use the littoral and/or floodplain zones for are recorded across ≥50% of sites within their known distribution at least once every two years	

	Adopt (OF3) with an increased metric: Each of the 15 bat species known to occur within the asset will be detected across ≥ 75% of sites within their known distribution at least once every two years.
Rationale	Increase in metric for (OF3) based on post workshop advice from SME. Where habitat is considered to be in poor condition, and species abundance is shown to be, or reasonably assumed to be, below carrying capacity, positive changes in occupancy of those habitats should reflect successful restoration of habitat via provision of environmental water.
Existing data	Beyond limited site-based data there is no routine monitoring for these targets.
Key use of targets	Reptiles, Mammals and Bats represent high value targets, achievement of which would indicate that environmental water delivery has been successful at attaining the broad overarching objective. Because the stated outcome is a downstream cascade effect, positive changes in species diversity should reflect successful restoration of habitat.
Further development	N/A
Complementary actions	Pest/predator control may be important.

Woodland dependent fauna – Woodland birds		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	N/A	Provide habitat conducive to supporting communities of native woodland birds, reptiles and mammals across the Floodplain PEA
SME workshop derived objective	Restore resilient populations of terrestrial birds	
Recommended Update to Objective	Restore resilient populations of native semi-aquatic and terrestrial reptiles, mammals and birds	
Rationale	The SME derived objective was merged with objective for reptiles and mammals. No objective or targets were provided for the Channel PEA in the 2020 versions of the LTWP. Areas inundated by, or adjacent to areas inundated by flows of ≤40,000 $MLday^{-1}$ provide important habitat that supports woodland birds. Focus of original objective was to provide habitat for fauna (which is one of the overarching objectives of ecosystem management) with a "build it and they will come" assumption. Assessing habitat occupation by fauna that are primarily dependent on, or intensively utilises riparian/floodplain habitat provides a direct measure of success, and therefore should be considered for inclusion.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	N/A	Each of the native bird species known to utilise similar floodplain/woodland habitats in the region will be recorded at 50% sites across the Floodplain PEA in any three-year period.
SME workshop derived targets	(TB1) Annual diversity of terrestrial bird species in woodland and shrubland habitats is maintained at ≥70 species	
	(TB2) Diversity of bird species in woodlands is maintained at ≥105 species over a rolling four-year period	
Recommended Update to targets	[WDFN_1] Across all sites, independent of habitat type, terrestrial bird species richness measured across all four seasons within one year, is maintained at or above 78 species	
	[WDFN_2] Across all sites, independent of habitat type, terrestrial bird species richness measured over a rolling four-year period, is maintained at or above 110 species	
Rationale	Change in metrics between SME workshop derived targets (TB1), (TB2) and the recommended targets presented here are based on post-workshop conversations and review of regionally relevant data sets with DEW SME. The metric for [WDFN_1] includes 63 species that would be expected every year on the floodplain in the Murray Valley, six common species of raptor, eight native species that are commonly observed on, but not tightly associated with floodplains and one introduced species from a list of seven that are widespread but not associated with floodplains. The metric for [WDFN_2] includes the core species expected annually, the incidence of encountering the odd nocturnal	

	species, the odd cryptic/rare species, a range (15) of inland nomadic species that are expected to be attracted to the floodplain under good conditions, a range of mallee/terrace species that are expected to be attracted to the floodplain under good conditions (10), and a higher diversity of raptors. The term woodland birds could be replaced with terrestrial birds. Surveys incorporate woodlands, grassland and shrubland areas. Surveys are to be undertaken at sites that include a representative mix of habitats including red gum and black box woodland habitats. Diversity is measured via pooled observations made across 4 seasons within a year, with reference to a regionally specific list of bird species classed as "terrestrial" birds.
Existing data	Yes. Surveys routinely undertaken at managed floodplains.
Key use of targets	Woodland birds represent high value targets, achievement of which would indicate that environmental water delivery has been successful at attaining the broad overarching objective. Because the stated outcome is a downstream cascade effect, positive changes in species diversity should reflect successful restoration of habitat.
Further development	The possibility of using positive and negative indicator species to assess change in habitat function was discussed based on data from Chowilla. However, there was considerable uncertainty of the application of those indicator species at other sites. Subsequently the indicator species concept was considered a hypothesis that could be tested at the site scale.
Complementary actions	N/A

Wetland dependent fauna – Waterbirds		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	N/A	Create conditions conducive to successful, small scale breeding events for waterbirds across the Floodplain PEA
		Provide refuge for the maintenance of adult populations of waterbirds across the Floodplain PEA
SME workshop derived objective	Restore resilient populations of waterbirds	
Recommended Update to Objective	Restore resilient populations of waterbirds, frogs and turtles	
Rationale	Proposed objective merges multiple biotic groups. No objective or targets were provided for the Channel PEA in the 2015/20 versions of the LTWP. Areas inundated by, or adjacent to areas inundated by flows of ≤40,000 $MLday^{-1}$ provide important habitat that supports waterbirds. Focus of original objective was to provide habitat for fauna (which is one of the overarching objectives of ecosystem management) with a "build it and they will come" assumption. Assessing habitat occupation by fauna that are primarily dependent on, or intensively utilises riparian/floodplain habitat provides a direct measure of success, and therefore should be considered for inclusion.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	N/A	Minimum inundation periods required for successful breeding by a range of water bird species are provided. Preliminary minimum 120 days
		During continental dry periods an increase in the observed to expected ratio of waterbird species
SME workshop derived targets	(WB1) [WBRD_1]: Increase the spatial extent of productive foraging zones (inundated mud flats, shallow water) by 50% above that occurring under entitlement flow and normal weir pool conditions to support adult waterbirds and survival of juveniles/sub-adults, during spring-summer for ≥30 days	
	(WB2) Detection of successful breeding by large wading waterbirds at least 3 years in 10 with a maximum return interval of 5 years	
	(WB3): Annual diversity of waterbird species is maintained at ≥ 55 species	
	(WB4) [WBRD_4]: Over a three-year period, species richness is maintained at ≥ 60 species, and includes small-bodied migratory waders	
Recommended Update to targets	Adopt SME workshop derived target (WB1)	
	Replace (WB2) with refined version of target developed post-workshop with DEW SME: [WBRD_2]: Maintain the water depth and duration of inundation of	

	emergent vegetation required to support waterbird breeding through to completion (egg laying, fledging and post fledging care) at least 3 years in 10 with a maximum return interval of 5 years.
	Adopt (WB3 and WB4) with minor changes: Annual species richness of waterbirds is maintained at ≥ 55 species
	Adopt SME workshop derived target (WB4)
Rationale	The focus of the breeding target is on large wading birds as a functional group that is particularly sensitive to the hydrology of the lower Murray and have specific breeding habitat requirements such as inundated lignum basins, rush/reed beds or stands of riparian trees overhanging water as well as shallow inundated emergent vegetation in which to forage. An expected species list has been developed and is provided in the appendices.
Existing data	Yes, waterbird surveys are routinely undertaken at a wide range of sites throughout the lower Murray
Key use of targets	Targeting outcomes for waterbirds is a commonly utilised and celebrated justification for use of environmental water within the lower Murray that facilitates other outcomes.
Further development	Agreed maps documenting productive foraging zones required.
Complementary actions	N/A

<table>
<tr><th colspan="3">Wetland dependent fauna – Frogs</th></tr>
<tr><th>Ecological objectives</th><th>Channel PEA</th><th>Floodplain PEA</th></tr>
<tr><td>Existing SA River Murray LTWP 2020 Objective</td><td>N/A</td><td>Provide habitat conducive to supporting diverse communities of riparian frogs within the Floodplain PEA</td></tr>
<tr><td>SME workshop derived objective</td><td colspan="2">Restore resilient populations of frogs</td></tr>
<tr><td>Recommended Update to Objective</td><td colspan="2">Restore resilient populations of waterbirds, frogs and turtles</td></tr>
<tr><td>Rationale</td><td colspan="2">Proposed objective merges multiple biotic groups. The 2020 LTWP did not provide an objective for the Channel PEA despite frogs utilising habitat within the PEA. Objective focus is shifted from providing functional habitat (which is one of the overarching objectives of ecosystem management) to focus on presence of those frog species that are reliant on aquatic habitat, and based on historical records would reasonably be expected to be present. Where species abundance is shown to be, or reasonably assumed to be, below carrying capacity, positive changes in occupancy and successful breeding effort of those habitats should reflect successful provision/restoration of functional habitat.</td></tr>
<tr><th>Ecological targets</th><th>Channel PEA</th><th>Floodplain PEA</th></tr>
<tr><td rowspan="2">Existing SA River Murray LTWP 2020 Targets</td><td rowspan="2">N/A</td><td>Each of 8 riparian frog species present within the Floodplain PEA will be recorded across the floodplain in any three-year period.</td></tr>
<tr><td>Tadpoles will be recorded from 8 species in later stages of metamorphosis across the Floodplain PEA in any three-year period.</td></tr>
<tr><td rowspan="4">SME workshop derived targets</td><td colspan="2">(FR1) [FROG_1]: Each of the 10 frog species known to occur within the asset will be detected at least once every two years at 75% of surveyed sites within their known distribution within the channel PEA</td></tr>
<tr><td colspan="2">(FR2) [FROG_2]: Each of the 10 frog species known to occur within the asset will be detected at least once every two years at 60% of surveyed sites within their known distribution within the floodplain PEA</td></tr>
<tr><td colspan="2">(FR3) [FROG_3]: Tadpoles from all 10 frog species will be recorded in later stages of metamorphosis 3 years in 10 with a maximum 3 year return interval</td></tr>
<tr><td colspan="2">(FR4) [FROG_4]: Maintain the existing distribution of the nationally listed Southern Bell Frog (Litoria raniformis) as evidenced by detection of adults 3 years in 5 within their known distribution</td></tr>
<tr><td rowspan="2">Recommended Update to targets</td><td colspan="2">Adopt SME workshop derived targets (FR1), (FR2) and (FR4)</td></tr>
<tr><td colspan="2">Adopt (FR3) with minor change: Tadpoles from each of the 10 frog species known to occur within the asset will be recorded in later stages of</td></tr>
</table>

	metamorphosis (Gosner stage >36), 3 years in 10 with a maximum 3 year return interval.
Rationale	Surveys are only conducted when wetlands hold water, hence the number of sites varies widely between years. Different metrics are provided for Channel [FROG_1] and Floodplain PEA [FROG_2] as there is a perception that (i) the Channel PEA should function as core habitat that supports frog populations during dry periods, and (ii) occupation of temporary wetlands across the Floodplain PEA is likely to be highly dependent on timing of filling, connectivity and development of appropriate habitat and food resources, which may not always occur within wetlands with a history of supporting frog populations. Furthermore, likelihood of detection is strongly influenced by magnitude of survey effort. Advice from SME (RM, 3rd November 2023) was that setting of # of species, percentage of sites and return intervals for [FROG1] and [FROG2] are educated hypotheses and, there are insufficient data to derive establish a more robust targets at this time. Southern Bell Frog are a threatened species with different breeding requirements to the other frog species. Advice from SME is that the core habitat for Southern Bell Frog occurs primarily in areas inundated at flows above >40,000 ML/day.
Existing data	Yes, frog surveys are routinely undertaken at a wide range of sites. Tadpole surveys infrequent.
Key use of targets	Targeting outcomes for frogs, and specifically Southern Bell Frog is a commonly utilised and celebrated justification for use of environmental water within the lower Murray that facilitates other outcomes.
Further development	N/A
Complementary actions	N/A

Wetland dependent fauna – Freshwater turtles		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	N/A	Provide habitat conducive to supporting communities of native woodland birds, reptiles and mammals across the Floodplain PEA
SME workshop derived objective	Restore resilient populations of native semi-aquatic and terrestrial reptiles and mammals.	
Recommended Update to Objective	Restore resilient populations of waterbirds, frogs and turtles	
Rationale	Proposed objective merges multiple biotic groups. Turtles should be considered for inclusion. This incorporates the three species; eastern long neck (*Chelodina longicollis*), Murray short neck (*Emydura macquarii*) and broad-shell (*Chelodina expansa*). It is generally recognised that the long-term trend is a substantial decline in populations, and broad-shell and Murray short neck are listed as vulnerable within South Australia.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	N/A	N/A
SME workshop derived targets	(TU1) Population age structure of turtles indicates an effective recruitment event 1 year in 5 (max 7 years), demonstrated by separate cohorts of juveniles/sub-adults and adults of each species	
	(TU2) Abundance (measured as CPUE) of juvenile/sub-adult turtles of each species exhibits a positive trajectory and increases by ≥30% over a 5-year period	
	(TU3) Abundance (measured as CPUE) of adult turtles of each species exhibits a positive trajectory and increases by ≥30% over a 10-year period	
	(TU4) All three species are recorded annually in 90% of sampling sites within permanent mesohabitats along length of PEA	
	(TU5) Long neck turtles are recorded annually in 90% of sampling sites within inundated temporary wetlands along the length of the PEA	
Recommended Update to targets	Adopt SME derived targets as high value targets that are dependent on the provision of appropriate aquatic habitat.	
Rationale	Whist considered to represent a high value target, the ability to achieve the desired outcomes specified in the SME workshop derived targets appears to be heavily dependent on non-flow rated ecological processes and anthropolgical stressors. Advice from SME (Dr James Van Dyke 30th November 2023) is that population response is not likely to be driven by flow; fox predation and other currently unknown habitat requirements that support juveniles are most likely to be the key bottle necks limiting population growth. Suggested that it may take 4-5 years post flood to see outcomes as it is unclear if 1-2 year olds are not present, or simply difficult to detect. Consequently, the relationship between flow and population abundance is not well established.	

Existing data	Limited available data to enable reporting. No routine monitoring.
Key use of targets	N/A
Further development	It is currently unknown if there is a relationship between flow and turtle survival, recruitment, or abundance, due to a lack of data. A minimum effort of turtle monitoring and detection (represented by TU4 and TU4) would contribute to establishing baseline data needed to be able to, in future, assess and achieve targets like TU1-TU3.
Complementary actions	Reduction of nest predation pressure by foxes

Ecosystem processes - Biofilms		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	Promote bacterial rather than algal dominance of biofilms and improve food resource quality for consumers	N/A
SME workshop derived objective	Not to be continued	
Recommended Update to Objective	Not to be continued	
Rationale	Not to be continued. Regionally specific research projects (e.g. Wallace and Fulton 2018; Wallace 2021) demonstrate that the conceptual model(s) underpinning these Ecological Targets are not supported by empirical data. There is substantial lack of certainty around ecological relevance of detectable changes.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	N/A	N/A
Recommended Update to targets	Not to be continued	
Rationale	See comments related to objective.	
Existing data	Limited research project based data. No routine monitoring projects	
Key use of targets	N/A	
Further development	N/A	
Complementary actions	N/A	

Ecosystem processes – Open water productivity		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	Provide for the mobilisation of carbon and nutrients from the floodplain to the river to reduce the reliance of in-stream foodwebs on autochthonous productivity	N/A
SME workshop derived objective	Restore lateral and longitudinal connectivity to support basal and secondary productivity, and flow dependent processes	
Recommended Update to Objective	Adopt SME derived objective	
Rationale	Intent of objective is retained, but revision provides improved clarity of expected responses.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	Open-water productivity shows a temporary shift from near zero or autotrophic dominance (positive Net Daily Metabolism) towards heterotrophy (negative Net Daily Metabolism) when QSA >30,000 ML/day	N/A
Recommended Update to targets	Not to be continued	
Rationale	Review of data and methodology (Wallace *et al.* 2023) identified several critical limitations with the practical application of the methodology used to generate values of gross primary productivity (GPP) and ecosystem respiration (ER) in the lower Murray and lack of certainty around magnitude of change in rates of metabolism required to be ecologically meaningful. Objective consolidated within lateral and longitudinal connectivity.	
Existing data	Yes. Extensive raw data set (15-minute intervals of dissolved oxygen) from multiple river and anabranch sites is available. Review of BASE methodology and GPP and ER data (Wallace et al. 2023) identified several critical limitations with the practical application of methodology in the lower Murray.	
Key use of targets	N/A	
Further development	If future research identifies a modelling methodology that is appropriate for the lower Murray, target could be reinstated.	
Complementary actions	N/A	

Lateral and longitudinal connectivity - river channel-wetland connectivity		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	Maintain habitats and provide for dispersal of organic and inorganic material and organisms between river and wetland	N/A
SME workshop derived objective	Restore lateral and longitudinal connectivity to support recruitment and secondary productivity	
Recommended Update to Objective	Restore lateral and longitudinal connectivity to support basal and secondary productivity, and flow dependent processes including salt export	
Rationale	Intent of objective is retained, but revision provides improved clarity of expected responses.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	Inundation periods in temporary wetlands have unrestricted lateral connectivity between the river and wetlands in >90% of inundation events.	N/A
SME workshop derived targets	(HC3) ≥75% of ephemeral wetland area is inundated with lateral connectivity to the river/creek for a minimum of 20 continuous days at least once every 3 years in order to restore functional role of native fish recruitment zones and sources of secondary productivity	
Recommended Update to targets	[CONN_10] Adopt with minor change; ≥75% of ephemeral wetland area is inundated with lateral connectivity to the river/creek for a minimum of 20 continuous days at least once every 3 years.	
Rationale	Target focus is to restore functional role of native fish recruitment zones and sources of secondary productivity. Ability to meet the target is strongly influenced by site-based wetland management decisions combined with river water levels and planned/delivered hydrographs.	
Existing data	There is dispersed data on status of wetland structures (open/closed) and commence to flow levels.	
Key use of targets	N/A	
Further development	Agreed mapping of wetland area may need to be improved in order to report on this target.	
Complementary actions	N/A	

Lateral and longitudinal connectivity – basal food resources		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	N/A	Provide for the mobilisation of carbon, nutrients and propagules from the floodplain to the river
SME workshop derived objective	Enable two-way exchange of carbon and nutrients between the river and the floodplain to fuel primary and secondary productivity	
Recommended Update to Objective	Restore lateral and longitudinal connectivity to support basal and secondary productivity, and flow dependent processes including salt export	
Rationale	Recommended change to wording of objective consolidates a number of objectives that respond to the same fundamental driver i.e. restoration of lateral and longitudinal connectivity. Despite being referred to in the objective, no target for nutrients was presented in the 2020 version of the LTWP. Revision retains original intent but allows for independent targets for (i) invertebrates and (ii) carbon and nutrients.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	N/A	During inundation periods, record an increase in the abundance and diversity of invertebrate food resources, nutrients and DOC relative to those available during base flow
SME workshop derived targets	(BR1) Percentage of labile dissolved organic carbon (DOC) increases by ≥30% above baseline values for at least 30 days during late spring/early summer	
	(WQ4) Within the main channel and connected anabranch creeks, dissolved organic carbon (DOC), Total Phosphorus (TP), Filterable Reactive Phosphorus (FRP), Total Kjeldahl Nitrogen, Nitrate and Nitrite (NOx), Total Nitrogen (TN), Ammonia, metals and metalloids remain within ANZECC guidelines (Australian and New Zealand Environment and Conservation Council and Agriculture and Management Council of Australia and New Zealand, 2000)	
Recommended Update to targets	[CONN_1]: Dissolved organic carbon concentration increases from baseflow values (3-4 mgL^{-1}) to ≥6 mgL^{-1} during the rising limb of hydrographs.	
Rationale	The 2020 target grouped invertebrates, nutrients and DOC. They should be spilt to clarify that there is separate monitoring and reporting requirements for these attributes. Therefore there should be separate reportable targets i.e. (i) invertebrate food resources, and (ii) nutrients and DOC. The SME workshop derived target for Dissolved Organic Carbon (BR1) did not provide a benchmark/reference value. Concentrations of DOC during flows <10,000 $MLday^{-1}$ is typically 3-4 mg/L. In terms of fuelling productivity, a modest increase in the percentage of labile organic carbon within a small change in DOC concentration, may be substantially more important than a large increase in DOC that is primarily recalcitrant. DOC values above 10 mg^{L-1} are problematic for potable water treatment but are not necessarily problematic from an ecological perspective, noting that an excessive increase in labile DOC may overwhelm the assimilative capacity of the river and result in a rapid and problematic decline in	

	dissolved oxygen. Hence a target of ≥6 mgL^{-1} is presented. The largest increase in DOC is expected during the rising limb of hydrograph as areas containing riparian litter load are inundated. The recommended target [CONN_1] outlines the desired conditions, and has a line of sight to the thresholds of concern utilised in the Integrated Operations Strategy (IOS) (DEW 2021). Whilst SA Water routine sampling incorporates carbon, nutrients and phytoplankton, labile DOC is not routinely analysed. Therefore, an increase in DOC is suggested as a surrogate measurement for achieving the proposed objective. SME workshop derived target for nutrients (WQ4) proposed use of the ANZECC guidelines for water quality. ANZECC guidelines for water quality are aimed at risk management and hence their use is counterintuitive in a system in which a pulse of carbon and nutrients that support increased productivity is an expected and desirable outcome of environmental flows. It is recommended that this target not be included at this time. To date, there has been no analysis of what constitutes a desirable increase in the various forms of nitrogen and phosphorus.
Existing data	Yes, noting that labile DOC is not assessed. Responses to flow can be analysed using DOC as a surrogate via SA Water routine data + supplementary/investigative data sets.
Key use of targets	The DO-DOC model built into SOURCE allows for assessment of the potential impact of various operating scenarios on dissolved oxygen and DOC. Whilst an increase in DOC and nutrients is a desired outcome, it is important to be mindful of increases that create challenges for potable water treatment. The levels of concern used in the IOS are based on the likelihood that operations may drive an increase in total DOC in the main river channel above the 10 mg/L threshold. Therefore the low level of concern is identified as an increase of <2 mg/L within the River Murray channel as a result of operations. A high level of concern is where the increase is expected to result in DOC exceeding 10 mg/L. The metrics for raw water considered within the IOS are relevant to consumptive purposes. The IOS real time planning will have regard for the raw water targets outlined in the Protocol while operations are being undertaken. Managers will work in conjunction with relevant entities (e.g. SA Water and EPA) to manage those risks if there are concerns that targets may be exceeded.
Further development	N/A
Complementary actions	N/A

Lateral and longitudinal connectivity – invertebrate food resources		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	N/A	Provide for the mobilisation of carbon, nutrients and propagules from the floodplain to the river
SME workshop derived Objective	Facilitate invertebrate food resources that support recruitment of native biota and underpin ecosystem carrying capacity.	
Recommended Update to Objective	Restore lateral and longitudinal connectivity to support basal and secondary productivity, and flow dependent processes including salt export.	
Rationale	Recommended change to wording of objective consolidates a number of objectives that respond to the same fundamental driver i.e. restoration of lateral and longitudinal connectivity. Revision retains original intent but allows for independent targets for (i) invertebrates and (ii) carbon and nutrients. Intent is to facilitate invertebrate food resources that support recruitment of native biota and underpin ecosystem carrying capacity. Revision also recognises importance of slackwater habitats and retaining areas that are inundated at flows <40,000 $MLday^{-1}$	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	N/A	During inundation periods, record an increase in the abundance and diversity of invertebrate food resources, nutrients and DOC relative to those available during base flow.
SME workshop derived targets	(IV1) [CONN_2]: Mean microinvertebrate abundance in the main channel is ≥1,000 individuals/L during late spring/early summer	
	(IV2) [CONN_3]: Peak microinvertebrate abundance in the main channel is ≥2,000 individuals/L during late spring/early summer	
	(IV3) [CONN_4]: During late spring/early summer, at least 25% of the microinvertebrate assemblage in the main channel is comprised of individuals from the littoral functional groups (e.g. littoral rotifers, cyclopoid copepods and cladocerans)	
	(IV4) [CONN_5]: During late spring/early summer the density of cyclopoid copepods and cladocerans is 100–1000 individuals/L within 3 weeks of inundation of shedding and retaining habitats on the floodplain	
	(IV5) Abundance of medium (*Paratya australiensis, Caridina mccullochi and Macrobrachium australiense*) and large crustaceans (*Cherax destructor, Euastacus armatus*) remain stable or exhibit a positive trajectory over a 10-year period	
Recommended Update to targets	Adopt (IV1) through to (IV4).	
	(IV5) is not required	

Rationale	Microinvertebrate focus is on cyclopoid copepods and cladocerans as these functional groups are recognised as critical food resources for early life stages of native fish. Text added to improve clarity on where the samples are to be collected. Target (IV5) was proposed during the workshop process, but was subsequently withdrawn based on advice from Fish SME's that abundance of these crustaceans is not considered a recruitment bottleneck.
Existing data	Limited data from investigative research projects, not routinely monitored. A spreadsheet with the functional group classifications is presented in the appendices.
Key use of targets	Assesses achievement/failure of expected outcome from delivery of environmental water. May assist in understanding success/failure of expected native fish recruitment outcomes.
Further development	The current invertebrate targets do not have a focus on macroinvertebrates (e.g. insects with aquatic life stages) that may also be important components in the food web. These may be taken into account in future revisions of the LTWP
Complementary actions	N/A

Lateral and longitudinal connectivity – water column stratification		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	Maintain a diurnally-mixed water column to ensure diverse phytoplankton and avoid negative water quality outcomes	N/A
SME workshop derived objective	Enable two way exchange of carbon and nutrients between the river and the floodplain to fuel primary and secondary productivity.	
Recommended Update to Objective	Restore lateral and longitudinal connectivity to support basal and secondary productivity, and flow dependent processes including salt export.	
Rationale	Recommended change to wording of objective consolidates a number of objectives that respond to the same fundamental driver i.e. restoration of lateral and longitudinal connectivity. Avoidance of thermal stratification should be a fundamental basis of flow management, particularly when actions are being taken during periods of relatively low flow and warm weather. Sufficient vertical turbulence to maintain neutrally and negatively buoyant propagules in suspension and sustain downstream drift should also be a key consideration. Therefore focus of single issue objective incorporated into a broader objective that encapsulates the overarching principles.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	Thermal stratification does not persist for more than 5 days at any time	N/A
SME workshop derived targets	(BR2) Maintain diurnal mixing of the water column to facilitate a high nutritional value, diverse phytoplankton community and avoid deoxygenation of sediments.	
Recommended Update to targets	[CONN_6]: Maintain passing flows at the downstream side of the locks above 4,000 ML/day to ensure at least one mixing event per day	
	[CONN_7]: Maintain passing flows at the downstream side of the locks above 10,000 ML/day to provide sufficient turbulence intensity to support downstream drift	
Rationale	Recommended update of targets [CONN_6 and CONN_7]: fully encapsulates the intent of the SME workshop derived targets but provides metrics that can be used within Source modelling to determine ability to meet criteria during delivery of planned environmental flows. Metrics also provide benchmark value to assess likelihood of negative outcomes during any given event. Neutrally and negatively buoyant propagules require vertical turbulence to remain in suspension. A diverse phytoplankton community is taken to be characterised by a high proportion of non-motile species (species than cannot control their buoyancy e.g. planktonic diatoms). Persistent stratification can cause a transition from non–motile to buoyant phytoplankton species such as Anabaena spp. Baker et al., (2000) state that under the high turbulence conditions produced by flows >10,000 MLday^{-1} the diatom *Aulacoseira granulata* is favoured. Bormans and Webster (1997) developed a mixing criterion model that takes into account velocity, water depth, temperature, humidity, wind speed light attenuation and solar radiation, and used the model to demonstrate that	

	the critical discharge ($MLday^{-1}$) and velocity (ms^{-1}) that leads to a shift from mixed to stratified conditions at Lock 1 is 4,000 $MLday^{-1}$ (0.1 ms^{-1}) (Bormans and Webster 1997; Baker *et al.* 2000). Whilst lower flows may facilitate at least one mixing event per day (i.e. prevent stratification) under typical conditions during the summer months within the SA River Murray. However, periods of low wind speed will facilitate onset of temporary stratification. Current guidance to support weir pool manipulation (WPM) and managed floodplain operations in a manner that can be expected to maintain a low likelihood of onset of stratification in the main channel, is to operate with flows at the mixing point (return flows from the managed inundation zone to the river) that are conducive to at least one mixing event per day under almost all conditions. Based on the results of Baker et al., (2000) and Bormans and Webster (1997), this value has been identified as 4,000 $MLday^{-1}$ (Bormans and Webster 1997; Baker *et al.* 2000). Sediment anoxia may lead to the release of metals and nutrients, some of which are toxic to aquatic organisms. Water column anoxia increases the risk of release of sediment bound redox-sensitive compounds, and concentration ammonia, metals and metalloids could exceed ANZECC guidelines.
Existing data	Yes. Thermistor chain data is available from select sites. Data is currently available in real time from Water Connect.
Key use of targets	For the purpose of Integrated Operations annual planning, >4,000 ML/day is used to indicate a low level of concern as flows of this magnitude are conducive to at least one mixing event per day under almost all conditions. Discharges of <2,900 ML/day can be used as a high level of concern value, as flows below this threshold provide a lower level of confidence of being conducive to at least one mixing event per day. Field data from thermistor chains would verify that conditions predicted via existing numerical models are being met.
Further development	The modelling undertaken using the mixing criterion model (Bormans and Webster 1997; Walsh *et al.* 2019), was undertaken with an assumption that the respective weirs would be operated at normal pool level (NPL). No modelling was undertaken with the weirs raised. Furthermore, no consideration was given to locations where a substantial proportion of the river discharge may be diverted through an anabranch. This leads to the following knowledge gap; how does the discharge threshold that facilitates onset of stratification vary with (i) season, (ii) position in each weir pool (WP), and (ii) WPM? Whilst the use of discharge and velocity receive a lot of focus as metrics related to mixing energy, the key variable is turbulence intensity (a function of flow, wind and temperature fluctuations). The magnitude of turbulence required to mitigate growth of cyanobacteria is dependent on cell/colony morphology, as the rate of vertical movement (sinking or floating) is a function of the particle size and shape as well as the density difference (i.e. Stokes Law). This implies that preventing onset of persistent stratification by facilitating at least one mixing per day may be sufficient to prevent problematic blooms by maintaining diatoms in suspension, but may not be sufficient to preclude blooms of species that can control their buoyancy and rapidly traverse the vertical distance and utilise the higher levels of Photosythetically Active Radiation (PAR) available near the surface. Hence “turbulence intensity” may provide a better Ecological Target than “maintain a diurnally-mixed water column”.
Complementary actions	N/A

Lateral and longitudinal connectivity – hydraulic conditions		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	Provide diverse hydraulic conditions over the range of velocity classes in the lower third of weir pools so that habitat and processes for dispersal of organic and inorganic material between reaches are maintained	Provide diverse hydraulic conditions and complex habitat for flow dependent biota and processes Implement a seasonal and multi-year hydrograph that encompasses variation in discharge, velocity and water levels
SME workshop derived objective	Restore lateral and longitudinal connectivity to support recruitment and secondary productivity	
Recommended Update to Objective	Restore lateral and longitudinal connectivity to support basal and secondary productivity, and flow dependent processes including salt export	
Rationale	Recommended change to SME workshop derived wording of objective consolidates a number of objectives that respond to the same fundamental driver i.e. restoration of lateral and longitudinal connectivity. In 2020, a similar objective and target using different phrasing was provided for the Channel and Floodplain PEA's. Objective/targets for the separate PEA's can be merged whilst retaining intent and refining phrasing. Reinstatement of flowing habitat should be a core function of environmental flows, and contributes to maintaining a diurnally mixed water column; principle aligns with targets [CONN_5] and [CONN_7]). Velocity is modelled as cross-sectional average.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	Habitat across the range of velocity classes is present in the lower third of weir pools for at least 60 consecutive days in Sep–Mar, at a maximum interval of 2 years.	Deliver flows in a manner that reduces the proportion of slow flowing habitat and increases the proportion of moderate velocity habitat thereby reinstating a diversity of velocity classes representative of natural conditions Discharge, water level and duration metrics of planned e-water represent a seasonally variable hydrograph
SME workshop derived targets	(HC1) [CONN_8]: Maintain contiguous flowing habitat with velocity ≥0.2 ms^{-1} from the junction of the Murray and Darling Rivers to Wellington during late spring-early summer to facilitate downstream transport/dispersal of drift dependent biota (HC2) [CONN_9]: Maintain contiguous flowing habitat with velocity ≥0.3 ms^{-1} from the junction of the Murray and Darling Rivers to Wellington during late spring-early summer to restore high value hydraulic habitat	
Recommended Update to targets	Adopt SME derived targets	

Rationale	Stated conditions are anticipated to facilitate downstream transport/dispersal of drift dependent biota. Velocity is modelled as cross-sectional average. Proposed target incorporates intent of 2020 targets for the Floodplain PEA, but shifts focus to measurable outcome; 2020 targets are operational principles, the desired outcomes of which are now stated within the hydraulic target metrics.
Existing data	Yes. There is extensive numerical modelling on the ability of different discharge rates to achieve the stated metrics. Velocity can be derived from numerical modelling or targeted field measurements Daily hydrograph metrics (water level and flow) are routinely collected.
Key use of targets	Achieving stated metrics is considered a core pre-requisite to stimulate breeding activity in flow responsive fish species (i.e. golden perch), support downstream drift of neutrally buoyant propagules and reinstate high value hydraulic habitat preferentially selected by large-bodied fish.
Further development	N/A
Complementary actions	N/A

Lateral and longitudinal connectivity – Salt export		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	Ensure adequate flushing of salt from the Murray to the Southern Ocean	N/A
SME workshop derived objective	Promote salt export	
Recommended Update to Objective	Restore lateral and longitudinal connectivity to support basal and secondary productivity, and flow dependent processes including salt export	
Rationale	Facilitating salt export should be a core function of environmental flows. The 2020 objective and target, and the SME workshop derived objective has a functional linkage within the restated objective "restore…flow dependent processes"	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	Salt export, averaged over the preceding 3 years, is ≥2 million tonnes per year	N/A
SME workshop derived targets	(SE1) Promote salt export from the floodplain and connected habitats through the river to the Southern Ocean	
Recommended Update to targets	No SME derived target update recommended at this time. The existing target [CONN_11] can continue to be used as a reference point until further work on refining the target is undertaken – see Rationale section below	
Rationale	The 2020 Target was taken directly from the Basin Plan and is for salt export to the sea. There is no current target for export from the channel and floodplain PEA's i.e. from the upstream to the downstream border of the channel and floodplain PEA's. An alternative target (SE1) was drafted during the workshop process. Whilst facilitating salt export should be a core function of environmental flows, it is considered that as written, the SME workshop derived target is functionally an objective, not a target. In addition the proposed target is not specific to the Channel or Floodplain PEA, as it is strongly influenced by conditions within the Coorong, Lower Lakes and Murray Mouth PEA. This target has a functional linkage to the in-stream salinity targets [WATR_3] and [WATR_4] and soil salinity (SC5, SC6).	
Existing data	Yes. There is an existing salinity monitoring network. Model values for salt export could be determined if resources were made available to undertake the work.	
Key use of targets	N/A	
Further development	At this stage there is no pre-existing metric, but analysis of data could be undertaken to determine target metric(s) for the channel and floodplain PEA's i.e. from the upstream to the downstream border of the channel and floodplain PEA's.	
Complementary actions	N/A	

Lateral and longitudinal connectivity – sedimentation and erosion		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	N/A	Maintain sedimentation and erosion processes within normal ranges during overbank flows within the Floodplain PEA
SME workshop derived objective	N/A	
Recommended Update to Objective	Restore lateral and longitudinal connectivity to support basal and secondary productivity, and flow dependent processes	
Rationale	In the 2020 versions of the LTWP, this target was listed under groundwater and soils. The 2020 objective and target has a functional linkage within the restated objective "restore…flow dependent processes"	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	N/A	Limit the maximum rate of drawdown (averaged over 3 consecutive days) to ≤0.025 m/day (0.05m/day in any one day) to minimise risk of bank failure
SME workshop derived targets	N/A	
Recommended Update to targets	No target recommended.	
Rationale	In the 2020 version of the LTWP, this target was listed under groundwater and soils. The intent of the 2020 objective is captured within the restated objective "restore…flow dependent processes". The metrics stated in the Ecological Target are operational principles, and are described by the EWRs.	
Existing data	Yes. Water levels are measured daily on the upstream and downstream side of locks, and are logged at a number of sites within anabranch creeks/off channel habitats.	
Key use of targets	The metrics stated in the 2020 Ecological Target are operational principles, and are described by the EWRs.	
Further development	N/A	
Complementary actions	N/A	

Water quality – phytoplankton blooms		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	Maintain water quality to support aquatic biota and normal biogeochemical processes	N/A
SME workshop derived objective	Maintain water quality conducive to supporting biota and recreational use.	
Recommended Update to Objective	Maintain water quality conducive to supporting biota, and have regard to consumptive and recreational use of river water.	
Rationale	SME workshop derived objective expanded to recognise impact of poor water quality on consumptive and recreational users. Inclusion of both PEA's recognises that algal blooms may be established in retaining areas on the floodplain and be transferred to the channel via return flows.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	Biovolume <4 mm3/L for all Cyanobacteria, where a known toxin producer is dominant.	N/A
	Biovolume <10 mm3/L for all Cyanobacteria, where toxins are not present.	
SME workshop derived targets	(WQ5) Algal cell counts/biovolume and toxin concentrations for cyanobacteria remain within the Guidelines for Managing Risks in Recreational Water	
Recommended Update to targets	[WATR_1] Algal cell counts and toxin concentrations for cyanobacteria remain within the parameters used by SA Water for managing risks related to algal blooms	
Rationale	Biovolume is not a routinely measured parameter. Recommend altering wording to reflect the standard parameters used by SA Water in routine water quality monitoring program	
Existing data	Yes. SA Water undertake routine sampling and reporting	
Key use of targets	For the purposes of Integrated Operations annual planning and assessing the potential risk of cyanobacterial blooms, the Integrated Operations Strategy (IOS) focuses on assessing the flows and velocities that increase the chance of stratification occurring in the main river channel. Integrated Operations real time planning takes into account reports of algal blooms upstream of the SA Border and SA Water sampling at water offtakes and Lake Victoria. SA water uses a threshold of concern of 500 cells/mL for a number of blue green algal species + any detection of Cryptosporidium and Giardia.	
Further development	N/A	
Complementary actions	N/A	

Water quality – dissolved oxygen		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	Maintain water quality to support aquatic biota and normal biogeochemical processes	Maintain water quality to support aquatic biota and normal biogeochemical processes
SME workshop derived objective	Maintain water quality conducive to supporting biota and recreational use.	
Recommended Update to Objective	Maintain water quality conducive to supporting biota, and have regard to consumptive and recreational use of river water.	
Rationale	Existing objective expanded to recognise impact of poor water quality on consumptive and recreational users.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	Basin Plan Target: Maintain dissolved oxygen above 50% saturation throughout water column at all times	Maintain dissolved oxygen above 50% saturation throughout water column at all times, in connected waters
SME workshop derived targets	WQ1) DO remains above 6 mgO_2L^{-1} in the main channel and connected flowing anabranch creeks at all times	
Recommended Update to targets	[WATR_2] Dissolved Oxygen remains above 6 mgO_2L^{-1} (or 90% saturation) in the main channel and connected anabranch creeks at all times	
Rationale	BP threshold of 50% saturation is below the documented threshold considered to induce stress responses in native fish. At 20 °C, 25 °C and 30 °C in freshwater, 50% saturation equates to approximately 4.5 mgL^{-1}, 4.1 mgL^{-1} and 3.8 mgL^{-1} respectively. Target increased to 6 mg/L, consistent with ANZECC guidelines and operational targets used at Chowilla, Pike and Katarapko. Recommended increase in % saturation metric makes target consistent with values used throughout SA to manage documented water quality risks associated with delivery of environmental water.	
Existing data	Yes. There is an established DO monitoring network throughout the river and key anabranch creeks. Data is logged every 15 minutes and is available in near-real time through web-based interfaces.	
Key use of targets	The DO-DOC model built into SOURCE allows for assessment of the potential impact of various operating scenarios on dissolved oxygen and DOC. The Integrated Operating Strategy (IOS) has adopted >8 mg/L as a low level of concern and <6 mg/L as a high level of concern. A critical threshold target of maintaining a DO concentration of >4mg/L at all times has been adopted in site-based management plans.	
Further development	N/A	
Complementary actions	N/A	

Water quality – in-stream pH and salinity		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	Maintain water quality to support aquatic biota and normal biogeochemical processes	N/A
SME workshop derived objective	Maintain water quality conducive to supporting biota and recreational use.	
Recommended Update to Objective	Maintain water quality conducive to supporting biota, and have regard to consumptive and recreational use of river water.	
Rationale	Existing objective expanded to recognise impact of poor water quality on consumptive and recreational users.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	No target(s) for water column pH or salinity were provided in the 2020 version of the LTWP	N/A
SME workshop derived targets	(WQ2) Water column pH remains within 6.5-9.0 at all times	
	(WQ3) Salinity remains below 1,000 mg/L (EC = 1,800 µScm-1) 100% of the time in the main channel and connected anabranch creeks	
Recommended Update to targets	Adopt SME derived target (WQ3)	
	[WATR_4] Increase in in-stream salinity facilitated by environmental watering actions does not exceed >200 EC for more than two weeks	
	[WATR_5] Water column pH in the main channel and connected anabranch creeks remains within 6.5-9.0 100% of the time	
Rationale	No target(s) for water column pH or salinity were provided in the 2020 version of the LTWP. Change to wording for pH target clarifies where measurements are expected to be made. Inclusion of [WATR_4] introduces linkage to threshold of concern stipulated in the Integrated Operating Strategy. Rapid and/or marked decreases in pH are an indicator of disturbance of sulfidic material. Presence of sulfidic material is an identified hazard associated with water level lowering (i.e. weir pool lowering), and high velocity flows may induce scouring and mobilisation of this material. Managing in-stream salinity to avoid impacts on irrigation water use efficiency is a key focus of consumptive and environmental water delivery, and salinity limits for consumptive use and salinity accounting are specified in the Basin Plan. The water quality target for irrigation water set out in the Basin Plan (Section 9.17 (3)) for the Southern Basin is for salinity to be maintained below 833 EC for 95% of the time over each 10-year period. This metric is primarily related to consumptive use. An ecological target should reflect possible ecological impacts of high salinity on aquatic biota.	
Existing data	Yes. There is an established salinity monitoring network throughout the river and key anabranch creeks.	

	There is limited logged pH data that is available in near-real time. Trials of maintaining pH loggers have been undertaken at a limited number of pontoons within the established salinity monitoring network throughout the river and key anabranch creeks.
Key use of targets	The Integrated Operating Strategy specifies a low level of concern for increases in in-stream salinity has been identified as a <100 EC increase due to environmental watering actions. The high level of concern is where there is >200 EC increase due to environmental watering actions. A duration of 2 weeks is applied to the medium and high levels of concern due to the fact that short term exceedances of these levels could be managed through appropriate communications with irrigators and other stakeholders. Rapid and/or marked decreases in pH and dissolved oxygen may indicate scouring and mobilisation of sulfidic material. Detection of change in these water quality parameters in near real time, particularly near areas where there is a known hazard, may increase capacity to alter management actions and minimise impacts.
Further development	N/A
Complementary actions	The salinity targets have functional linkages to the 2020 LTWP target (which is taken from the Basin Plan) for salt export.

Native fish – Murray cod		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	Restore resilient populations of Murray cod (a long-lived apex predator)	Restore resilient populations of circa-annual nester-spawners within the South Australian River Murray
SME workshop derived objective	Restore resilient populations of Murray cod (*Maccullochella peelii*)	
Recommended Update to Objective	Adopt SME derived objective	
Rationale	Ecological Objective to be retained with single species focus by removing reference to circa-annual nester spawners from Floodplain PEA objective. Note. Objective could be consolidated to "restore resilient populations of native fish", with species specific targets nested within a single objective.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	Population age structure of Murray cod includes recent recruits, sub-adults and adults in 9 years in 10.	Population age structure of Murray cod includes recent recruits, sub-adults and adults in 9 years in 10.
	Population age structure of Murray cod indicates a large recruitment event 1 year in 5, demonstrated by a cohort representing >50% of the population.	Population age structure of Murray cod indicates a large recruitment event 1 year in 5, demonstrated by a cohort representing >50% of the population.
	Abundance (CPUE) of Murray cod increases by ≥50% over a 10-year period.	Abundance (CPUE) of Murray cod increases by ≥50% over a 10-year period.
SME workshop derived targets	(MC1) [FISH_1]:Population age structure of Murray cod includes recent recruits, subadults and adults in 9 years in 10	
	(MC2) [FISH_2]: Abundance (measured as CPUE) of Murray cod exhibits a positive trajectory and increases by ≥50% over a 10-year period	
	(MC3) Abundance (measured as Catch Per Unit Effort) of Murray cod in the main channel and permanent anabranches is >0.8 fish per minute	
Recommended Update to targets	Recommend adopting (MC1) and (MC2).	
	Target (MC3) may be redundant. It is an ancillary target that overlaps with (MC2). No other species has a CPUE target expressed in this manner	
Rationale	Two x population age structure targets presented in the 2020 LTWP have been consolidated. If (MC1) and (MC2) are met, it could be considered that the 2020 target "*Population age structure of Murray cod indicates a large recruitment event 1 year in 5, demonstrated by a cohort representing >50% of the population*" has been met, and that 2020 LTWP target is therefore redundant. However, (MC1) and (MC2) could be met if recruitment is at a consistent level across 5 years and no year class is dominant. If it is perceived that occasional high level (episodic)	

	recruitment during large infrequent flow events is a driver of population sustainability, the 2020 LTWP target could also be retained. Catch Per Unit Effort (CPUE) for these fish surveys is based on standardised, targeted electrofishing.
Existing data	Yes. Data is available from existing monitoring programs.
Key use of targets	Murray cod are an iconic species. Populations have been severely disrupted by historical overfishing and river regulation. Targeting outcomes for Murray cod is a commonly utilised and celebrated justification for use of environmental water within the lower Murray that facilitates other outcomes.
Further development	An additional target “Abundance (measured as CPUE) of Murray cod is >0.8 fish per minute” was proposed during the workshop process. It is considered that this target could be removed, as it is likely to be redundant if other abundance metric is met. This target may have more value within site based monitoring/research programs.
Complementary actions	N/A

Native fish – Golden Perch		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	Restore resilient populations of golden perch and silver perch (flow-dependent specialists)	Restore resilient populations of flow-dependent specialists within the SA River Murray
SME workshop derived objective	Restore resilient populations of golden perch (*Macquaria ambigua*)	
Recommended Update to Objective	Adopt SME derived objective	
Rationale	Ecological Objective to be retained with single species focus due to key differences in life history and longevity between golden perch and silver perch. Note. Objective could be consolidated to "restore resilient populations of native fish", with species specific targets nested within a single objective.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	Population age structure of golden perch and silver perch includes YOY with sub-adults and adults in 8 years in 10.	Population age structure of golden perch and silver perch includes YOY with sub-adults and adults in 8 years in 10.
	Population age structure of golden perch and silver perch indicates a large recruitment event 2 years in 5, demonstrated by separate cohorts representing >30% of the population.	Population age structure of golden perch and silver perch indicates a large recruitment event 2 years in 5, demonstrated by separate cohorts representing >30% of the population.
	Abundance (CPUE) of golden perch and silver perch increases by ≥30% over a 5-year period.	Abundance (CPUE) of golden perch and silver perch increases by ≥30% over a 5-year period.
SME workshop derived targets	(GP1) [FISH_3]: Population age structure of golden perch indicates a large recruitment event 2 years in 5, demonstrated by separate cohorts that combined, represent >30% of the population.	
	(GP2) [FISH_4]: Abundance (measured as CPUE) of golden perch exhibits a positive trajectory and increases by ≥30% over a 5-year period	
	(GP3) [FISH_5]: Cohorts of golden perch originate from multiple spatial recruitment sources including the lower Murray	
Recommended Update to targets	Recommend adoption of SME workshop derived targets	
Rationale	Reference to YOY (Young of Year) included in 2020 LTWP target removed from proposed target based on advice from SME's (small group workshop 1st November 2023) because YOY may not be detected in field sampling of size classes, however the age (year) classes are detected in the population in later years via otolith aging. Inclusion of new target related to origin of spawned fish due to recognition of importance of different recruitment zones and the influence of upstream	

	hydrology on achieving the desired outcomes. Multiple spatial recruitment sources implies (1) Murray River upstream of Darling, (2) Murray River downstream of Darling, (3) Darling River. Difference in metrics between GP and SP as there is no evidence that SP live past 6 years in the lower Murray and as there is evidence of near-annual recruitment, SP are not dependent on episodic boom recruitment events like GP.
Existing data	Yes. Data is available from existing monitoring programs. Catch Per Unit Effort (CPUE) for these fish surveys is based on standardised, targeted electrofishing.
Key use of targets	Golden perch are an iconic species. Populations have been severely disrupted by historical overfishing and river regulation. Targeting outcomes for this species is a commonly utilised and celebrated justification for use of environmental water within the lower Murray that facilitates other outcomes. The influence of recreational take of golden perch on ability to achieve the stated targets is currently unknown.
Further development	Target (GP3) [FISH_5] would be evaluated via otolith chemistry. Consideration should be given to establishing a benchmark for percentage/number of assessed fish from each origin for the target to be considered met i.e. does detection of one fish from a source imply the target is met?
Complementary actions	N/A

Native fish – Silver Perch		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	Restore resilient populations of golden perch and silver perch (flow-dependent specialists)	Restore resilient populations of flow-dependent specialists within the SA River Murray
SME workshop derived objective	Restore resilient populations of silver perch (*Bidyanus bidyanus*)	
Recommended Update to Objective	Adopt SME derived objective	
Rationale	Ecological Objective to be retained with single species focus due to key differences in life history and longevity between golden perch and silver perch. Note. Objective could be consolidated to “restore resilient populations of native fish”, with species specific targets nested within a single objective	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	Population age structure of golden perch and silver perch includes YOY with sub-adults and adults in 8 years in 10.	Population age structure of golden perch and silver perch includes YOY with sub-adults and adults in 8 years in 10.
	Population age structure of golden perch and silver perch indicates a large recruitment event 2 years in 5, demonstrated by separate cohorts representing >30% of the population.	Population age structure of golden perch and silver perch indicates a large recruitment event 2 years in 5, demonstrated by separate cohorts representing >30% of the population.
	Abundance (CPUE) of golden perch and silver perch increases by ≥30% over a 5-year period.	Abundance (CPUE) of golden perch and silver perch increases by ≥30% over a 5-year period.
SME workshop derived targets	(SP1) [FISH_6]: Population age structure of silver perch indicates recruitment 4 years in 5, indicated by presence of year classes	
	(SP2) [FISH_7]: Abundance (measured as CPUE) of silver perch exhibits a positive trajectory and increases by ≥30% over a 5-year period	
	(SP3) [FISH_8]: Cohorts of silver perch originate from multiple spatial recruitment sources including the lower Murray	
Recommended Update to targets	Recommend adoption of SME workshop derived targets	
Rationale	Reference to YOY (Young of Year) included in 2020 LTWP target removed from proposed target based on advice from SME’s (small group workshop 1st November 2023) because YOY may not be detected in field sampling of size classes, however the age (year) classes are detected in the population in later years via otolith aging. Inclusion of new target related to origin of spawned fish due to recognition of importance of different recruitment zones and the influence of upstream hydrology on achieving the desired outcomes. Multiple spatial recruitment	

	sources implies (1) Murray River upstream of Darling, (2) Murray River downstream of Darling, (3) Darling River. Difference in metrics between Golden Perch (GP) and Siver Perch (SP) as there is no evidence that SP live past 6 years in the lower Murray and as there is evidence of near-annual recruitment, SP are not dependent on episodic boom recruitment events like GP. Low abundance of this species may limit capability to assess targets that relate to recruitment, age structure and natal origin.
Existing data	Yes. Data is available from existing monitoring programs. Catch Per Unit Effort (CPUE) for these fish surveys is based on standardised, targeted electrofishing.
Key use of targets	Silver perch are an iconic species. Populations have been severely disrupted by historical overfishing and river regulation. Targeting outcomes for this species is a commonly utilised and celebrated justification for use of environmental water within the lower Murray that facilitates other outcomes.
Further development	N/A
Complementary actions	N/A

Native fish – Freshwater catfish		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	Restore resilient populations of freshwater catfish	Restore resilient populations of circa-annual nester-spawners within the South Australian River Murray
SME workshop derived objective	Restore resilient populations of freshwater catfish (*Tandanus tandanus*)	
Recommended Update to Objective	Adopt SME derived objective	
Rationale	Ecological Objective to be retained with single species focus by removing reference to circa-annual nester spawners from Floodplain PEA objective. Note. Objective could be consolidated to "restore resilient populations of native fish", with species specific targets nested within a single objective.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	Population age structure of freshwater catfish includes YOY, with sub-adults and adults in 9 years in 10.	Population age structure of freshwater catfish includes YOY, with sub-adults and adults in 9 years in 10.
	Population age structure of freshwater catfish indicates a large recruitment event 2 years in 5, demonstrated by separate cohorts representing >30% of the population.	Population age structure of freshwater catfish indicates a large recruitment event 2 years in 5, demonstrated by separate cohorts representing >30% of the population.
	Abundance (CPUE) of freshwater catfish increases by ≥30% over a 5-year period.	Abundance (CPUE) of freshwater catfish increases by ≥30% over a 5-year period.
SME workshop derived targets	(FC1) [FISH_9]: Population age structure of freshwater catfish includes recent recruits, subadults and adults in 9 years in 10	
	(FC2) [FISH_10]: Abundance (measured as CPUE) of freshwater catfish exhibits a positive trajectory and increases by ≥50% over a 10-year period	
Recommended Update to targets	Recommend adoption of SME workshop derived targets	
Rationale	Freshwater catfish are a threatened species. Populations have been severely disrupted by historical overfishing and river regulation. Whist considered to represent a high value target, outcome appears to be heavily dependent on non-flow rated ecological processes, low dispersal rates and anthropological stressors.	
Existing data	Yes. Limited data is available from existing monitoring programs.	
Key use of targets	Whilst there is little data on population demographics, catfish is a notable species within the riverine and wetland environments of the lower Murray.	
Further development	The 2020 LTWP target "Population age structure of freshwater catfish indicates a large recruitment event 2 years in 5, demonstrated by separate cohorts representing >30% of the population" was removed as (i) it is probable that	

	target [FISH_9] provides a robust measure of recruitment, and (ii) there is little data on catfish demographics in the lower Murray. Further consideration could be given to refining and subsequently reinstating a similar target. Main channel fyke netting may be a more appropriate method to target catfish than standardised electrofishing. However, this is not currently being undertaken.
Complementary actions	N/A

Native fish – Lamprey		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	Restore the distribution of native fish	N/A
SME workshop derived objective	Restore resilient populations of pouched lamprey (*Geotria australis*) and short headed lamprey (*Mordacia mordax*)	
Recommended Update to Objective	Objective and target not to be continued.	
Rationale	No specific objective or target was provided for distribution of Lamprey in the 2020 version of the LTWP. Note. Objective could be consolidated to “restore resilient populations of native fish”, with species specific targets nested within a single objective.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	N/A	N/A
SME workshop derived targets	LM1) Improve longitudinal connectivity to support upstream movement of lamprey	
Recommended Update to targets	SME workshop derived target not recommended for inclusion	
Rationale	As a threatened species, lamprey should be considered for inclusion. During the workshop process, a draft target of “*Improve longitudinal connectivity to support upstream movement of lamprey*” was proposed. However, "Improve" is not a measurable target (could be an objective), and there is currently insufficient data and/or conceptual model/understanding to establish metrics similar to those proposed for Murray cod, golden perch etc. SME’s considered that the key driver of “improvement” in abundance with increasing flow is improved connectivity achieved through removal of weirs at high flows. Flows ≥60,000 ML/day may be expected to make "moderate" contribution towards achieving target as all weirs are removed at flows above this magnitude. Achievement of target would also require upstream movement from the Coorong, Lower Lakes, Murray Mouth (CLLMM) to the downstream river reaches.	
Existing data	Limited available data – cryptic species not regularly encountered in routine monitoring programs.	
Key use of targets	N/A	
Further development	N/A	
Complementary actions	Removal of weirs at high flows.	

Native fish - distribution		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	Restore the distribution of native fish	N/A
SME workshop derived objective	Objective and target not to be continued.	
Recommended Update to Objective	Objective and target not to be continued.	
Rationale	Acknowledging fundamental issues associated with barriers to upstream and downstream movement, the critical limitation to achieving sustainable populations of native fish is not the absence of species from within specific reaches. Key factors include reinstating a sustainable population age structure and abundance. Note. Objective could be consolidated to "restore resilient populations of native fish"	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	Expected species occur in each mesohabitat (channel, anabranch, wetlands) in each weir pool/reach.	N/A
SME workshop derived targets	N/A	
Recommended Update to targets	Objective and target not to be continued.	
Rationale	As per objective	
Existing data	Yes. Data on relative abundance of fish can be derived from existing monitoring programs.	
Key use of targets	N/A	
Further development	N/A	
Complementary actions	N/A	

Native fish - Foraging generalists		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	Restore and maintain resilient populations of foraging generalists e.g. Australian smelt, bony herring, Murray rainbowfish, unspecked hardyhead, carp gudgeons, flathead gudgeons (Channel PEA)	N/A
SME workshop derived objective	Support resilient populations of foraging generalist native fish	
Recommended Update to Objective	Objective and target not to be continued.	
Rationale	Foraging generalists are considered to thrive in slow flowing weir pool environments, and high flows may actually disadvantage this guild. Hence focus can shift from "restore" to "support". Note. Objective could be consolidated to "restore resilient populations of native fish".	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	The length-frequency distributions for foraging generalists include size classes showing annual recruitment.	N/A
SME workshop derived targets	(FG1) The length-frequency distributions for foraging generalists indicate annual recruitment.	
Recommended Update to targets	No target recommended	
Rationale	During the workshop process, a draft target (FG1) was proposed. However, the target could be removed on the basis that delivery of e-water would not be specifically requested to achieve this outcome as elevated flows are considered to disadvantage this guild.	
Existing data	Yes. Data is available from several monitoring programs.	
Key use of targets	N/A	
Further development	N/A	
Complementary actions	N/A	

Native fish - Wetland/floodplain specialists		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	N/A	Restore resilient populations of wetland/floodplain specialists within aquatic zones across the Floodplain PEA during floodplain flow events
SME workshop derived objective	Maintain populations of wetland/floodplain specialists e.g. southern purple spotted gudgeon (*Mogurnda adspersa*), Murray hardyhead (*Craterocephalus fluviatilis*)	
Recommended Update to Objective	Objective and target not to be continued.	
Rationale	Proposed wording retains intent of objective. However, objective may not be required; increasing the range and abundance of wetland/floodplain specialists will require active wetland management including restocking. Delivery of reach scale environmental flows is not considered to be a key driver required to achieve restoration. Note. Objective could be consolidated to “restore resilient populations of native fish”.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	N/A	The length-frequency distributions for wetland/floodplain (native fish) specialists within aquatic zones across the Floodplain PEA include size classes showing annual recruitment.
		Increase range and abundance of wetland/floodplain (native fish) specialists within aquatic zones across the Floodplain PEA.
SME workshop derived targets	(WS1) Wetland/floodplain (native fish) specialists are detected within expected habitats annually	
	(WS2) The length-frequency distributions for wetland/floodplain (native fish) specialists indicate annual recruitment	
Recommended Update to targets	No target recommended	
Rationale	During the workshop process two draft targets (WS1) and (WS2) were proposed. Advice from SME is that achievement of these targets requires site specific wetland habitat management actions including restocking; hydrological management alone will not achieve restoration. Therefore, it is considered that the targets may be able to be removed.	
Existing data	Yes. There is data from target monitoring/research programs.	
Key use of targets	N/A	
Further development	N/A	

Complementary actions	Achievement of the draft targets will require site specific wetland habitat management actions including restocking; hydrological management alone will not achieve restoration.

Non-native fish		
Ecological objectives	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Objective	Minimise the risk of carp recruitment	A low proportion of total fish community, measured as abundance and biomass, is comprised of non-native species.
SME workshop derived objective	Objective not to be continued	
Recommended Update to Objective	Objective and target not to be continued.	
Rationale	SME's consider that carp response to increased flows and resultant inundation is inevitable. Therefore, the focus on planning for environmental water delivery should be on optimising timing, hydraulic conditions and hydrograph characteristics to maximise outcomes for native fish.	
Ecological targets	**Channel PEA**	**Floodplain PEA**
Existing SA River Murray LTWP 2020 Targets	The relative abundance and biomass of common carp does not increase in the absence of increases in abundance and biomass of flow-dependent native fish.	The relative abundance and biomass of common carp does not increase in the absence of increases in abundance and biomass of flow-dependent native fish.
SME workshop derived targets	N/A	
Recommended Update to targets	Target not to be continued	
Rationale	SME's consider that carp response to increased flows and resultant inundation is inevitable. Therefore, the focus on planning for environmental water delivery should be on optimising timing, hydraulic conditions and hydrograph characteristics to maximise outcomes for native fish.	
Existing data	Yes. There is data from target monitoring/research programs	
Key use of targets	N/A	
Further development	N/A	
Complementary actions	Focus on planning for environmental water delivery should be on optimising timing, hydraulic conditions and hydrograph characteristics to maximise outcomes for native fish.	

6 Ecological Objectives and Targets recommended for inclusion in the 2025 update of the Long Term Environmental Watering Plan for SA River Murray

The following set of Ecological Objectives and Targets are recommended for inclusion in the 2025 update of the Long Term Environmental Watering Plan for South Australian River Murray.

Table 6.1. Ecological Objectives and Targets recommended for inclusion in the 2025 update of the Long Term Watering Plan for SA River Murray

Attribute	Group	Proposed Ecological Objective	Target code	Proposed Ecological Target
Woodland dependent fauna	Terrestrial birds	Restore resilient populations of native semi-aquatic and terrestrial reptiles, mammals and birds	[WDFN_1]	Across all sites, independent of habitat type, terrestrial bird species richness measured across all four seasons within one year, is maintained at or above 78 species
			[WDFN_2]	Across all sites, independent of habitat type, terrestrial bird species richness measured over a rolling four-year period, is maintained at or above 110 species
	Reptiles and mammals		[WDFN_3]	Each of the terrestrial reptile species that use the littoral and/or floodplain zones are recorded across ≥50% of sites within their known distribution at least once every two years
			[WDFN_4]	Each of the terrestrial mammal species that use the littoral and/or floodplain zones for are recorded across ≥50% of sites within their known distribution at least once every two years
			[WDFN_5]	Each of the 15 bat species known to occur within the asset will be detected across ≥ 75% of sites within their known distribution at least once every two years

Attribute	Group	Proposed Ecological Objective	Target code	Proposed Ecological Target
Wetland dependent fauna	Waterbirds	Restore resilient populations of waterbirds, frogs and turtles	[WBRD_1]	Increase the spatial extent of productive foraging zones (inundated mud flats, shallow water) by 50% above that occurring under entitlement flow and normal weir pool conditions to support adult waterbirds and survival of juveniles/sub-adults, during spring-summer for ≥30 days
			[WBRD_2]	Maintain the water depth and duration of inundation of emergent vegetation required to support waterbird breeding through to completion (egg laying, fledging and post fledging care) at least 3 years in 10 with a maximum return interval of 5 years.
			[WBRD_3]	Annual species richness of waterbirds is maintained at ≥ 55 species
			[WBRD_4]	Over a three-year period, species richness is maintained at ≥ 60 species, and includes small-bodied migratory waders
	Frogs		[FROG_1]	Each of the 10 frog species known to occur within the asset will be detected at least once every two years at 75% of surveyed sites within their known distribution within the channel PEA
			[FROG_2]	Each of the 10 frog species known to occur within the asset will be detected at least once every two years at 60% of surveyed sites within their known distribution within the floodplain PEA
			[FROG_3]	Tadpoles from each of the 10 frog species known to occur within the asset will be recorded in achieve later stages of metamorphosis (Gosner stage >36), 3 years in 10 with a maximum 3 year return interval
			[FROG_4]	Maintain the existing distribution of the nationally listed Southern Bell Frog (*Litoria raniformis*) as evidenced by detection of adults 3 years in 5 within their known distribution
	Turtles		[TURT_1]	Population age structure of turtles indicates an effective recruitment event 1 year in 5 (max 7 years), demonstrated by

Attribute	Group	Proposed Ecological Objective	Target code	Proposed Ecological Target
				separate cohorts of juveniles/sub-adults and adults of each species
			[TURT_2]	Abundance (measured as CPUE) of juvenile/sub-adult turtles of each species exhibits a positive trajectory and increases by ≥30% over a 5-year period
			[TURT_3]	Abundance (measured as CPUE) of adult turtles of each species exhibits a positive trajectory and increases by ≥30% over a 10-year period
			[TURT_4]	All three species are recorded annually in 90% of sampling sites within permanent mesohabitats along length of PEA
			[TURT_5]	Long neck turtles are recorded annually in 90% of sampling sites within inundated temporary wetlands along the length of the PEA

Attribute	Group	Proposed Ecological Objective	Target code	Proposed Ecological Target
Lateral and longitudinal connectivity	Basal food resources	Restore lateral and longitudinal connectivity to support basal and secondary productivity, and flow dependent processes including salt export	[CONN_1]	Dissolved organic carbon concentration increases from baseflow values (3-4 mgL^{-1}) to ≥6 mgL^{-1} during the rising limb of hydrographs.
	Invertebrate food resources		[CONN_2]	Mean microinvertebrate abundance in the main channel is ≥1,000 individuals/L during late spring/early summer
			[CONN_3]	Peak microinvertebrate abundance in the main channel is ≥2,000 individuals/L during late spring/early summer
			[CONN_4]	During late spring/early summer, at least 25% of the microinvertebrate assemblage in the main channel is comprised of individuals from the littoral functional groups (e.g. littoral rotifers, cyclopoid copepods and cladocerans)
			[CONN_5]	During late spring/early summer the density of cyclopoid copepods and cladocerans is 100–1000 individuals/L within 3 weeks of inundation of shedding and retaining habitats on the floodplain
	Water column stratification		[CONN_6]	Maintain passing flows at the downstream side of the locks above 4,000 ML/day to ensure at least one mixing event per day
			[CONN_7]	Maintain passing flows at the downstream side of the locks above 10,000 ML/day to provide sufficient turbulence intensity to support downstream drift
	Hydraulic conditions		[CONN_8]	Maintain contiguous flowing habitat with velocity ≥0.2 ms^{-1} from the junction of the Murray and Darling Rivers to Wellington during late spring-early summer to facilitate downstream transport/dispersal of drift dependent biota
			[CONN_9]	Maintain contiguous flowing habitat with velocity ≥0.3 ms^{-1} from the junction of the Murray and Darling Rivers to Wellington during late spring-early summer to restore high value hydraulic habitat

Attribute	Group	Proposed Ecological Objective	Target code	Proposed Ecological Target
	River channel-wetland connectivity		[CONN_10]	≥75% of ephemeral wetland area is inundated with lateral connectivity to the river/creek for a minimum of 20 continuous days at least once every 3 years
	Salt export		[CONN_11]	Salt export, averaged over the preceding 3 years, is ≥2 million tonnes per year

Attribute	Group	Proposed Ecological Objective	Target code	Proposed Ecological Target
Water quality	Phytoplankton blooms	Maintain water quality conducive to supporting biota, and have regard to consumptive and recreational use of river water	[WATR_1]	Algal cell counts and toxin concentrations for cyanobacteria remain within the parameters used by SA Water for managing risks related to algal blooms
	Dissolved oxygen		[WATR_2]	Dissolved Oxygen remains above 6 mgO_2L^{-1} (or 90% saturation) in the main channel and connected anabranch creeks at all times
	In-stream salinity		[WATR_3]	Salinity remains below 1,000 mg/L (EC = 1,800 μScm^{-1}) 100% of the time in the main channel and connected anabranch creeks
	In-stream pH		[WATR_4]	Increase in in-stream salinity facilitated by environmental watering actions does not exceed >200 EC for more than two weeks
			[WATR_5]	Water column pH in the main channel and connected anabranch creeks remains within 6.5-9.0 100% of the time

Attribute	Group	Proposed Ecological Objective	Target code	Proposed Ecological Target
Native fish	Murray cod	Restore resilient populations of Murray cod (*Maccullochella peelii*)	[FISH_1]	Population age structure of Murray cod includes recent recruits, subadults and adults in 9 years in 10
			[FISH_2]	Abundance (measured as CPUE) of Murray cod exhibits a positive trajectory and increases by ≥50% over a 10-year period
	Golden Perch	Restore resilient populations of golden perch (*Macquaria ambigua*)	[FISH_3]	Population age structure of golden perch indicates a large recruitment event 2 years in 5, demonstrated by separate cohorts that combined, represent >30% of the population.
			[FISH_4]	Abundance (measured as CPUE) of golden perch exhibits a positive trajectory and increases by ≥30% over a 5-year period
			[FISH_5]	Cohorts of golden perch originate from multiple spatial recruitment sources including the lower Murray
	Silver Perch	Restore resilient populations of silver perch (*Bidyanus bidyanus*)	[FISH_6]	Population age structure of silver perch indicates recruitment 4 years in 5, indicated by presence of year classes
			[FISH_7]	Abundance (measured as CPUE) of silver perch exhibits a positive trajectory and increases by ≥30% over a 5-year period
			[FISH_8]	Cohorts of silver perch originate from multiple spatial recruitment sources including the lower Murray
	Freshwater catfish	Restore resilient populations of freshwater catfish (*Tandanus tandanus*)	[FISH_9]	Population age structure of freshwater catfish includes recent recruits, subadults and adults in 9 years in 10
			[FISH_10]	Abundance (measured as CPUE) of freshwater catfish exhibits a positive trajectory and increases by ≥50% over a 10-year period

Attribute	Group	Proposed Ecological Objective	Target code	Proposed Ecological Target
Floodplain trees	River Red Gum	Maintain spatial extent and restore ecologically functional River Red Gum woodlands	[TREE_1]	In standardised transects spanning the elevation gradient, ≥90% of viable River Red Gum will have a Tree Condition Index Score ≥10
			[TREE_3]	Effective regeneration of River Red Gum woodlands at least 1 in 10 years, as evidenced by >85 % of assessment areas containing saplings and/or sub-adult trees (DBH <10cm) comprising >30% of the population
			[TREE_4]	The rate of loss (die back to a TCI = 0) of mature River Red Gums will not exceed 0.15% per year
	Black Box	Maintain spatial extent and restore ecologically functional Black Box woodlands	[TREE_5]	In standardised transects spanning the elevation gradient, ≥90% of viable Black Box will have a Tree Condition Index Score ≥10
			[TREE_7]	Effective regeneration of Black Box woodlands at least 1 in 20 years, as evidenced by >75 % of assessment areas containing saplings (size) and/or sub-adult trees (DBH <10cm) comprising >30% of the population
			[TREE_8]	The rate of loss (die back to a TCI = 0) of mature Black Box will not exceed will not exceed 0.15% per year
	River Cooba	Maintain spatial extent and restore ecologically functional River Cooba woodlands	[TREE_9]	In standardised transects spanning the elevation gradient, ≥90% of viable River Cooba will have a Tree Condition Index Score ≥10

Attribute	Group	Proposed Ecological Objective	Target code	Proposed Ecological Target
Shrublands	Lignum shrublands	Maintain spatial extent and restore ecologically functional lignum shrublands	[LIGN_1]	30% of lignum sites receive condition values indicative of good condition at least once every 2 years
			[LIGN_2]	60% of lignum sites receive condition values indicative of good condition at least once every 3 years
			[LIGN_3]	80% of lignum sites receive condition values indicative of good condition at least once every 4 years
			[LIGN_4]	Percentage of dead (non-viable plants) within assessment areas decreases

Attribute	Group	Proposed Ecological Objective	Target code	Proposed Ecological Target
Non-woody vegetation	Permanently inundated areas	Establish ecologically functional native understorey vegetation community in permanently inundated habitats	[UVEG_1]	In permanently inundated channels and pool connected wetlands, a minimum of 90% of survey cells located on the bed, bank toe, slope and crest are either inundated or contain native flood-dependent and/or amphibious taxa at least once every 2 years
			[UVEG_2]	In permanently inundated channels and pool connected wetlands, survey cells will have species richness of native flood-dependent, amphibious and aquatic plants ≥ 60 at least once every 2 years
	Frequently inundated temporary wetlands and shedding floodplain	Establish ecologically functional native understorey vegetation community in frequently inundated habitats	[UVEG_3]	In temporary wetlands inundated at flows ≤40,000 $MLday^{-1}$, a minimum of 70% of survey cells located on the bed, bank toe, slope and crest are either inundated or contain native flood-dependent and/or amphibious taxa at least once every 2 years
			[UVEG_4]	In temporary wetlands inundated at flows ≤40,000 $MLday^{-1}$, survey cells will have species richness of native flood-dependent, amphibious and aquatic plants ≥ 80 at least once every 2 years
			[UVEG_5]	The shedding floodplain inundated at flows ≤40,000 $MLday^{-1}$ has a minimum of 70% of survey cells either inundated or containing native flood-dependent and/or amphibious taxa at least once every 2 years
			[UVEG_6]	The shedding floodplain inundated at flows ≤40,000 $MLday^{-1}$ survey cells will have species richness of native flood-dependent, amphibious and aquatic plants ≥ 80 at least once every 2 years
	Infrequently inundated temporary wetlands	Establish ecologically functional native understorey vegetation community in infrequently inundated temporary wetlands	[UVEG_7]	In temporary wetlands inundated at flows >40,000 $MLday^{-1}$, a minimum of 40% of survey cells located on the bed, bank toe, slope and crest are either inundated or contain native flood-dependent and/or amphibious taxa once every 2 years on average with maximum interval ≤4 years.
			[UVEG_8]	In temporary wetlands inundated at flows >40,000 $MLday^{-1}$, survey cells located on the bed, bank toe, slope and crest will have species richness of native flood-dependent, amphibious and

Attribute	Group	Proposed Ecological Objective	Target code	Proposed Ecological Target
				aquatic plants ≥40 once every 2 years on average with maximum interval ≤ 4 years.
			[UVEG_9]	In temporary wetlands inundated at flows >40,000 $MLday^{-1}$, a minimum of 80% of survey cells located on the bed, bank toe, slope and crest are either inundated or contain native flood-dependent and/or amphibious taxa once every 4 years on average with maximum interval ≤ 6 years.
			[UVEG_10]	In temporary wetlands inundated at flows >40,000 $MLday^{-1}$, survey cells located on the bed, bank toe, slope and crest will have species richness of native flood-dependent, amphibious and aquatic plants ≥60 once every four years on average with maximum interval ≤ 6 years.
	Infrequently inundated shedding floodplain	Establish ecologically functional native understorey vegetation community on infrequently inundated shedding floodplain areas	[UVEG_11]	The shedding floodplain inundated at flows >40,000 $MLday^{-1}$ has a minimum of 20% of survey cells that are either inundated or contain native flood-dependent and/or amphibious taxa once every 3 years on average with maximum interval ≤5 years.
			[UVEG_12]	On the shedding floodplain inundated at flows >40,000 $MLday^{-1}$, survey cells will have species richness of native flood-dependent, amphibious and aquatic plants ≥ 50 once every 3 years on average with maximum interval ≤ 5 years.
			[UVEG_13]	The shedding floodplain inundated at flows >40,000 $MLday^{-1}$ has a minimum of 40% of survey cells that are either inundated or contain native flood-dependent and/or amphibious taxa once every 5 years on average with maximum interval ≤7 years.
			[UVEG_14]	On the shedding floodplain inundated at flows >40,000 $MLday^{-1}$, survey cells will have species richness of native flood-dependent, amphibious and aquatic plants ≥ 75 once every 5 years on average with maximum interval ≤ 7 years.
			[UVEG_15]	The shedding floodplain inundated at flows >40,000 $MLday^{-1}$ has a minimum of 70% of survey cells that are either inundated or

Attribute	Group	Proposed Ecological Objective	Target code	Proposed Ecological Target
				contain native flood-dependent and/or amphibious taxa once every 7 years on average with maximum interval ≤10 years.
			[UVEG_16]	On the shedding floodplain inundated at flows >40,000 $MLday^{-1}$, survey cells will have species richness of native flood-dependent, amphibious and aquatic plants ≥ 100 once every 7 years on average with maximum interval ≤ 10 years.

Attribute	Group	Proposed Ecological Objective	Target code	Proposed Ecological Target
Groundwater	Groundwater depth	Establish and maintain groundwater conditions conducive to supporting diverse ecologically functional native vegetation	[GWTR_1]	Where the watertable resides within the active rooting depth, groundwater salinity in the top one metre of the saturated zone is within the range utilisable as a water source for river red gum (≤ 5,000 μScm^{-1})
			[GWTR_2]	Where the watertable resides within the active rooting depth, groundwater salinity in the top one metre of the saturated zone is within the range utilisable as a water source for black box (≤ 8,000 μScm^{-1})
			[GWTR_3]:	Where groundwater salinity in the top 1 metre of the saturated zone exceeds the range utilisable as a water source for trees, depth to groundwater returns to pre-watering baseline values during inter-flood periods

Attribute	Group	Proposed Ecological Objective	Target code	Proposed Ecological Target
Soil condition	Soil water potential	Establish soil conditions conducive to supporting diverse ecologically functional non-woody native vegetation	[SOIL_1]	In River Red Gum woodlands, at least one depth interval between 0.2 m and the water table has soil water potential ≥ -1.0 MPa
			[SOIL_2]	In Black Box woodlands, at least one depth interval between 0.2 m and the water table has soil water potential ≥ -2.0 MPa
			[SOIL_3]	In lignum shrublands, at least one depth interval between 0.2 m and the water table has soil water potential ≥ -2.0 MPa
	Soil salinity		[SOIL_4]	Soil salinity (EC 1:5) is <2,700 μScm^{-1} in the 0.2-0.5 m depth interval
			[SOIL_5]	Soil salinity (EC 1:5) is <1,300 μScm^{-1} (non-moderately saline) in the 0.2-0.5 m depth interval at least once every 2 years in the Channel PEA
			[SOIL_6]	Soil salinity (EC 1:5) is <1,300 μScm^{-1} (non-moderately saline) in the 0.2-0.5 m depth interval at least once every 5 years in the Floodplain PEA

7 EWR contribution tables

7.1 Assessment of EWR contribution against updated EWRs

The assessment undertaken here utilises the updated EWR's developed by Gehrig *et al*. (2020) (Table 7.1) and the contribution matrix outlined in Table 7.2 to make an assessment of the expected contribution of the delivery of a single flow event that meets the stated metrics for the flow magnitude, duration and timing of the respective EWR's (Table 7.1) on achieving the proposed Ecological Targets (Table 6.1).

Key inputs into development of the expected contribution tables included (i) hydrodynamic modelling of cross sectional velocity, (ii) inundation response curves (see Figure 8.4) for targeted vegetation groups (e.g. black box, red gum, lignum) and functional water management units (e.g. temporary wetlands), (iii) the assessments made by Gehrig *et al*. (2020) and (iv) advice from subject matter experts during small group discussions. The results are presented in Table 7.3. It is anticipated that the results will be able to be used to support decisions about potential benefits or trade-offs of different environmental flow scenarios.

The assessment uses a coarse ranking system and so a result of no change in ranking does not necessarily mean there is no improvement in contribution, and outcomes will be dependent on antecedent flows and prevailing ecosystem condition.

Table 7.1. Environmental Water Requirements for the SA River Murray Channel (IC) and Floodplain (FP) PEAs (excluding average return frequency and maximum interval metrics) for inclusion in the 2024 update of the SA River Murray LTWP (from Gehrig *et al.*, 2020)

PEA	EWR #	Median discharge (ML/day QSA)	Duration	Timing
Channel	EF	≥3,000	365	All year
	IC1	≥10,000	≥60	Sep-Mar
	IC2	≥20,000	≥60	Oct-Dec
	IC3	≥30,000	≥60	Oct-Dec
	IC4	≥40,000	≥60	Oct-Dec
Floodplain	FP1	50,000	≥40	Sep-Dec
	FP2	60,000	≥20	Sep-Dec
	FP3	70,000	≥20	Sep-Dec
	FP4	80,000	≥10	Sep-Dec
	FP5	80,000	≥30	Sep-Dec

Table 7.2. Contribution matrix used for assessing the expected contribution of the revised EWRs towards achieving the Ecological Targets outlined for the Channel and Floodplain PEA.

Score	Description
0	No contribution expected
1	very minor contribution may occur, difficult to detect without intense and targeted survey effort
2	minor contribution, may only be detectable in some locations
3	moderate contribution towards achieving target expected
4	major contribution towards achieving target expected

Table 7.3. Expected contributions of the revised Channel and Floodplain EWRs towards the proposed Ecological Targets.

Attribute	Functional group	Code	EF ≥3,000 all year	IC1 ≥10000 ≥60	IC2 ≥20000 ≥60	IC3 ≥30000 ≥60	IC4 ≥40000 ≥60	FP1 50,000 ≥40	FP2 ≥60000 ≥20	FP3 ≥70000 ≥20	FP4 ≥80000 ≥10	FP5 ≥80000 ≥30
Woodland dependent fauna	Terrestrial birds	WDFN_1	0	0	0	0	0	1	2	3	4	4
		WDFN_2	0	0	0	0	0	1	2	3	4	4
	Reptiles and mammals	WDFN_3	0	0	2	2	4	4	4	4	4	4
		WDFN_4	0	0	2	2	4	4	4	4	4	4
		WDFN_5	0	2	2	2	2	2	2	2	2	2
Wetland dependent fauna	Frogs	FROG_1	0	1	2	2	4	4	4	4	4	4
		FROG_2	0	0	0	0	0	1	2	3	3	4
		FROG_3	0	0	2	3	4	3	3	3	3	3
		FROG_4	0	0	2	2	4	4	4	4	4	4
	Waterbirds	WBRD_1	0	0	1	2	3	4	4	4	4	4
		WBRD_2	0	0	0	1	2	3	4	4	4	4
		WBRD_3	0	0	0	1	2	3	4	4	4	4
		WBRD_4	0	0	0	0	2	2	3	4	4	4
	Turtles	TURT_1	0	0	0	0	0	1	1	1	1	1
		TURT_2	0	0	0	0	0	1	1	1	1	1
		TURT_3	0	0	0	0	0	1	1	1	1	1
		TURT_4	0	1	1	1	1	2	2	2	2	2
		TURT_5	0	0	0	0	0	1	1	2	2	2

Attribute	Functional group	Code	EF ≥3,000 all year	IC1 ≥10000 ≥60	IC2 ≥20000 ≥60	IC3 ≥30000 ≥60	IC4 ≥40000 ≥60	FP1 50,000 ≥40	FP2 ≥60000 ≥20	FP3 ≥70000 ≥20	FP4 ≥80000 ≥10	FP5 ≥80000 ≥30
Lateral and longitudinal connectivity	Basal Resources	CONN_1	0	0	2	3	4	4	4	4	4	4
	Invertebrate food resources	CONN_2	0	0	1	2	3	3	3	4	4	4
		CONN_3	0	0	1	2	3	3	3	4	4	4
		CONN_4	0	0	1	2	3	3	3	4	4	4
		CONN_5	0	0	0	0	1	2	3	4	4	4
	Water column stratification	CONN_6	1	4	4	4	4	4	4	4	4	4
		CONN_7	1	4	4	4	4	4	4	4	4	4
	Hydraulic conditions	CONN_8	0	0	3	4	4	4	4	4	4	4
		CONN_9	0	0	1	3	4	4	4	4	4	4
		CONN_10	0	0	0	0	1	2	2	3	4	4
		CONN_11	1	1	2	3	3	4	4	4	4	4

Attribute	Functional group	Code	EF ≥3,000 all year	IC1 ≥10000 ≥60	IC2 ≥20000 ≥60	IC3 ≥30000 ≥60	IC4 ≥40000 ≥60	FP1 50,000 ≥40	FP2 ≥60000 ≥20	FP3 ≥70000 ≥20	FP4 ≥80000 ≥10	FP5 ≥80000 ≥30
Water Quality	Phytoplankton blooms	WATR_1	1	3	4	4	4	4	4	4	4	4
	Dissolved Oxygen	WATR_2	3	4	4	4	4	4	4	4	4	4
	In-stream salinity	WATR_3	2	3	4	4	4	4	4	4	4	4
		WATR_4	2	3	4	4	4	4	4	4	4	4
	In-stream pH	WATR_5	4	4	4	4	4	4	4	4	4	4

Attribute	Functional group	Code	EF ≥3,000 all year	IC1 ≥10000 ≥60	IC2 ≥20000 ≥60	IC3 ≥30000 ≥60	IC4 ≥40000 ≥60	FP1 50,000 ≥40	FP2 ≥60000 ≥20	FP3 ≥70000 ≥20	FP4 ≥80000 ≥10	FP5 ≥80000 ≥30
Native fish	Murray cod	FISH_1	0	1	2	3	4	4	4	4	4	4
		FISH_2	0	1	2	3	4	4	4	4	4	4
	Golden Perch	FISH_3	0	0	2	3	3	3	4	4	4	4
		FISH_4	0	0	2	3	3	3	4	4	4	4
		FISH_5	0	0	2	3	3	3	4	4	4	4
	Silver Perch	FISH_6	0	1	3	3	3	3	3	3	3	3
		FISH_7	0	1	2	3	3	3	4	4	4	4
		FISH_8	0	0	2	3	3	3	4	4	4	4
	Freshwater catfish	FISH_9	0	1	1	1	1	2	2	2	2	2
		FISH_10	0	1	1	1	1	2	2	2	2	2
Floodplain trees	River Red Gum	TREE_1	0	0	1	1	2	2	3	3	3	4
		TREE_3	0	0	1	1	2	2	3	3	3	4
		TREE_4	0	0	1	1	2	2	3	3	3	4
	Black Box	TREE_5	0	0	0	0	0	1	2	3	3	4
		TREE_7	0	0	0	0	0	1	2	3	3	4
		TREE_8	0	0	0	0	0	1	2	3	3	4
	River Cooba	TREE_9	0	0	2	3	4	4	4	4	4	4
Shrublands	Lignum condition	LIGN_1	0	0	0	1	2	3	4	4	4	4
		LIGN_2	0	0	0	2	3	3	3	4	4	4
		LIGN_3	0	0	0	2	3	3	3	3	3	4
		LIGN_4	0	0	0	1	2	3	4	4	4	4

Attribute	Functional group	Code	EF	IC1	IC2	IC3	IC4	FP1	FP2	FP3	FP4	FP5
			≥3,000	≥10000	≥20000	≥30000	≥40000	50,000	≥60000	≥70000	≥80000	≥80000
			all year	≥60	≥60	≥60	≥60	≥40	≥20	≥20	≥10	≥30
Non-woody vegetation	Understory vegetation	UVEG_1	1	2	3	4	4	4	4	4	4	4
		UVEG_2	1	2	3	4	4	4	4	4	4	4
	Frequently inundated temporary wetlands and shedding floodplain	UVEG_3	0	1	2	3	4	4	4	4	4	4
		UVEG_4	0	1	2	3	4	4	4	4	4	4
		UVEG_5	0	1	1	2	4	4	4	4	4	4
		UVEG_6	0	1	1	2	4	4	4	4	4	4
	Infrequently inundated wetlands	UVEG_7	0	0	0	0	1	2	2	3	3	4
		UVEG_8	0	0	0	0	1	2	2	3	3	4
		UVEG_9	0	0	0	0	0	0	2	3	3	4
		UVEG_10	0	0	0	0	0	0	2	3	3	4
	Infrequently inundated shedding floodplain	UVEG_11	0	0	0	0	0	1	2	3	3	4
		UVEG_12	0	0	0	0	0	1	2	3	3	4
		UVEG_13	0	0	0	0	0	1	2	3	3	4
		UVEG_14	0	0	0	0	0	1	2	3	3	4
		UVEG_15	0	0	0	0	0	1	2	3	3	4
		UVEG_16	0	0	0	0	0	1	2	3	3	4
Groundwater	Conditions conducive to diverse native vegetation	GWTR_1	0	0	2	3	3	4	4	4	4	4
		GWTR_2	0	0	1	2	3	4	4	4	4	4
Soil condition	Soil moisture availability	SOIL_1	0	0	1	2	2	3	3	4	4	4
		SOIL_2	0	0	0	0	1	1	2	3	3	4
		SOIL_3	0	0	0	2	3	3	3	3	3	4
	Soil Salinity	SOIL_4	0	0	0	0	1	1	2	3	3	4
		SOIL_5	0	0	0	0	0	1	1	2	3	3
		SOIL_6	0	0	0	0	0	1	1	2	3	3

8 Supporting information

The following sub-sections contain information that underpins the proposed Ecological Targets that is not presented in other readily available documents/formats.

8.1 Increased condition metric for tree condition

Within the conceptual model (Figure 8.1) that underpins the management utility of the tree condition data (Wallace *et al.* 2020), TCI scores ≥10 are considered to represent good condition, and TCI scores ≤8 are considered to indicate a high degree of water stress. For trees with TCI scores ≤8, continuation of dry conditions is likely to lead to either (i) a marked loss of condition requiring multiple, back-to-back delivery of water for trees to improve sufficiently to achieve "good" condition, or (ii) an irreversible loss (death) of trees. Because the strength of the response to environmental watering decreases as the TCI score decrease, avoiding the need for repeat (high frequency) watering by delivering water when trees are still in good condition should be a management priority.

Intuitively, it would be expected that the "target condition" would be for viable trees to be in "good" condition and the assessment area to be rated as *very low* priority for delivery of environmental water. However, the Ecological Target specified in the existing SA River Murray LTWP (DEWNR 2015) utilises a metric of *70% of trees have a Tree Condition Index score ≥10*. The benchmark hypothetical dataset for this condition distribution (Figure 8.2) shows that it is possible to meet the Ecological Target whilst (i) having a number of trees within the assessment area with TCI scores ≤8, and (ii) rating the site as *moderate* priority for delivery of environmental water. This outcome is evident within the data collected from the quasi annual tree condition surveys conducted at Chowilla (Wallace 2023a), Pike (Wallace 2023d) and Katarapko (Wallace 2023b). Therefore, it is considered that the existing target metric (*70% of trees have a Tree Condition Index score ≥10*) is too low, and that the target metric should be increased such that no viable trees receive scores ≤8 and the assessment area is rated as *very low* priority for environmental water delivery.

Benchmark hypothetical data sets with 74%, 81% and 93% of viable trees with TCI scores ≥10 (Figure 8.3) contain 10%, 7% and 0% of trees receiving TCI scores ≤8. Within the system currently utilised to ascertain the need for delivery of environmental water to the three major floodplain complexes of Chowilla, Pike and Katarapko (e.g. Wallace 2023d), this equates to *moderate*, *low* and *very low priority* for environmental water delivery respectively. Hence it is recommended that the target metric be increased to *90% of trees have a Tree Condition Index score ≥10*. Analysis of data from quasi-annual surveys undertaken at Chowilla (Wallace 2023a), Pike (Wallace 2023d) and Katarapko (Wallace 2023b) demonstrate that achieving the proposed target benchmark of *90% of trees have a Tree Condition Index score ≥10* is readily achievable in areas that receive environmental water at an appropriate frequency and duration.

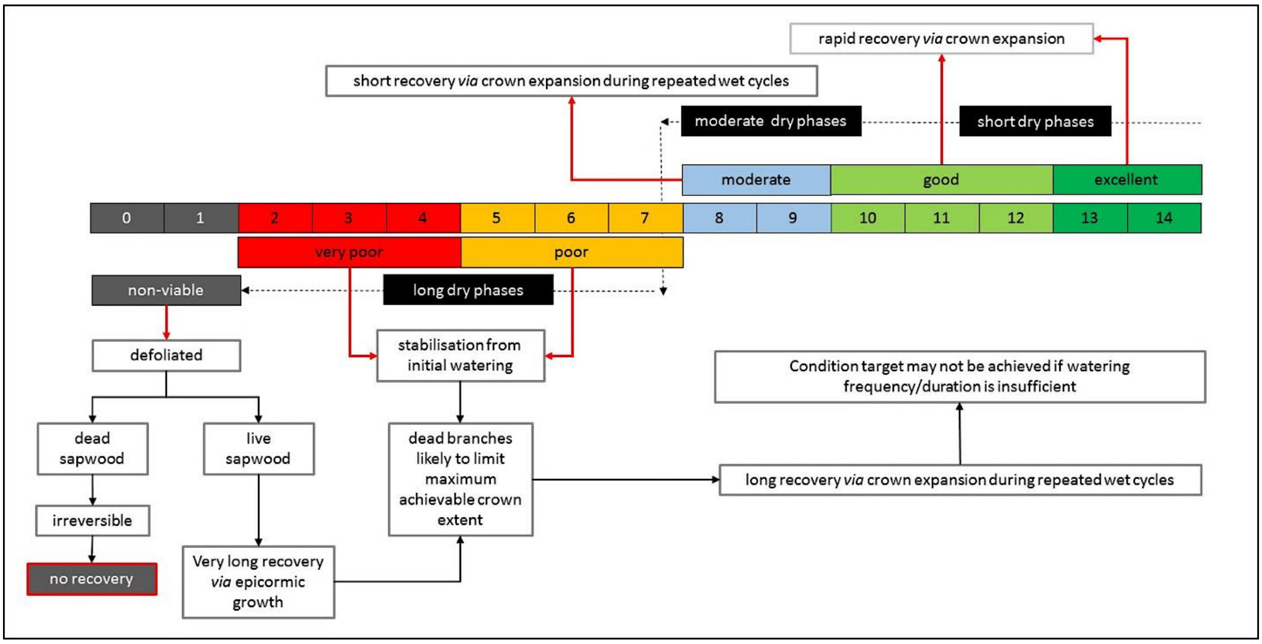

Figure 8.1. Conceptual model of stress-recovery (state transition model) for floodplain eucalypts

From Wallace *et al.* (2020); Conceptual model of stress-recovery (state transition model) for floodplain eucalypts that builds on Wallace (2015b), Souter et al. (2010b) and Bond et al. (2018) and recognises that (i) trajectories for crown decline and recovery occur via different pathways rather than a simple linear reversal, and (ii) recovery and decline do not proceed at the same rates. TCI values range from 0 (non-viable) to 14 (excellent). Short-interval dry periods facilitate maintaining condition within the good-excellent range (trees with TCI ≥10). Moderate-interval dry periods degrade crown condition to moderate condition (i.e. TCI 8 and 9) but a return to near natural inundation return intervals will restore trees to "good" condition within less than 3 years. Long-interval dry periods result in a major decline from poor to very poor condition (TCI 4 to 6), and a much longer period is required to recover trees. Very poor condition trees (TCI ≤4) undergo a much slower recovery rate and may become non-viable and fail to recover because of a lack of live sapwood to support transpiration. Delivery of environmental water would ideally be triggered before tree TCI scores fall below 8 to preclude the long recovery times and intensive management regimes required to restore severely stressed woodlands.

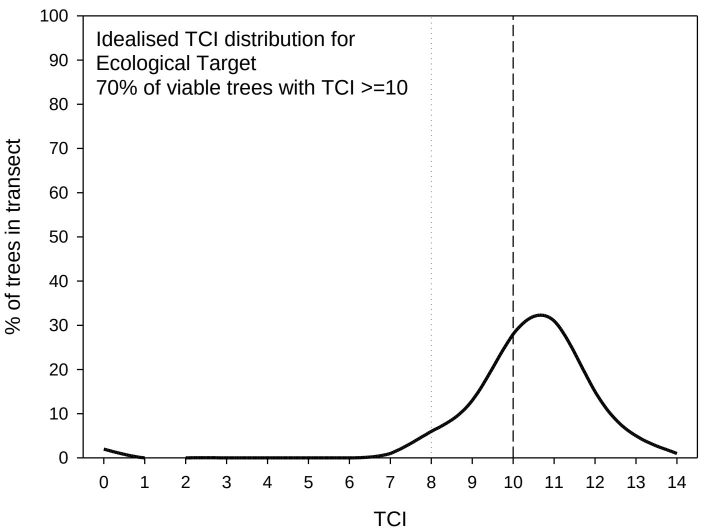

Figure 8.2. Idealised TCI distribution for ecological target

A hypothetical transect in which 70% of trees have TCI scores ≥10. The spline curve fitted to this hypothetical data set generates a reference condition against which observational data from existing transects can be considered. The vertical reference line at TCI 10 indicates the target. The vertical reference line at TCI 8 indicates the threshold at which delivery of water is considered a priority. From Wallace (2019a).

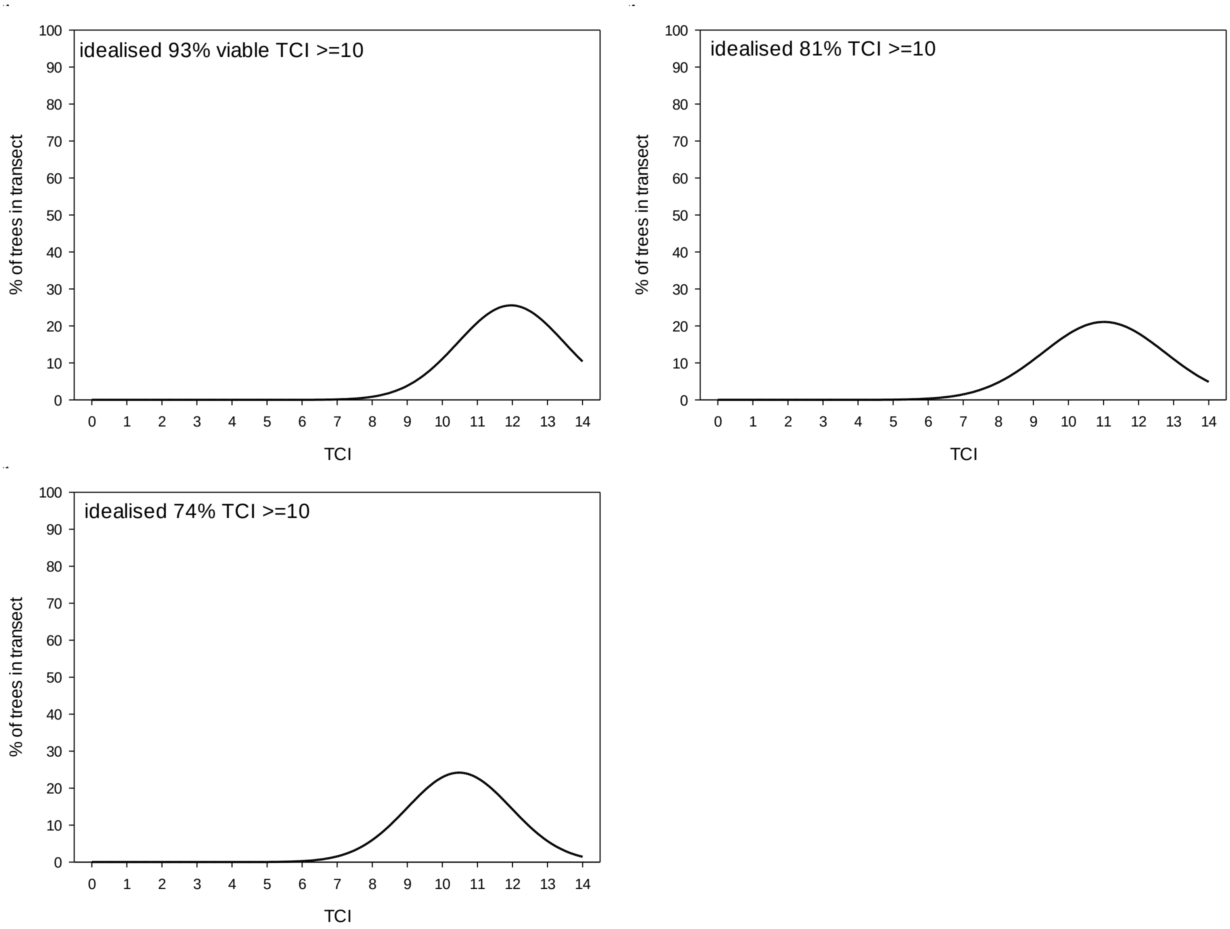

Figure 8.3. **Idealised TCI benchmark datasets**

Benchmark data sets in which 74%, 81% and 93% of trees have TCI scores ≥10. The spline curve fitted to these hypothetical data sets generates a reference condition against which observational data from existing transects can be considered.

8.2 Expected species list for bats

Expected species list for bats on the SA River Murray Floodplain, based on floodplain monitoring (Linke 2022; Linke 2023; Redleaf Environmental 2021) and datasets in Biological Databases of South Australia and Australasian Bat Society https://www.ausbats.org.au/batmap.html

Table 8.1. **Expected species lists for bats**

Family	Common name	Scientific name
Vespertilionidae	Gould's Wattled Bat	*Chalinolobus gouldii*
	Chocolate Wattled Bat	*Chalinolobus morio*
	Little Pied Bat	*Chalinolobus picatus*
	Large-footed Myotis	*Myotis macropus*
	Corben’s Long-eared Bat	*Nyctophilus corbeni*

Family	Common name	Scientific name
	Lesser Long-eared Bat	*Nyctophilus geoffroyi*
	Inland Broad-nosed Bat	*Scotorepens balstoni*
	Inland Forest Bat	*Vespadelus baverstocki*
	Large Forest Bat	*Vespadelus darlingtoni*
	Southern Forest Bat	*Vespadelus regulus*
	Little Forest Bat	*Vespadelus vulturnus*
Molossidae	White-striped Free-tailed Bat	*Austronomus australis*
	Inland Free-tailed Bat	*Ozimops petersi*
	Southern Free-tailed Bat	*Ozimops planiceps*
	Ride's Free-tailed Bat	*Ozimops ridei*
Emballonuridae	Yellow-bellied Sheath-tailed Bat	*Saccolaimus flaviventris*
Pteropodidae	Grey-headed Flying-fox	*Pteropus poliocephalus*

8.3 Expected species list for waterbirds

Table 8.2. Expected species list for waterbirds (Hodder pers comm, 27th November 2024)

Species	Common name
Acrocephalus australis australis	Australian Reed Warbler
Actitis hypoleucos	Common Sandpiper
Anas castanea	Chestnut Teal
Anas gracilis gracilis	Grey Teal
Anas platyrhynchos platyrhynchos	Mallard
Anas superciliosa	Pacific Black Duck
Anhinga novaehollandiae novaehollandiae	Australasian Darter
Anseranas semipalmata	Magpie Goose
Ardea alba modesta	Great Egret
Ardea intermedia plumifera	Intermediate Egret
Ardea pacifica	White-necked Heron
Arenaria interpres interpres	Ruddy Turnstone
Aythya australis	Hardhead
Biziura lobata menziesi	Musk Duck
Botaurus poiciloptilus	Australasian Bittern
Bubulcus ibis coromandus	Eastern Cattle Egret
Calidris acuminata	Sharp-tailed Sandpiper
Calidris ferruginea	Curlew Sandpiper
Calidris melanotos	Pectoral Sandpiper
Calidris ruficollis	Red-necked Stint
Calidris subminuta	Long-toed Stint
Cereopsis novaehollandiae novaehollandiae	Cape Barren Goose
Charadrius bicinctus bicinctus	Double-banded Plover
Charadrius ruficapillus	Red-capped Plover
Charadrius veredus	Oriental Plover
Chenonetta jubata	Australian Wood Duck
Chlidonias hybrida javanicus	Whiskered Tern

Species	Common name
Chlidonias leucopterus	White-winged Tern
Chroicocephalus novaehollandiae novaehollandiae	Silver Gull
Circus approximans	Swamp Harrier
Cisticola exilis exilis	Golden-headed Cisticola
Cladorhynchus leucocephalus	Banded Stilt
Cygnus atratus	Black Swan
Egretta garzetta nigripes	Little Egret
Egretta novaehollandiae	White-faced Heron
Elseyornis melanops	Black-fronted Dotterel
Erythrogonys cinctus	Red-kneed Dotterel
Fulica atra australis	Eurasian Coot
Gallinago hardwickii	Latham's Snipe
Gallinula tenebrosa tenebrosa	Dusky Moorhen
Gallirallus philippensis mellori	Buff-banded Rail
Gelochelidon macrotarsa	Australian Tern
Gelochelidon nilotica affinis	Gull-billed Tern
Haliaeetus leucogaster	White-bellied Sea Eagle
Himantopus leucocephalus	Pied Stilt
Hydroprogne caspia	Caspian Tern
Lewin pectoralis pectoralis	Lewin's Rail
Limosa lapponica	Bar-tailed Godwit
Limosa limosa melanuroides	Black-tailed Godwit
Malacorhynchus membranaceus	Pink-eared Duck
Microcarbo melanoleucos melanoleucos	Little Pied Cormorant
Numenius madagascariensis	Far Eastern Curlew
Numenius minutus	Little Curlew
Nycticorax caledonicus australasiae	Nankeen Night Heron
Oxyura australis	Blue-billed Duck
Pelecanus conspicillatus	Australian Pelican
Peltohyas australis	Inland Dotterel
Phalacrocorax carbo	Great Cormorant
Phalacrocorax sulcirostris	Little Black Cormorant
Phalacrocorax varius hypoleucos	Australian Pied Cormorant
Platalea flavipes	Yellow-billed Spoonbill
Platalea regia	Royal Spoonbill
Plegadis falcinellus	Glossy Ibis
Pluvialis fulva	Pacific Golden Plover
Pluvialis squatarola squatarola	Grey Plover
Podiceps cristatus australis	Great Crested Grebe
Poliocephalus poliocephalus	Hoary-headed Grebe
Poodytes gramineus goulburni	Little Grassbird
Porphyrio melanotus melanotus	Australasian Swamphen
Porzana fluminea	Australian Crake (Australian Spotted Crake)
Recurvirostra novaehollandiae	Red-necked Avocet

Species	Common name
Rostratula australis	Australian Painted-snipe
Spatula rhynchotis	Australasian Shoveler
Stictonetta naevosa	Freckled Duck
Stiltia isabella	Australian Pratincole
Tachybaptus novaehollandiae novaehollandiae	Australasian Grebe
Tadorna tadornoides	Australian Shelduck
Threskiornis molucca molucca	Australian White Ibis
Threskiornis spinicollis	Straw-necked Ibis
Tribonyx ventralis	Black-tailed Nativehen
Tringa glareola	Wood Sandpiper
Tringa nebularia	Common Greenshank
Tringa stagnatilis	Marsh Sandpiper
Vanellus miles	Masked Lapwing
Vanellus tricolor	Banded Lapwing
Zapornia pusilla palustris	Baillon's Crake
Zapornia tabuensis	Spotless Crake

8.4 Expected species list for woodland (terrestrial) birds

Table 8.3. Expected species list for woodland (terrestrial) birds (Hodder pers. Comm 27 November 2024)

Species	Common name
Struthidea cinerea cinerea	Apostlebird
Ninox boobook boobook	Australian Boobook
Pachycephala pectoralis youngi	Australian Golden Whistler
Falco longipennis murchisonianus	Australian Hobby
Gymnorhina tibicen	Australian Magpie
Aegotheles cristatus cristatus	Australian Owlet-nightjar
Anthus australis australis	Australian Pipit
Corvus coronoides	Australian Raven
Sugomel niger	Black Honeyeater
Milvus migrans affinis	Black Kite
Daphoenositta chrysoptera pileata	Black-capped Sittella
Chalcites osculans	Black-eared Cuckoo
Manorina flavigula melanotis	Black-eared Miner
Coracina novaehollandiae	Black-faced Cuckooshrike
Artamus cinereus melanops	Black-faced Woodswallow
Elanus axillaris	Black-shouldered Kite
Entomyzon cyanotis cyanotis	Blue-faced Honeyeater
Neophema chrysostoma	Blue-winged Parrot
Falco berigora berigora	Brown Falcon
Accipiter fasciatus fasciatus	Brown Goshawk
Coturnix ypsilophora australis	Brown Quail
Cincloramphus cruralis	Brown Songlark

Species	Common name
Climacteris picumnus picumnus	Brown Treecreeper
Melithreptus brevirostris pallidiceps	Brown-headed Honeyeater
Melopsittacus undulatus	Budgerigar
Burhinus grallarius	Bush Stonecurlew
Pomatostomus ruficeps	Chestnut-crowned Babbler
Acanthiza uropygialis	Chestnut-rumped Thornbill
Nymphicus hollandicus	Cockatiel
Accipiter cirrocephalus cirrocephalus	Collared Sparrowhawk
Turdus merula merula	Common Blackbird
Phaps chalcoptera	Common Bronzewing
Sturnus vulgaris vulgaris	Common Starling
Oreoica gutturalis	Crested Bellbird
Ocyphaps lophotes lophotes	Crested Pigeon
Epthianura tricolor	Crimson Chat
Platycercus elegans	Crimson Rosella
Geopelia cuneata	Diamond Dove
Artamus cyanopterus cyanopterus	Dusky Woodswallow
Tyto javanica delicatula	Eastern Barn Owl
Northiella haematogaster haematogaster	Eastern Bluebonnet
Falcunculus frontatus frontatus	Eastern Shriketit
Neophema elegans elegans	Elegant Parrot
Dromaius novaehollandiae novaehollandiae	Emu
Alauda arvensis arvensis	Eurasian Skylark
Carduelis carduelis britannica	European Goldfinch
Petrochelidon ariel	Fairy Martin
Cacomantis flabelliformis flabelliformis	Fan-tailed Cuckoo
Columba livia	Feral Pigeon
Eolophus roseicapilla albiceps	Galah
Pachycephala inornata	Gilbert's Whistler
Cracticus torquatus leucopterus	Grey Butcherbird
Strepera versicolor	Grey Currawong
Rhipidura albiscapa	Grey Fantail
Colluricincla harmonica harmonica	Grey Shrikethrush
Ptilotula plumula	Grey-fronted Honeyeater
Coracina maxima	Ground Cuckooshrike
Melanodryas cucullata cucullata	Hooded Robin
Chalcites basalis	Horsfield's Bronze Cuckoo
Mirafra javanica	Horsfield's Bush Lark
Passer domesticus domesticus	House Sparrow
Acanthiza apicalis albiventris	Inland Thornbill
Microeca fascinans assimilis	Jacky Winter
Dacelo novaeguineae novaeguineae	Laughing Kookaburra
Cacatua sanguinea gymnopis	Little Corella
Corvus bennetti	Little Crow

Species	Common name
Hieraaetus morphnoides	Little Eagle
Philemon citreogularis citreogularis	Little Friarbird
Corvus mellori	Little Raven
Grallina cyanoleuca cyanoleuca	Magpielark
Lophochroa leadbeateri leadbeateri	Major Mitchell's Cockatoo
Barnardius zonarius barnardi	Mallee Ringneck
Artamus personatus	Masked Woodswallow
Dicaeum hirundinaceum hirundinaceum	Mistletoebird
Psephotellus varius	Mulga Parrot
Glossopsitta concinna	Musk Lorikeet
Falco cenchroides cenchroides	Nankeen Kestrel
Phylidonyris novaehollandiae novaehollandiae	New Holland Honeyeater
Manorina melanocephala	Noisy Miner
Oriolus sagittatus sagittatus	Olive-backed Oriole
Epthianura aurifrons	Orange Chat
Apus pacificus pacificus	Pacific Swift/fork-tailed swift
Turnix varius varius	Painted Buttonquail
Cacomantis pallidus	Pallid Cuckoo
Geopelia placida placida	Peaceful Dove
Falco peregrinus macropus	Peregrine Falcon
Cracticus nigrogularis nigrogularis	Pied Butcherbird
Certhionyx variegatus	Pied Honeyeater
Malurus assimilis assimilis	Purple-backed Fairywren
Parvipsitta porphyrocephala	Purple-crowned Lorikeet
Lichenostomus cratitius occidentalis	Purple-gaped Honeyeater
Merops ornatus	Rainbow Bee-eater
Trichoglossus moluccanus moluccanus	Rainbow Lorikeet
Anthochaera carunculata	Red Wattlebird
Todiramphus pyrrhopygius	Red-backed Kingfisher
Petroica goodenovii	Red-capped Robin
Psephotus haematonotus	Red-rumped Parrot
Pyrrholaemus brunneus	Redthroat
Polytelis anthopeplus monarchoides	Regent Parrot
Myiagra inquieta	Restless Flycatcher
Cincloramphus mathewsi	Rufous Songlark
Pachycephala rufiventris rufiventris	Rufous Whistler
Todiramphus sanctus sanctus	Sacred Kingfisher
Zosterops lateralis pinarochrous	Silvereye
Gavicalis virescens sonorus	Singing Honeyeater
Drymodes brunneopygia	Southern Scrub Robin
Aphelocephala leucopsis leucopsis	Southern Whiteface
Acanthagenys rufogularis	Spiny-cheeked Honeyeater
Malurus splendens	Splendid Fairywren
Spilopelia chinensis	Spotted Dove

Species	Common name
Circus assimilis	Spotted Harrier
Eurostopodus argus	Spotted Nightjar
Pardalotus punctatus	Spotted Pardalote
Pardalotus striatus substriatus	Striated Pardalote
Plectorhyncha lanceolata	Striped Honeyeater
Coturnix pectoralis	Stubble Quail
Cacatua galerita	Sulphur-crested Cockatoo
Malurus cyaneus leggei	Superb Fairywren
Podargus strigoides brachypterus	Tawny Frogmouth
Gliciphila melanops	Tawny-crowned Honeyeater
Petrochelidon nigricans neglecta	Tree Martin
Aquila audax audax	Wedge-tailed Eagle
Smicrornis brevirostris occidentalis	Weebill
Hirundo neoxena neoxena	Welcome Swallow
Gerygone fusca	Western Gerygone
Haliastur sphenurus	Whistling Kite
Cheramoeca leucosterna	White-backed Swallow
Artamus leucorynchus	White-breasted Woodswallow
Pomatostomus superciliosus	White-browed Babbler
Artamus superciliosus	White-browed Woodswallow
Nesoptilotis leucotis depauperata	White-eared Honeyeater
Epthianura albifrons	White-fronted Chat
Purnella albifrons	White-fronted Honeyeater
Melithreptus lunatus	White-naped Honeyeater
Ptilotula penicillata penicillata	White-plumed Honeyeater
Corcorax melanorhamphos melanorhamphos	White-winged Chough
Malurus leucopterus leuconotus	White-winged Fairywren
Lalage tricolor	White-winged Triller
Rhipidura leucophrys leucophrys	Willie Wagtail
Acanthiza nana	Yellow Thornbill
Ptilotula ornata	Yellow-plumed Honeyeater
Acanthiza chrysorrhoa leighi	Yellow-rumped Thornbill
Manorina flavigula	Yellow-throated Miner
Taeniopygia guttata castanotis	Zebra Finch

8.5 Species list and functional group classification for microinvertebrates

Table 8.4. Species list and functional group classification for microinvertebrates

Species	Functional group
Habrotrocha sp.	Littoral
Philodina sp.	Littoral
Rotaria neptunia	Littoral
Rotaria sp.	Littoral

Species	Functional group
indet. bdelloid [sm]	Littoral
indet. bdelloid [lg]	Littoral
Asplanchna cf. *brightwellii*	Pelagic
Asplanchna priodonta	Pelagic
Asplanchna sp.	Pelagic
Asplanchnopus sp.	Pelagic
Anuraeopsis coelata	Pelagic
Anuraeopsis fissa	Pelagic
Brachionus angularis	Pelagic
Brachionus bennini	Pelagic/Littoral
Brachionus bidens	Pelagic
Brachionus bidentatus	Pelagic/Littoral
Brachionus budapestinensis	Pelagic
Brachionus calyciflorus amphiceros	Pelagic
Brachionus calyciflorus s.l.	Pelagic
Brachionus caudatus personatus	Pelagic
Brachionus diversicornis	Pelagic
Brachionus falcatus	Pelagic
Brachionus keikoa	Pelagic
Brachionus lyratus	Pelagic
Brachionus nilsoni	Pelagic
Brachionus novaezealandiae	Pelagic
Brachionus quadridentatus cluniorbicularis	Pelagic/Littoral
Brachionus quadridentatus s. str.	Pelagic
Brachionus rubens	Pelagic
Brachionus urceolaris	Pelagic
Brachionus n. sp.	Pelagic
Brachionus sp.	Pelagic
Keratella australis	Pelagic
Keratella cochlearis	Pelagic
Keratella javana	Pelagic
Keratella procurva	Pelagic
Keratella quadrata	Pelagic
Keratella shieli	Pelagic
Keratella slacki	Pelagic
Keratella tropica	Pelagic
Plationus patulus	Pelagic
Collotheca cf. *tenuilobata*	Pelagic
Collotheca sp.	Littoral
Conochilus dossuarius	Pelagic
Conochilus natans	Pelagic
cf. *Dicranophoroides* sp.	Littoral
cf. *Dicranophorus* sp.	Littoral
cf. *Encentrum* spp.	Littoral

Species	Functional group
cf. *Epiphanes* sp.	Pelagic
cf. *Microcodides* sp.	Pelagic
Proalides tentaculatus	Pelagic
Proalides sp.	Pelagic
Euchlanis sp.	Littoral
Ptygura sp.	Pelagic
flosculariid sp. [cf. *Sinanatherina*]	Littoral
Ascomorpha cf. *ovalis*	Pelagic
Ascomorpha saltans	Pelagic
Hexarthra intermedia	Pelagic
Hexarthra sp.	Pelagic
Lecane bulla	Littoral
Lecane 'bulloid'	Littoral
Lecane closterocerca	Littoral
Lecane crepida	Littoral
Lecane curvicornis	Littoral
Lecane flexilis	Littoral
Lecane hamata	Littoral
Lecane nr *hamata*	Littoral
Lecane ludwigii	Littoral
Lecane luna	Littoral
Lecane lunaris	Littoral
Lecane obtusa	Littoral
Lecane signifera	Littoral
Lecane stenroosi	Littoral
Lecane ungulata	Littoral
Lecane (*s. str.*) sp.	Littoral
Lecane (*M.*) sp. a	Littoral
Lecane (*M.*) sp. b	Littoral
Colurella obtusa	Littoral
Colurella uncinata bicuspidata	Littoral
Colurella sp.	Littoral
Lepadella acuminata	Littoral
Lepadella patella	Littoral
Lepadella rhomboides	Littoral
Lepadella sp.	Littoral
Squatinella sp.	Littoral
Lindia sp.	Littoral
Lophocharis salpina	Littoral
cf. *Proales* sp.	Littoral
Cephalodella catellina	Littoral
Cephalodella gibba	Littoral
Cephalodella sp. a	Littoral
Cephalodella sp. b	Littoral

Species	**Functional group**
Cephalodella sp. c	Littoral
Eosphora sp.	Littoral
Monommata sp.	Littoral
Notommata spp.	Littoral
cf. *Taphrocampa* sp.	Littoral
indet. elong. notommatid	Littoral
Scaridium cf. *longicaudum*	Littoral
Polyarthra dolichoptera	Pelagic
Polyarthra vulgaris	Pelagic
Synchaeta oblonga	Pelagic
Synchaeta pectinata	Pelagic
Synchaeta n. sp.	Pelagic
Pompholyx complanata	Pelagic
Testudinella patina	Pelagic
Trichocerca bicristata	Littoral (facultatively pelagic)
Trichocerca bidens	Littoral (facultatively pelagic)
Trichocerca pusilla	Littoral (facultatively pelagic)
Trichocerca similis	Littoral (facultatively pelagic)
Trichocerca similis grandis	Littoral (facultatively pelagic)
Trichocerca cf. *tigris*	Littoral (facultatively pelagic)
Trichocerca cf. *weberi*	Littoral (facultatively pelagic)
Trichotria tetractis similis	Littoral
Filinia australiensis	Pelagic
Filinia brachiata	Pelagic
Filinia grandis	Pelagic
Filinia longiseta	Pelagic
Filinia opoliensis	Pelagic
Filinia passa	Pelagic
Filinia pejleri	Pelagic
Filinia terminalis	Pelagic
indet. 2-toed rotifer	Littoral
indet. glob. rotifer	Littoral
indet. plicate rotifer	Littoral
Bosmina meridionalis	Pelagic
Armatalona macrocopa	Littoral
Chydorus cf. *eurynotus*	Littoral
Leberis diaphanus	Littoral
Picripleuroxus quasidenticulatus	Littoral
Pseudochydorus globosus	Littoral
Pseudomonospilus diporus	Littoral
indet. chydorid	Littoral
Ceriodaphnia cornuta	Pelagic
Ceriodaphnia sp.	Pelagic
Daphnia carinata s.l.	Pelagic

Species	Functional group
Daphnia lumholtzi	Pelagic
Daphnia sp.	Pelagic
Simocephalus sp.	Littoral
Ilyocryptus sp.	Littoral
Macrothrix sp.	Lottoral
Moina cf. *australiensis*	Pelagic
Moina micrura	Pelagic
Moina cf. tenuicornis	Pelagic
Neothrix sp.	Littoral
Diaphanosoma excisum	Pelagic
Boeckella triarticulata	Pelagic
Calamoecia ampulla	Pelagic
Calamoecia sp.	Pelagic
Gladioferens sp.	Pelagic
calanoid copepodite	Pelagic
calanoid nauplii	Pelagic
Australocyclops australis	Littoral
Microcyclops varicans	Littoral
Thermocyclops sp.	Littoral
indet subadult cyclopoid	Littoral
cyclopoid copepodite	Littoral
cyclopoid nauplii	Littoral
indet. cyclopoid nauplius	Littoral
indet. harpac.	Littoral
harpac. copepodite	Littoral
indet. copepod nauplius	Littoral
Limnocythere sp.	Littoral
indet. ostracod [juv.]	Littoral

8.6 Groundwater salinity thresholds

The groundwater salinity thresholds utilised to define low salinity lens (LSL) for river red gum (<8,000 µScm^{-1}) and black box (<8,000 µScm^{-1}) are derived from a workshop held in 2016 (Denny *et al.* 2016) to facilitate ecological interpretation of groundwater modelling data (Table 8.5).

Table 8.5. Groundwater salinity thresholds for river red gum and black box. Adapted from Denny *et al.* (2016)

Red gum

DEPTH (metres below ground)	EC -> <5,000	5,000 – 20,000	20,000 – 28,000	28,000+
0 – 0.5	Waterlogging hazard	Waterlogging hazard	Waterlogging - saline	Waterlogging - saline
0.5 – 2.5	Fresh groundwater lens	Potential alternative water	Transition - shallow	Saline – not available, shallow
2.5 – 4.5	Fresh groundwater lens	Potential alternative water	Transition	Saline – not available
4.5 – 9	Fresh groundwater lens - deep	Potential alternative water - deep	Transition - deep	Saline – not available
9+	N/A	N/A	N/A	N/A

Black box

WATERTABLE DEPTH (mbgl)	Salinity ($\mu S.cm^{-1}$) <8000	8000 – 39,000	39,000 – 55,000	55,000+
0 – 0.5	Waterlogging hazard	Waterlogging hazard	Waterlogging – saline	Waterlogging – saline
0.5 – 2.5	Fresh groundwater lens	Potential alternative water	Transition – shallow	Saline – not available, shallow
2.5 – 6	Fresh groundwater lens	Potential alternative water	Transition	Saline – not available
6 – 9	Fresh groundwater lens – deep	Potential alternative water – deep	Transition – deep	Saline – not available
9+	Beyond potential rooting depth	Beyond potential rooting depth	Beyond potential rooting depth	Beyond potential rooting depth

- Groundwater at or below this salinity is conducive to supporting trees in good condition. (→ Fresh groundwater lens – deep)
- expected to be able to sustain tree transpiration between surface water inundation and/or effective rainfall events (→ Potential alternative water – deep)
- Very marginal water source, reliance on water of this salinity is expected to result in rapid decline in tree condition (→ Transition – deep)

8.7 Assessment of EWR contributions for extent of river channel with velocity above 0.2 and 0.3 m/s

Key inputs into development of the expected contribution tables (Table 7.3) included the hydrodynamic modelling of cross-sectional velocity (Montazeri and Gibbs 2019). The data utilised in the assessment is presented in Table 8.6.

Table 8.6. Hydrodynamic modelling results for percentage of weir pools with velocity exceeding 0.2 and 0.3 m/s

Weir pool	% weir pool with velocity exceeding 0.2 m/s			% weir pool with velocity exceeding 0.3 m/s		
	@ QSA 15,000 ML/day	@ QSA 20,000 ML/day	@ QSA 30,000 ML/day	@ QSA 15,000 ML/day	@ QSA 20,000 ML/day	@ QSA 30,000 ML/day
Weir pool 5	64%	91%	99%	17%	35%	89%
Weir pool 4	68%	98%	99%	18%	37%	94%
Weir pool 3	80%	97%	100%	25%	61%	95%
Weir pool 2	97%	100%	100%	45%	88%	100%
Weir pool 1	87%	99%	100%	30%	61%	99%

8.8 Assessment of EWR contributions for long lived vegetation outcomes

Key inputs into development of the expected contribution tables (Table 7.3) included inundation response curves for targeted vegetation groups (e.g. black box, red gum, lignum) and functional water management units (e.g. temporary wetlands). An example of the response curves used in the assessment is presented in Figure 8.4. Changes in the expected magnitude of contribution (Table 7.3) were determined via an assessment of changes in the area inundated as flows increase. The assessment utilised (i) points of inflexion, (ii) step changes in area, and (iii) large increases in area for relatively small increases in flow (see Figure 8.4 as an example) to assign contribution scores, rather than categorical (e.g <5%, 5-24%, 25-49%, 50-74% and >75%) breakpoints. Whilst data is available for flow bands between 20,000 and 100,000 $MLday^{-1}$, in all cases scores were assessed on the basis of the percent of habitat within the boundary of the Floodplain PEA was at 80,000 ML/day.

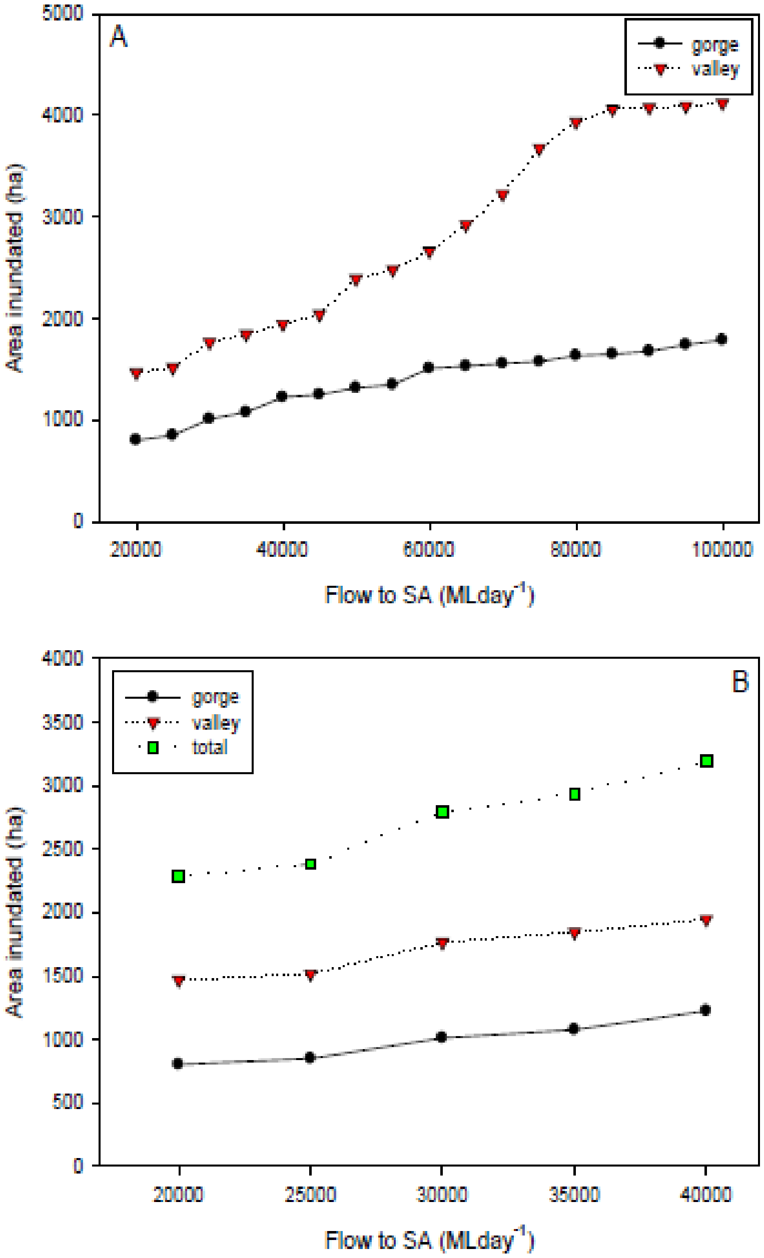

Figure 8.4. Flow-area inundation plots for ephemeral (temporary wetlands). Note the step-change in area (ha) inundated for flows of 25,000-30,000 $MLday^{-1}$. Data from Wallace *et al.* (2014a)

9 Non-environmental water related targets

The following targets were discussed during the workshop process and identified as being important indicators of floodplain condition. They did not make the initial list (Section 5) nor the refined list (Section 6) of recommended targets for inclusion in the 2024 update of the long-term watering plan, as they are either (i) river operations/structure operation issues, (ii) land management issues, or (iii) the respective attributes is unlikely to respond to or be able to be managed directly by delivery of environmental flows.

Table 9.1. Non-environmental water related targets. Not recommended for inclusion in the 2024 update of the LTWP

Objective	Target
Restore the distribution of native fish	Water levels remain within operational envelopes that facilitate effective fishway operation between mid September and mid March
	85% of managed wetlands have unrestricted lateral connectivity to the river/creek for a minimum of 60 continuous days during late spring-early summer, when flows are above 20,000 $MLday^{-1}$ and water temperature is ≥18 °C
Minimise the proportion of total fish biomass within the Lower Murray comprised of common carp	Relative proportion of total biomass of fish that is comprised of common carp does not increase
Decrease in turtle nest predation rate	Turtle nest predation rates ≤ 90% 1 in 5 years
Weeds do not compromise the resilience, population sustainability or habitat values of native vegetation	In temporary wetlands, a maximum of 1% of cells containing declared weeds in any given survey.
	In temporary wetlands, a maximum of 20% of cells containing exotic taxa in any given survey.
	In shedding floodplain zones, a maximum of 1% of cells containing declared weeds in any given survey
	In shedding floodplain zones in late Summer to early Autumn, a maximum of 5% of cells containing exotic taxa in any given survey
	Cumbungi distribution is maintained within ±20% of the range recorded during the baseline survey period
Grazing pressure does not compromise the resilience, population sustainability or habitat values of native vegetation	Grazing pressure does not reduce species diversity
	Grazing pressure does not reduce woody seedling abundance
	Grazing pressure does not reduce the number of distinct vegetation strata
	Grazing pressure does not increase the percentage of bare ground

Objective	Target
Establish and maintain soil conditions conducive to supporting diverse ecologically functional native vegetation	Where groundwater salinity is >8,000 μScm^{-1}, the capillary fringe is below the extinction depth for evaporation during inter-flood (dry) periods
	Soil pH in the unsaturated zone is maintained between 5.4-8.3 (slightly acidic-slightly alkaline)
	Soil sodicity in the 0.0-0.2 m interval shows a stable or declining trend relative to the baseline
	Groundwater pH remains within Australian & New Zealand Guidelines for fresh & Marine Water quality guidelines (6.5-9)

10Glossary

BWS — Basin-Wide Environmental Watering Strategy – published by the Murray-Darling Basin Authority, a legislative requirement under Chapter 8 of the Basin Plan.

DEW — South Australian Department for Environment and Water.

DEWNR — South Australian Department of Environment, Water and Natural Resources.

Discharge — The volumetric flow rate of water i.e. volume of streamflow over a given time. In South Australia, this is often represented as ML/day.

EEO — Expected Environmental Outcomes

EPBC Act — *Environment Protection and Biodiversity and Conservation Act 1999.*

EWR — Environmental Water Requirement - the water regime needed to sustain the ecological values of aquatic ecosystems and biological diversity at a low level of risk.

GDE — Groundwater dependent ecosystem.

Landscape Act — *Landscape South Australia Act 2019.*

Lower Lakes — Lakes Alexandrina and Albert.

LTWP — Long-Term Environmental Watering Plan – a legislative requirement under Chapter 8 of the Basin Plan.

MDBA — Murray-Darling Basin Authority.

ML/day — Megalitres per day – a measure of flow or discharge, where a megalitre equals 1,000,000 litres.

NRM — Natural resource management.

PEA — Priority Environmental Asset – defined in s8.49 of the Basin Plan as an environmental asset that can be managed with environmental water.

PEF — Priority Environmental Function - defined in s8.50 of the Basin Plan as an ecosystem functions that can be managed with environmental water.

QSA — Flow to South Australia

SARFIIP — South Australian Riverland Floodplains Integrated Infrastructure Program

SA River Murray LTWP — The Long-Term Environmental Watering Plan for the South Australian River Murray Water Resource Plan Area.

SA River Murray WRP Area (also SARM) — South Australian River Murray Water Resource Plan Area – defined in Chapter 3 of the Basin Plan.

SMART — Specific, measureable, achievable, realistic, time bound

TCI — Tree Condition Index

WAP — Water allocation plan.

WAP Area — Water Resource Plan Area – water planning units identified for the purpose of implementing the Basin Plan. The water resource plan areas are listed in Chapter 3 of the Basin Plan.

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