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SDL Floodplain Watering Projects: Monitoring and Evaluation

Mallee Catchment Management Authority

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CONTENTS

CONTENTS

CONTENTS

TABLES

1. INTRODUCTION

SCOPE OF WORK

Ecological Associates was engaged by the Mallee Catchment Management Authority to identify the monitoring and evaluation requirements to support proposed supply measure projects under the Murray-Darling Basin Plan Sustainable Diversion Limit (SDL) offset process.

The Basin Plan limits the water that can be extracted from the system for irrigation and other uses in order to sustain the viability and ecological health of the river. To meet the initial Basin Plan SDL, it is necessary to reduce diversions by purchasing water entitlements and transferring them to environmental water accounts.

The Basin Plan includes a mechanism to adjust the SDL. The SDL may be increased if there are supply measures available that achieve an equivalent environmental benefit with less water. A program to develop supply measures and other SDL offset measures has been developed to meet the requirements of the Basin Plan. After business cases have been prepared for each project and funding arrangements have been made, offset measures from across the southern connected basin will be modelled to determine a final SDL adjustment.

The Mallee CMA is preparing business cases for seven supply measure projects: Lindsay Island, Wallpolla Island, Hattah North, Belsar-Yungera, , Burra Creek, Nyah Park and Vinifera Park. The projects will deliver water to floodplain ecosystems to directly address environmental water needs.

The successful operation of the projects will involve a monitoring and evaluation program. Monitoring data is required to plan watering events, to optimise water delivery, to manage risks and to refine ecological objectives. The evaluation process involves analysing the data and improving operations.

The monitoring and evaluation program will focus on the effects of local watering actions. However local hydrological conditions also reflect the flow regime in the River Murray. Environmental flows will become a more important part of river management in the future and have the potential to affect many of the objectives and risks that this program covers. The local monitoring and evaluation program will therefore account for regional environmental water management and will be consistent with their monitoring methodologies.

This report addresses the obligation for the business case to identify monitoring and evaluation needs:

- evaluating water use
- measuring ecological outcomes
- refining conceptual models and improving knowledge
- managing risk.

This report identifies the agencies responsible for commissioning, reviewing and acting on monitoring data. The linkages back to decision-making are described.

2. LINDSAY ISLAND

The Lindsay Floodplain Management Project is a Supply Measure project located in Murray-Sunset National Park on the River Murray floodplain, 100 km west of Mildura in northwest Victoria.

The Lindsay Island floodplain system comprises Lindsay Island and adjacent floodplain areas. The system is located on the left (southern) bank of the River Murray and has an area of 15,000 ha.

The purpose of the project is to restore the productivity and integrity of the ecosystem by increasing the frequency and duration of floodplain inundation. The project concept is to use a weir, stop banks, regulators and pumps to intermittently pond water across the floodplain to meet environmental watering targets.

WATER DELIVERY, USE AND SALINITY IMPACTS

Water level monitoring is required to record the floodplain water regime and to identify priorities for future watering. The project involves several hydraulic units where water levels will be monitored:

- Berribee Weir Pool
- Crankhandle Wetland
- Crankhandle West (Upper)
- Wallawalla West
- Wallawalla East
- Lindsay South Effluent

Water level monitoring is also required to evaluate the effectiveness of watering in achieving ecological outcomes. Ecological responses can be related to watering events to test assumptions and improve the effectiveness and efficiency of water use.

Maintaining minimum flowing conditions in Mullaroo Creek is an important component of the project, and water velocity will be monitored.

Managed watering events involve capturing flow peaks and storing pumped water. These events will result in water losses to evaporation and seepage. Water use will be calculated using a water balance model informed by local monitoring data. It is expected that after a number of watering events have been completed, general rules of thumb for water use will be developed to estimate water use and water balance modelling will no longer be required.

Wallpolla is located in a region of the River Murray that receives groundwater discharge. Floodplain inundation presents a risk of increased salt loads to the River Murray. Monitoring of salinity impacts involves a groundwater monitoring program involving bores and surface water conductivity.

Table 1. Water delivery, use and salinity monitoring at Lindsay Island

Factor	Requirement	Monitoring
Operations	Records of structure operation are required to confirm hydraulic relationships.	All structure settings will be recorded during watering events.
Water regime	Water levels will be monitored to record the water regime in each hydraulic unit. The data will be used - to determine future watering needs and - to relate environmental outcomes to water regimes - to maintain minimum habitat conditions	Floodplain water level in each floodplain watering area. Velocity in Mullaroo Creek
Net water losses from watering events	The net loss of water to evaporation and seepage must be quantified to determine return flows of environmental water and to budget for future environmental watering events.	Net water use cannot be quantified directly due to the complexities of inflows and outflows and diversions in the system. Net water use will be quantified indirectly using a water balance model informed by: - hydraulic modelling - river discharge - records of operational settings (weir levels, regulator opening and closing) - flows at gauged locations (Lock 10, Frenchmans Creek, Lock 8, diverions including Lake Cullulleraine)
Net salinity impacts from watering events	The net salinity impact of environmental watering must be quantified to estimate the EC impact at Morgan.	The salinity impact of individual events cannot be assessed because watering events have long-term and cumulative effects on groundwater discharge. It will therefore be difficult to distinguish the effects of the watering program from existing salinity impacts. Salinity impacts must be evaluated by relating continuous records of salinity to past watering actions. Net salinity impacts will be evaluted by developing a salinity budget based on continuous monitoring the salinity of the River Murray upstream and downstream of Wallpolla Island. It is expected that net salinity impacts can only be reported retrospectively over integrated periods (say 5 year cycles).

OUTCOME MONITORING

The ecological objectives for Lindsay Island are described by Ecological Associates (2014). The objectives centre on the restoration of vegetation communities, floodplain productivity and aquatic habitat through environmental water management. The water regime delivered to Hattah North will be a product of both local water management and flow management in the River Murray. Monitoring and evaluation will be required to inform both processes.

Outcome monitoring will measure progress towards the objectives. Initial monitoring will provide a baseline of the existing status of the objectives and future monitoring will report how well the objectives are achieved.

Outcome monitoring will feed directly back to operations at the site. Water regime and ecological data will be reviewed during and after watering events to identify opportunities to promote ecological objectives more effectively and efficiently.

Outcome monitoring will also be used to test assumptions. The ecological objectives are predictions of the future status of the site and are based on imperfect site data and ecological knowledge. Monitoring data will refine the conceptual models on which the objectives are based by reporting how environmental conditions and species respond to water regimes.

Table 2. Outcome monitoring at Lindsay Island

Objectives	Components	Measures	Evaluation	Knowledge Gaps and Investigations
Enhance murray cod habitat	Maintain fast flowing habitat	Measure velocity under a range of operational settings	Determine the operational settings that maintain or optimise fast-flowing habitat in terms of velocity and extent	How does murray cod respond to different flow environments? What is the optimal flowing environment?
	Productivity of riparian zones	Diversity of plant assemblages in riparian zone of Mullaroo Creek The lateral extent of aquatic macrophyte cover in riparian zone, especially backwaters and river benches	Riparian vegetation is more extensive and diverse.	
	Productivity of connected wetlands	Frequency and duration of inundation in adjacent wetlands Spatial of aquatic macrophytes in wetlands Organic matter load (kg dry weight per m^2) on wetland bed in autumn	Wetlands are producing more organic matter. Wetlands are providing more aquatic vegetation cover when flooded.	
	Murray cod population	Number of fish Fish size classes Fish health	Fish size, age classes and health measures are improving	
Maintain resident populations of frogs and small fish in wetlands	Frog populations	In permanent and semi-permanent wetlands monitor frog species and abundance	Frog populations persist in the wetlands, including through 'very dry' climate conditions.	
	Small fish populations	In permanent and semi-permanent wetalnds monitor small fish species and abundance	Small fish populations persist in the wetlands, including through 'very dry' climate conditions.	
Provide reliable breeding habitat for waterbirds, including colonial nesting species	Waterbird species that breed readily - ducks, crakes, rails, waterhens and coots	Number of species breeding Number of breeding waterbirds Number of breeding sites	Species that breed readily breed 9 years in 10	
	Colonial nesting species - egret, ibis, spoonbills, cormorant	Number of species breeding Number of breeding waterbirds Number of breeding sites	Colonial nesting species breed 5 years in 10	What are the factors that promote breeding events: - local habitat quality and watering? - Seasonal conditions? - Regional flooding?
Frequently provide habitat for tens of thousands of waterbirds	Waterbirds	Number of waterbirds present during extensive flooding events	Frequency of years with tens of thousands of waterbirds present	Which species are promoted by widespread floodplain inundation? Does the site have a significant role in the habitat requirements of migratory species? If so, what watering sites, times and durations best promotes their requirements?
Restoring floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, bats and giles' planigale	Floodplain productivity	Organic matter load (kg dry weight per m^2) on floodplain	Organic matter load increases. Compare watered and unwatered areas.	
	Floodplain vertebrate fauna	10 yearly survey of vertebrate fauna distribution and abundance	Floodplain vertebrate fauna species are more abundant and diverse. Compare watered and unwatered areas.	Which floodplain vertebrate species are promoted by flooding? What are the energy pathways and habitat components that promote them?
Contributing to the organic carbon requirements of the River Murray channel ecosystem	Organic carbon export	Dissolved and particulate organic matter concentrations in water draining from floodplain	The average annual organic carbon export increases	Does the organic matter in the River Murray downstream of watered areas increase significantly?

RISK MONITORING

The environmental risks from the implementation of the proposed water regime have been identified by Lloyd Environmental (2014).

Monitoring data is central to the strategy for risk management. Monitoring data will identify emerging hazards so that managers can adapt operations to minimise risk.

Monitoring data will also improve knowledge of how watering events promote hazards. By reporting on water regimes and hazard responses, monitoring data will help develop practices that minimise hazard development and most effectively control them when they occur.

Table 3. Risk monitoring at Lindsay Island

Risk	Consequences	Mitigation	Risk Management Variables	Investigations to Refine Risk Assessment
Red gum germinate at the fringes of managed watering areas including watercourses	Watercourses become choked creating blockages to flow and aquatic fauna	Vary water levels each season and year Periodically provide high water levels to drown seedlings Schedule watering to minimise germination	Distribution and density of red gum seedlings in watercourses	What conditions promote red gum germination? What flooding techniques most effectively kill red gum seedlings?
Water table rises in response to managed flood events	Soil salinisation reduces vegetation health and floodplain productivity	Reduce the frequency or extent of floodplain inundation in recharge zones	Groundwater levels Groundwater salinity Tree health	What are the highest risk areas for salinity impacts based on groundwater recharge, salinity and discharge? At which sites should watering be reduced to manage salt risks?
Managed flood events reduce fast-flowing habitat in watercourses	Flow-dependent fauna in Mullaroo Creek and Lindsay River decline in health or abundance	Manage structures to maintain minimum flowing conditions in Mullaroo while Beribee Weir is raised	Monitor Mullaroo Creek to verify flowing habiat	Monitor fish abundance and age class to test assumption that the minimum flowing conditions are adequate
Managed flood events increase carp abundance	Wetland and watercourse water quality; aquatic vegetation is degraded; carp impact on native aquatic fauna	Provide water regimes that promote native fish to increase resiliance to carp impacts and to compete with carp Operate structures to minimise benefits to carp	Carp abundance Carp size classes	What conditions promote carp recruitment and growth? What conditions impact on carp but not native fish species?
Changed flow regime favouring high risk weed species	Weeds that benefit from summer waterlogging such as noogoora burr and horehound will become established on the floodplain	Periodically inundate infested areas during the growing season of these weeds to eradicate populations	Extent and density of weed infestations	What seasonal and flooding conditions best promote weeds? What is the most efficient use of water to control weeds?
Blackwater events result from watering	Blackwater leads to the death of local populations of aquatic fauna.	Assess blackwater risk before watering events begin. Do not proceed if the risk of blackwater is high. Monitor risk factors during watering event and abort if risk becomes high.	When a watering event is planned evaluate risk in terms of: - time since last watered - time of year when watering event will take place - the depth of the watered area and likelihood of stratification - the accumulated organic matter in the target area During a watering event monitor: - vertical water temperature profile - vertical dissolved oxygen profile	How well do the identified hazards predict blackwater development? What are the impacts on watered areas when blackwater cannot be released and is retaine on the floodplain longer than planned?
Inability to discharge poor quality water	Managed flooding events are disrupted because water cannot be re-used in other wetlands and watercourses; water cannot be released to the River Murray	Monitor water quality during watering event and abort if risk becomes high. Transfer water to a low-value floodplain area, if possible. Retain a reserve of environmental water to dilute poor quality water outflows if necessary.	During a watering event monitor: - vertical water temperature profile - vertical dissolved oxygen profile - algal abundance - salinity	What conditions promote or mitigate against algal blooms?
Increase in native and non-native pest mammals (kangaroos, rabbits, pig)	Severe grazing and trampling of vegetation; poor water quality and habitat value in wetlands	Control of pest animals	Annual population counts of pest mammals Annual analysis of pest risk based on seasonal conditions and planned watering events	To what extent do watering events promote pest animals? Under what conditions (seasonal, pest animal abundance, habitat type) do pest animals have significant impacts on watered areas?

3. WALLPOLLA ISLAND

The Wallpolla Floodplain Management Project is a Supply Measure project located in the Murray-Sunset National Park on the River Murray floodplain, 40 km west of Mildura in northwest Victoria.

The Wallpolla Island floodplain system comprises Wallpolla Island and adjacent floodplain areas. The system is located on the left (southern) bank of the River Murray between Lock 10 and Lock 9 and has an area of approximately 9,000 ha.

The purpose of the project is to restore the integrity and productivity of the ecosystem by increasing the frequency and duration of floodplain inundation. The project concept is to construct a series of stop banks to intermittently pond water across the floodplain to meet environmental watering targets.

WATER DELIVERY, USE AND SALINITY IMPACTS

Water level monitoring is required to record the floodplain water regime and to identify priorities for future watering. The project involves two of hydraulic units where water levels will be monitored - mid, upper and south Wallpolla.

Water level monitoring is also required to evaluate the effectiveness of watering in achieving ecological outcomes. Ecological responses can be related to watering events to test assumptions and improve the effectiveness and efficiency of water use.

Managed watering events involve capturing flow peaks and storing pumped water. These events will result in water losses to evaporation and seepage. Water use will be calculated using a water balance model informed by local monitoring data. It is expected that after a number of watering events have been completed, general rules of thumb for water use will be developed to estimate water use and water balance modelling will no longer be required.

Wallpolla is located in a region of the River Murray that receives groundwater discharge. Floodplain inundation presents a risk of increased salt loads to the River Murray. Monitoring of salinity impacts involves a groundwater monitoring program involving bores and surface water conductivity.

Table 4. Water delivery, use and salinity monitoring at Wallpolla Island

Factor	Requirement	Monitoring
Operations	Records of structure operation are required to confirm hydraulic relationships.	All structure settings will be recorded during watering events.
Water regime	Water levels will be monitored to record the water regime in each hydraulic unit. The data will be used - to determine future watering needs and - to relate environmental outcomes to water regimes - to maintain minimum habitat conditions	Floodplain water level in each floodplain watering area.
Net water losses from watering events	The net loss of water to evaporation and seepage must be quantified to determine return flows of environmental water and to budget for future environmental watering events.	Net water use cannot be quantified directly due to the complexities of inflows and outflows and consumptive diversions in the system. Net water use will be quantified indirectly using a water balance model informed by: - hydraulic modelling - river discharge - records of operational settings (weir levels, regulator opening and closing) - flows at gauged locations (Lock 10, Frenchmans Creek, Lock 8, diverions including Lake Cullulleraine)
Net salinity impacts from watering events	The net salinity impact of environmental watering must be quantified to estimate the EC impact at Morgan.	The salinity impact of individual events cannot be assessed because watering events have long-term and cumulative effects on groundwater discharge. It will therefore be difficult to distinguish the effects of the watering program from existing salinity impacts. Salinity impacts must be evaluated by relating continuous records of salinity to past watering actions. Net salinity impacts will be evaluted by developing a salinity budget based on continuous monitoring the salinity of the River Murray upstream and downstream of Wallpolla Island. It is expected that net salinity impacts can only be reported retrospectively over integrated periods (say 5 year cycles).

OUTCOME MONITORING

The ecological objectives for Wallpolla Island are described by Ecological Associates (2014). The objectives centre on the restoration of vegetation communities, floodplain productivity and aquatic habitat through environmental water management. The water regime delivered to Hattah North will be a product of both local water management and flow management in the River Murray. Monitoring and evaluation will be required to inform both processes.

Outcome monitoring will measure progress towards the objectives. Initial monitoring will provide a baseline of the existing status of the objectives and future monitoring will report how well the objectives are achieved.

Outcome monitoring will feed directly back to operations at the site. Water regime and ecological data will be reviewed during and after watering events to identify opportunities to promote ecological objectives more effectively and efficiently.

Outcome monitoring will also be used to test assumptions. The ecological objectives are predictions of the future status of the site and are based on imperfect site data and ecological knowledge. Monitoring data will refine the conceptual models on which the objectives are based by reporting how environmental conditions and species respond to water regimes.

Table 5. Outcome monitoring at Wallpolla Island

Objectives	Components	Measures	Evaluation	Knowledge Gaps and Investigations
Enhancing local populations of channel-specialist fish by augmenting anabranch habitat and improving the productivity of connected riparian zones and wetlands	Productivity of riparian zones	Diversity of plant assemblages in riparian zone of floodplain watercourses The lateral extent of aquatic macrophyte cover in riparian zone, especially backwaters and river benches	Riparian vegetation is more extensive and diverse.	
	Productivity of connected wetlands	Frequency and duration of inundation in adjacent wetlands Spatial of aquatic macrophytes in wetlands Organic matter load (kg dry weight per m^2) on wetland bed in autumn	Wetlands are producing more organic matter. Wetlands are providing more aquatic vegetation cover when flooded.	
	Channel-specialist fish population	Fish population sizes Fish size classes Fish health	Fish species, size, age classes and health measures are improving	
Increasing resident populations of frogs and small fish in wetlands	Frog populations	In permanent and semi-permanent wetlands monitor frog species and abundance	Frog populations persist in the wetlands, including through 'very dry' climate conditions.	
	Small fish populations	In permanent and semi-permanent wetalnds monitor small fish species and abundance	Small fish populations persist in the wetlands, including through 'very dry' climate conditions.	
Provide reliable breeding habitat for waterbirds, including colonial nesting species	Waterbird species that breed readily - ducks, crakes, rails, waterhens and coots	Number of species breeding Number of breeding waterbirds Number of breeding sites	Species that breed readily breed 9 years in 10	
	Colonial nesting species - egret, ibis, spoonbills, cormorant	Number of species breeding Number of breeding waterbirds Number of breeding sites	Colonial nesting species breed 5 years in 10	What are the factors that promote breeding events: - local habitat quality and watering? - Seasonal conditions? - Regional flooding?
Frequently provide habitat for tens of thousands of waterbirds	Waterbirds	Number of waterbirds present during extensive flooding events	Frequency of years with tens of thousands of waterbirds present	Which species are promoted by widespread floodplain inundation? Does the site have a significant role in the habitat requirements of migratory species? If so, what watering sites, times and durations best promotes their requirements?
Restoring floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, bats and giles' planigale	Floodplain productivity	Organic matter load (kg dry weight per m^2) on floodplain	Organic matter load increases. Compare watered and unwatered areas.	
	Floodplain vertebrate fauna	10 yearly survey of vertebrate fauna distribution and abundance	Floodplain vertebrate fauna species are more abundant and diverse. Compare watered and unwatered areas.	Which floodplain vertebrate species are promoted by flooding? What are the energy pathways and habitat components that promote them?
Contributing to the organic carbon requirements of the River Murray channel ecosystem	Organic carbon export	Dissolved and particulate organic matter concentrations in water draining from floodplain	The average annual organic carbon export increases	Does the organic matter in the River Murray downstream of watered areas increase significantly?

RISK MONITORING

The environmental risks from the implementation of the proposed water regime have been identified by Lloyd Environmental (2014).

Monitoring data is central to the strategy for risk management. Monitoring data will identify emerging hazards so that managers can adapt operations to minimise risk.

Monitoring data will also improve knowledge of how watering events promote hazards. By reporting on water regimes and hazard responses, monitoring data will help develop practices that minimise hazard development and most effectively control them when they occur.

Table 6. Risk monitoring at Wallpolla Island

Risk	Consequences	Mitigation	Risk Management Variables	Investigations to Refine Risk Assessment
Red gum germinate at the fringes of managed watering areas including watercourses	Watercourses become choked creating blockages to flow and aquatic fauna	Vary water levels each season and year Periodically provide high water levels to drown seedlings Schedule watering to minimise germination	Distribution and density of red gum seedlings in watercourses	What conditions promote red gum germination? What flooding techniques most effectively kill red gum seedlings?
Water table rises in response to managed flood events	Soil salinisation reduces vegetation health and floodplain productivity	Reduce the frequency or extent of floodplain inundation in recharge zones	Groundwater levels Groundwater salinity Tree health	What are the highest risk areas for salinity impacts based on groundwater recharge, salinity and discharge? At which sites should watering be reduced to manage salt risks?
Managed flood events increase carp abundance	Wetland and watercourse water quality; aquatic vegetation is degraded; carp impact on native aquatic fauna	Provide water regimes that promote native fish to increase resiliance to carp impacts and to compete with carp Operate structures to minimise benefits to carp	Carp abundance Carp size classes	What conditions promote carp recruitment and growth? What conditions impact on carp but not native fish species?
Changed flow regime favouring high risk weed species	Weeds that benefit from summer waterlogging such as noogoora burr and horehound will become established on the floodplain	Periodically inundate infested areas during the growing season of these weeds to eradicate populations	Extent and density of weed infestations	What seasonal and flooding conditions best promote weeds? What is the most efficient use of water to control weeds?
Blackwater events result from watering	Blackwater leads to the death of local populations of aquatic fauna.	Assess blackwater risk before watering events begin. Do not proceed if the risk of blackwater is high. Monitor risk factors during watering event and abort if risk becomes high.	When a watering event is planned evaluate risk in terms of: - time since last watered - time of year when watering event will take place - the depth of the watered area and likelihood of stratification - the accumulated organic matter in the target area During a watering event monitor: - vertical water temperature profile - vertical dissolved oxygen profile	How well do the identified hazards predict blackwater development? What are the impacts on watered areas when blackwater cannot be released and is retaine on the floodplain longer than planned?
Inability to discharge poor quality water	Managed flooding events are disrupted because water cannot be re-used in other wetlands and watercourses; water cannot be released to the River Murray	Monitor water quality during watering event and abort if risk becomes high. Transfer water to a low-value floodplain area, if possible. Retain a reserve of environmental water to dilute poor quality water outflows if necessary.	During a watering event monitor: - vertical water temperature profile - vertical dissolved oxygen profile - algal abundance - salinity	What conditions promote or mitigate against algal blooms?
Increase in native and non-native pest mammals (kangaroos, rabbits, pig)	Severe grazing and trampling of vegetation; poor water quality and habitat value in wetlands	Control of pest animals	Annual population counts of pest mammals Annual analysis of pest risk based on seasonal conditions and planned watering events	To what extent do watering events promote pest animals? Under what conditions (seasonal, pest animal abundance, habitat type) do pest animals have significant impacts on watered areas?

4. HATTAH NORTH

The Hattah Lakes North Floodplain Management Project is a Supply Measure project located in the Hattah-Kulkyne National Park on the River Murray floodplain, 60 km south-east of Mildura in northwest Victoria.

The Hattah floodplain system is located on the left (western) bank of the River Murray between Robinvale and Colignan. The system comprises approximately 20 lakes and surrounding woodlands that are flooded by peaks in River Murray flow.

The Hattah Lakes North Floodplain Management Project proposes to build on the benefits of TLM works by extending the flood management area at two locations, the Chalka North Area and the Lake Boolca Area. The project provides inundation of up to 720 ha of floodplain in areas that support a suite of threatened flora and fauna species.

WATER DELIVERY, USE AND SALINITY IMPACTS

Water level monitoring is required to record the floodplain water regime and to identify priorities for future watering. The project involves two hydraulic units where water levels will be monitored - the Lake Boolca Area and Chalka North Area.

Water level monitoring is also required to evaluate the effectiveness of watering in achieving ecological outcomes. Ecological responses can be related to watering events to test assumptions and improve the effectiveness and efficiency of water use.

Managed watering events involve capturing flow peaks and storing pumped water. These events will result in water losses to evaporation and seepage. Water use will be calculated using a water balance model informed by local monitoring data. It is expected that after a number of watering events have been completed, general rules of thumb for water use will be developed to estimate water use and water balance modelling will no longer be required.

Belsar and Yungera is located in a region of the River Murray that receives groundwater discharge. Floodplain inundation presents a risk of increased salt loads to the River Murray. Monitoring of salinity impacts involves a monitoring program using bores and surface water conductivity measurements.

Table 7. Water delivery, use and salinity monitoring at Hattah North

Factor	Requirement	Monitoring
Operations	Records of structure operation are required to confirm hydraulic relationships.	All structure settings will be recorded during watering events.
Water regime	Water levels will be monitored to record the water regime in each hydraulic unit. The data will be used - to determine future watering needs and - to relate environmental outcomes to water regimes - to maintain minimum habitat conditions	Floodplain water level in each floodplain watering area.
Net water losses from watering events	The net loss of water to evaporation and seepage must be quantified to determine return flows of environmental water and to budget for future environmental watering events.	Net water use can be calculated for the Lake Boolca Area. Inflows via Lake Bitterang or Raakjlim Creek can be gauged to calculate total inflows and outflows. Net water use in the Chalka North area is can be estimated using a water balance model informed by: - hydraulic modelling - river discharge - records of operational settings (regulator opening and closing) - flows at gauged locations (Oateys) - water level records in the storage area
Net salinity impacts from watering events	The net salinity impact of environmental watering must be quantified to estimate the EC impact at Morgan.	The salinity impact of individual events cannot be assessed because watering events have long-term and cumulative effects on groundwater discharge. It will therefore be difficult to distinguish the effects of the watering program from existing salinity impacts. Salinity impacts must be evaluated by relating continuous records of salinity to past watering actions. Net salinity impacts will be evaluted by developing a salinity budget based on continuous monitoring the salinity of the River Murray upstream and downstream of Hattah Lakes. It is expected that net salinity impacts can only be reported retrospectively over integrated periods (say 5 year cycles).

OUTCOME MONITORING

The ecological objectives for Hattah North are described by Ecological Associates (2014). The objectives centre on the restoration of vegetation communities, floodplain productivity and aquatic habitat through environmental water management. The water regime delivered to Hattah North will be a product of both local water management and flow management in the River Murray. Monitoring and evaluation will be required to inform both processes.

Outcome monitoring will measure progress towards the objectives. Initial monitoring will provide a baseline of the existing status of the objectives and future monitoring will report how well the objectives are achieved.

Outcome monitoring will feed directly back to operations at the site. Water regime and ecological data will be reviewed during and after watering events to identify opportunities to promote ecological objectives more effectively and efficiently.

Outcome monitoring will also be used to test assumptions. The ecological objectives are predictions of the future status of the site and are based on imperfect site data and ecological knowledge. Monitoring data will refine the conceptual models on which the objectives are based by reporting how environmental conditions and species respond to water regimes.

Table 8. Ecologcial outcome monitoring at Hattah North

Objectives	Components	Measures	Evaluation	Knowledge Gaps and Investigations
Restoring floodplain productivity to maintain resident populations of vertebrate fauna including lace monitor and bats	Floodplain productivity	Organic matter load (kg dry weight per m^2) on floodplain	Organic matter load increases. Compare watered and unwatered areas.	
	Floodplain vertebrate fauna	10 yearly survey of vertebrate fauna distribution and abundance	Floodplain vertebrate fauna species are more abundant and diverse. Compare watered and unwatered areas.	Which floodplain vertebrate species are promoted by flooding? What are the energy pathways and habitat components that promote them?
Providing occasional breeding habitat for waterbirds	Platform-building waterbirds including ibis, cormorants and freckled duck.	Number of bird species breeding Number of breeding waterbirds Number of breeding sites	Breeding events 2 years in 10	
Maintain the health and age structure of red gum and black box trees	Red gum and black box trees	Tree health Tree age classes	Tree health is restored Tree recruitment is sufficient to maintain exisitng habitat trees	
Maintaining a plant community of drought-tolerant wetland species in infrequently flooded areas	Drought-tolerant wetland species	Abundance and extent of drought-tolerant wetland plants (*Eleocharis acuta, Cyperus gymnocaulos* etc.) during watering events	Emergent wetland vegetation is present in watered areas.	
Contributing to the organic carbon requirements of the River Murray channel ecosystem	Organic carbon export	Dissolved and particulate organic matter concentrations in water draining from floodplain	The average annual organic carbon export increases	Does the organic matter in the River Murray downstream of watered areas increase significantly?

RISK MONITORING

The environmental risks from the implementation of the proposed water regime have been identified by Lloyd Environmental (2014).

Monitoring data is central to the strategy for risk management. Monitoring data will identify emerging hazards so that managers can adapt operations to minimise risk.

Monitoring data will also improve knowledge of how watering events promote hazards. By reporting on water regimes and hazard responses, monitoring data will help develop practices that minimise hazard development and most effectively control them when they occur.

Table 9. Risk monitoring at Hattah North

Risk	Consequences	Mitigation	Risk Management Variables	Investigations to Refine Risk Assessment
Red gum germinate at the fringes of managed watering areas including watercourses	Watercourses become choked creating blockages to flow and aquatic fauna	Vary water levels each event Periodically provide high water levels to drown seedlings Schedule watering to minimise germination	Distribution and density of red gum seedlings in watercourses	What conditions promote red gum germination? What flooding techniques most effectively kill red gum seedlings?
Water table rises in response to managed flood events	Soil salinisation reduces vegetation health and floodplain productivity	Reduce the frequency or extent of floodplain inundation in recharge zones	Groundwater levels Groundwater salinity Tree health	What are the highest risk areas for salinity impacts based on groundwater recharge, salinity and discharge? At which sites should watering be reduced to manage salt risks?
Managed flood events increase carp abundance	Wetland and watercourse water quality; aquatic vegetation is degraded; carp impact on native aquatic fauna	Provide water regimes that promote native fish to increase resiliance to carp impacts and to compete with carp Operate structures to minimise benefits to carp	Carp abundance Carp size classes	What conditions promote carp recruitment and growth? What conditions impact on carp but not native fish species?
Changed flow regime favouring high risk weed species	Weeds that benefit from summer waterlogging such as noogoora burr and horehound will become established on the floodplain	Periodically inundate infested areas during the growing season of these weeds to eradicate populations	Extent and density of weed infestations	What seasonal and flooding conditions best promote weeds? What is the most efficient use of water to control weeds?
Blackwater events result from watering	Blackwater leads to the death of local populations of aquatic fauna.	Assess blackwater risk before watering events begin. Do not proceed if the risk of blackwater is high. Monitor risk factors during watering event and abort if risk becomes high.	When a watering event is planned evaluate risk in terms of: - time since last watered - time of year when watering event will take place - the depth of the watered area and likelihood of stratification - the accumulated organic matter in the target area During a watering event monitor: - vertical water temperature profile - vertical dissolved oxygen profile	How well do the identified hazards predict blackwater development? What are the impacts on watered areas when blackwater cannot be released and is retaine on the floodplain longer than planned?
Inability to discharge poor quality water	Managed flooding events are disrupted because water cannot be re-used in other wetlands and watercourses; water cannot be released to the River Murray	Monitor water quality during watering event and abort if risk becomes high. Transfer water to a low-value floodplain area, if possible. Retain a reserve of environmental water to dilute poor quality water outflows if necessary.	During a watering event monitor: - vertical water temperature profile - vertical dissolved oxygen profile - algal abundance - salinity	What conditions promote or mitigate against algal blooms?
Increase in native and non-native pest mammals (kangaroos, rabbits, pig)	Severe grazing and trampling of vegetation; poor water quality and habitat value in wetlands	Control of pest animals	Annual population counts of pest mammals Annual analysis of pest risk based on seasonal conditions and planned watering events	To what extent do watering events promote pest animals? Under what conditions (seasonal, pest animal abundance, habitat type) do pest animals have significant impacts on watered areas?

5. BELSAR AND YUNGERA

The Belsar and Yungera Floodplain Management Project is a Supply Measure project located on the River Murray floodplain, 17 km south east of the township of Robinvale in northwest Victoria. The system comprises Belsar and Yungera Islands, Lakes Powell and Carpul and adjacent floodplain with a total area of 8,200 ha.

The purpose of the project is to restore the integrity and productivity of the ecosystem by increasing the frequency and duration of floodplain inundation. The project concept is to use structures to retain and regulate water over extensive areas of the floodplain. The project provides inundation of up to 2,444 ha of intact floodplain habitat.

WATER DELIVERY, USE AND SALINITY IMPACTS

Water level monitoring is required to record the floodplain water regime and to identify priorities for future watering. The project involves a number of hydraulic units where water levels will be monitored including Lake Powell, Parnee Malloo Creek upstream of the ER1 regulating structure, Yungera Creek and the J1 creek system.

The promotion of flowing water habitat and River Murray connectivity is an important component of the project. Water levels and velocity will be monitored in Narcooyia Creek.

Water level monitoring is also required to evaluate the effectiveness of watering in achieving ecological outcomes. Ecological responses can be related to watering events to test assumptions and improve the effectiveness and efficiency of water use.

Managed watering events involve capturing flow peaks and storing pumped water. These events will result in water losses to evaporation and seepage. Water use will be calculated using a water balance model informed by local monitoring data. It is expected that after a number of watering events have been completed, general rules of thumb for water use will be developed to estimate water use and water balance modelling will no longer be required.

Belsar and Yungerais located in a region of the River Murray that recharges the aquifer. Floodplain inundation presents a low risk of increased salt loads to the River Murray. Monitoring of salinity impacts involves a low-level surveillance program using existing resources.

Table 10. Water delivery, use and salinity monitoring at Belsar and Yungera

Factor	Requirement	Monitoring
Operations	Records of structure operation are required to confirm hydraulic relationships.	All structure settings will be recorded during watering events.
Water regime	The water levels in the forest will be monitored to record the water regime. The data will be used - to determine future watering needs and - to relate environmental outcomes to water regimes	Floodplain water level Flow (depth, discharge and velocity) in Narcooyia Creek
Net water losses from watering events	The net loss of water to evaporation and seepage must be quantified to determine return flows of environmental water and to budget for future environmental watering events.	Net water use will be quantified indirectly using a water balance model informed by: - hydraulic modelling - records of operational settings (pumping volumes, regulator opening and closing) - river discharge - flows and water levels at gauged locations on the floodplain
Net salinity impacts from watering events	The net salinity impact of environmental watering must be quantified to estimate the EC impact at Morgan.	Belsar and Yungera is located in a losing reach of the River Murray and environmental watering is not expected to generate a salt load. The potential for salinity impacts will be monitored by measuring river EC upstream and downstream of Belsar and Yungera and relating salinity levels to watering events.

OUTCOME MONITORING

The ecological objectives for Belsar and Yungera are described by Ecological Associates (2014). The objectives centre on the restoration of vegetation communities, floodplain productivity and aquatic habitat through environmental water management. The water regime delivered to Belsar and Yungera will be a product of both local water management and flow management in the River Murray. Monitoring and evaluation will be required to inform both processes.

Outcome monitoring will measure progress towards the objectives. Initial monitoring will provide a baseline of the existing status of the objectives and future monitoring will report how well the objectives are achieved.

Outcome monitoring will feed directly back to operations at the site. Water regime and ecological data will be reviewed during and after watering events to identify opportunities to promote ecological objectives more effectively and efficiently.

Outcome monitoring will also be used to test assumptions. The ecological objectives are predictions of the future status of the site and are based on imperfect site data and ecological knowledge. Monitoring data will

refine the conceptual models on which the objectives are based by reporting how environmental conditions and species respond to water regimes.

Table 11. Outcome monitoring at Belsar and Yungera

Objectives	Components	Measures	Evaluation	Knowledge Gaps and Investigations
Restoring habitat linkages between the river and Narcooyia Creek for murray cod and other native fish	Murray cod and other native fish	Fish movements between Narcooyia Creek and the River Channel based on fish tagging.	Size of fish in Narcooyia Creek increases. Diversity of size classes in Narcooyia Creek increases	How important is the movement of fish between refuges like Narcooyia Creek and the main channel for growth and development of native fish?
Enhancing native fish habitat by improving the productivity of riparian zones and wetlands	Productivity of riparian zones	Diversity of plant assemblages in riparian zone of floodplain watercourses The lateral extent of aquatic macrophyte cover in riparian zone, especially backwaters and river benches	Riparian vegetation is more extensive and diverse.	
	Productivity of connected wetlands	Frequency and duration of inundation in adjacent wetlands Spatial of aquatic macrophytes in wetlands Organic matter load (kg dry weight per m^2) on wetland bed in autumn	Wetlands are producing more organic matter. Wetlands are providing more aquatic vegetation cover when flooded.	
	Native fish population	Fish population sizes Fish size classes Fish health	Fish species, size, age classes and health measures are improving	
Restoring semi-permanent wetlands capable of supporting growling grass frog	Semi-permanent wetland habitat quality	Wetlands have semi-permanent, deep open water habitat surrounded by emergent macrophyte beds and forest.	Habitat structure and water regime is achieved at target sites	
	Growling grass frog	Abundance of growling grass frog and other fauna that depend on aquatic refuges	Fauna that depend on aquatic refuges become established at target sites	
Maintaining lignum shrubland as a frequently flooded and productive habitat for fish and waterbirds	Lignum shrublands	Lignum density	Density and productivity of lignum increases	
	Breeding by platform-building waterbirds including spoonbill, ibis and egret	Number of breeding birds Number of breeding species	Major breeding events in 4 out of 10 years	What local and regional flooding and sesaonal conditions promote waterbird breeding? What is the optimal flood timing and duration to promote waterbird breeding?
	Vegetation-dependent native fish species	Abundance of native fish in lignum shrublands during flood events. Number of native fish species in lignum shrublands during flood events	Abundance and diversity of native fish in lignum is high compared to other flooded habiats	
Restoring floodplain productivity to maintain resident populations of vertebrate fauna including carpet python and bats	Floodplain productivity	Organic matter load (kg dry weight per m^2) on floodplain	Organic matter load increases. Compare watered and unwatered areas.	
	Floodplain vertebrate fauna	10 yearly survey of vertebrate fauna distribution and abundance	Floodplain vertebrate fauna species are more abundant and diverse. Compare watered and unwatered areas.	Which floodplain vertebrate species are promoted by flooding? What are the energy pathways and habitat components that promote them?
Intermittently providing productive lake habitat for thousands of waterbirds	Waterbirds	Number of birds Number or bird species	Thousands of waterbirds are present in Lakes Powell and Carpul in 25% of years	
Contributing to the organic carbon requirements of the River Murray channel ecosystem	Organic carbon export	Dissolved and particulate organic matter concentrations in water draining from floodplain	The average annual organic carbon export increases	Does the organic matter in the River Murray downstream of watered areas increase significantly?

RISK MONITORING

The environmental risks from the implementation of the proposed water regime have been identified by Lloyd Environmental (2014).

Monitoring data is central to the strategy for risk management. Monitoring data will identify emerging hazards so that managers can adapt operations to minimise risk.

Monitoring data will also improve knowledge of how watering events promote hazards. By reporting on water regimes and hazard responses, monitoring data will help develop practices that minimise hazard development and most effectively control them when they occur.

Table 12. Outcome monitoring at Belsar and Yungera

Risk	Consequences	Mitigation	Risk Management Variables	Investigations to Refine Risk Assessment
The native fish population in Narcooyia Creek is degraded when connectivity to the River Murray Channel is increased.	The Narcooyia Creek population of murray cod and golden perch is degraded	Restore pre-existing connection arrangements	Size of native fish Native fish size classes Abundance of native fish	What conditions degraded the population?
Red gum germinate at the fringes of managed watering areas including watercourses	Watercourses become choked creating blockages to flow and aquatic fauna	Vary water levels each event Periodically provide high water levels to drown seedlings Schedule watering to minimise germination	Distribution and density of red gum seedlings in watercourses	What conditions promote red gum germination? What flooding techniques most effectively kill red gum seedlings?
Managed flood events increase carp abundance	Wetland and watercourse water quality; aquatic vegetation is degraded; carp impact on native aquatic fauna	Provide water regimes that promote native fish to increase resiliance to carp impacts and to compete with carp Operate structures to minimise benefits to carp	Carp abundance Carp size classes	What conditions promote carp recruitment and growth? What conditions impact on carp but not native fish species?
Changed flow regime favouring high risk weed species	Weeds that benefit from summer waterlogging such as noogoora burr and horehound will become established on the floodplain	Periodically inundate infested areas during the growing season of these weeds to eradicate populations	Extent and density of weed infestations	What seasonal and flooding conditions best promote weeds? What is the most efficient use of water to control weeds?
Blackwater events result from watering	Blackwater leads to the death of local populations of aquatic fauna.	Assess blackwater risk before watering events begin. Do not proceed if the risk of blackwater is high. Monitor risk factors during watering event and abort if risk becomes high.	When a watering event is planned evaluate risk in terms of: - time since last watered - time of year when watering event will take place - the depth of the watered area and likelihood of stratification - the accumulated organic matter in the target area During a watering event monitor: - vertical water temperature profile - vertical dissolved oxygen profile	How well do the identified hazards predict blackwater development? What are the impacts on watered areas when blackwater cannot be released and is retaine on the floodplain longer than planned?
Inability to discharge poor quality water	Managed flooding events are disrupted because water cannot be re-used in other wetlands and watercourses; water cannot be released to the River Murray	Monitor water quality during watering event and abort if risk becomes high. Transfer water to a low-value floodplain area, if possible. Retain a reserve of environmental water to dilute poor quality water outflows if necessary.	During a watering event monitor: - vertical water temperature profile - vertical dissolved oxygen profile - algal abundance - salinity	What conditions promote or mitigate against algal blooms?
Increase in native and non-native pest mammals (kangaroos, rabbits, pig)	Severe grazing and trampling of vegetation; poor water quality and habitat value in wetlands	Control of pest animals	Annual population counts of pest mammals Annual analysis of pest risk based on seasonal conditions and planned watering events	To what extent do watering events promote pest animals? Under what conditions (seasonal, pest animal abundance, habitat type) do pest animals have significant impacts on watered areas?

6. BURRA CREEK

PROJECT DESCRIPTION

The Burra Creek Floodplain Management Project is a Supply Measure project located on the River Murray floodplain, 63 km southeast of Robinvale in northwest Victoria. This project addresses flooding requirements in the northern section of the floodplain which includes creek habitat.

The purpose of the project is to restore the integrity and productivity of the ecosystem by increasing the frequency and duration of floodplain inundation. The project concept is to remove blockages to flow and to use structures to retain and regulate water over the floodplain. The project inundates up to 340 ha of intact floodplain habitat.

WATER DELIVERY, USE AND SALINITY IMPACTS

Water management at Burra is designed to meet deficits in the ecological water requirements. Continuous water level monitoring is required to record the forest water regime and to identify priorities for future watering.

Water level monitoring is also required to evaluate the effectiveness of watering in achieving ecological outcomes. Ecological responses can be related to watering events to test assumptions and improve the effectiveness and efficiency of water use.

Managed watering events involve capturing flow peaks and storing pumped water. These events will result in water losses to evaporation and seepage. Water use will be calculated using a water balance model informed by local monitoring data. It is expected that after a number of watering events have been completed, general rules of thumb for water use will be developed to estimate water use and water balance modelling will no longer be required.

Burra Creek is located in a region of the River Murray that recharges the aquifer. Floodplain inundation presents a low risk of increased salt loads to the River Murray. Monitoring of salinity impacts involves a low-level surveillance program using existing resources.

Table 13. Water delivery, use and salinity monitoring at Burra Creek

Factor	Requirement	Monitoring
Operations	Records of structure operation are required to confirm hydraulic relationships.	All structure settings will be recorded during watering events.
Water regime	Water levels will be monitored to record the water regime in each hydraulic unit. The data will be used - to determine future watering needs and - to relate environmental outcomes to water regimes - to maintain minimum habitat conditions	Floodplain water level in each floodplain watering area.
Net water losses from watering events	The net loss of water to evaporation and seepage must be quantified to determine return flows of environmental water and to budget for future environmental watering events.	Net water use will be quantified indirectly using a water balance model informed by: - hydraulic modelling - records of operational settings (pumping volumes, regulator opening and closing) - river discharge - flows and water levels at gauged locations on the floodplain
Net salinity impacts from watering events	The net salinity impact of environmental watering must be quantified to estimate the EC impact at Morgan.	Burra Creek is located in a losing reach of the River Murray and environmental watering is not expected to generate a salt load. The potential for salinity impacts will be monitored by measuring river EC upstream and downstream of Burra Creek and relating salinity levels to watering events.

OUTCOME MONITORING

The ecological objectives for Nyah are described by Ecological Associates (2014). The objectives centre on the restoration of vegetation communities, floodplain productivity and aquatic habitat through environmental water management. The water regime delivered to Burra Creek will be a product of both local water management and flow management in the River Murray. Monitoring and evaluation will be required to inform both processes.

Outcome monitoring will measure progress towards the objectives. Initial monitoring will provide a baseline of the existing status of the objectives and future monitoring will report how well the objectives are achieved.

Outcome monitoring will feed directly back to operations at the site. Water regime and ecological data will be reviewed during and after watering events to identify opportunities to promote ecological objectives more effectively and efficiently.

Outcome monitoring will also be used to test assumptions. The ecological objectives are predictions of the future status of the site and are based on imperfect site data and ecological knowledge. Monitoring data will refine the conceptual models on which the objectives are based by reporting how environmental conditions and species respond to water regimes.

Table 14. Outcome monitoring at Burra Creek

Objectives	Components	Measures	Evaluation	Knowledge Gaps and Investigations
Restoring seasonal aquatic habitat to Burra Creek	Vegetatinon-dependent native fish	Abundance and diversity of fish species	Abundance and diversity of native fish is comparable to other seasonally flooded habitats	
	Aquatic macrophytes	Extent of aquatic macrophytes	Aquatic macrophytes become established in the bed and riparian zones of the creek.	
Restoring floodplain productivity to maintain resident populations of vertebrate fauna including bats, sugar glider and lace monitor	Floodplain productivity	Organic matter load (kg dry weight per m^2) on floodplain	Organic matter load increases. Compare watered and unwatered areas.	
	Floodplain vertebrate fauna	10 yearly survey of vertebrate fauna distribution and abundance	Floodplain vertebrate fauna species are more abundant and diverse. Compare watered and unwatered areas.	Which floodplain vertebrate species are promoted by flooding? What are the energy pathways and habitat components that promote them?
Providing intermittent breeding habitat for platform-building waterbirds	Lignum shrublands	Lignum density	Density and productivity of lignum increases	
	Breeding by platform-building waterbirds including spoonbill, ibis and egret	Number of breeding birds Number of breeding species	Major breeding events in 4 out of 10 years	What local and regional flooding and sesaonal conditions promote waterbird breeding? What is the optimal flood timing and duration to promote waterbird breeding?
Contributing to the organic carbon requirements of the River Murray channel ecosystem	Organic carbon export	Dissolved and particulate organic matter concentrations in water draining from floodplain	The average annual organic carbon export increases	Does the organic matter in the River Murray downstream of watered areas increase significantly?

RISK MONITORING

The environmental risks from the implementation of the proposed water regime have been identified by Lloyd Environmental (2014).

Monitoring data is central to the strategy for risk management. Monitoring data will identify emerging hazards so that managers can adapt operations to minimise risk.

Monitoring data will also improve knowledge of how watering events promote hazards. By reporting on water regimes and hazard responses, monitoring data will help develop practices that minimise hazard development and most effectively control them when they occur.

Table 15. Risk monitoring at Burra Creek

Risk	Consequences	Mitigation	Risk Management Variables	Investigations to Refine Risk Assessment
Red gum germinate at the fringes of managed watering areas including watercourses	Watercourses become choked creating blockages to flow and aquatic fauna	Vary water levels each event Periodically provide high water levels to drown seedlings Schedule watering to minimise germination	Distribution and density of red gum seedlings in watercourses	What conditions promote red gum germination? What flooding techniques most effectively kill red gum seedlings?
Managed flood events increase carp abundance	Wetland and watercourse water quality; aquatic vegetation is degraded; carp impact on native aquatic fauna	Provide water regimes that promote native fish to increase resiliance to carp impacts and to compete with carp Operate structures to minimise benefits to carp	Carp abundance Carp size classes	What conditions promote carp recruitment and growth? What conditions impact on carp but not native fish species?
Changed flow regime favouring high risk weed species	Weeds that benefit from summer waterlogging such as noogoora burr and horehound will become established on the floodplain	Periodically inundate infested areas during the growing season of these weeds to eradicate populations	Extent and density of weed infestations	What seasonal and flooding conditions best promote weeds? What is the most efficient use of water to control weeds?
Blackwater events result from watering	Blackwater leads to the death of local populations of aquatic fauna.	Assess blackwater risk before watering events begin. Do not proceed if the risk of blackwater is high. Monitor risk factors during watering event and abort if risk becomes high.	When a watering event is planned evaluate risk in terms of: - time since last watered - time of year when watering event will take place - the depth of the watered area and likelihood of stratification - the accumulated organic matter in the target area During a watering event monitor: - vertical water temperature profile - vertical dissolved oxygen profile	How well do the identified hazards predict blackwater development? What are the impacts on watered areas when blackwater cannot be released and is retaine on the floodplain longer than planned?
Inability to discharge poor quality water	Managed flooding events are disrupted because water cannot be re-used in other wetlands and watercourses; water cannot be released to the River Murray	Monitor water quality during watering event and abort if risk becomes high. Transfer water to a low-value floodplain area, if possible. Retain a reserve of environmental water to dilute poor quality water outflows if necessary.	During a watering event monitor: - vertical water temperature profile - vertical dissolved oxygen profile - algal abundance - salinity	What conditions promote or mitigate against algal blooms?
Increase in native and non-native pest mammals (kangaroos, rabbits, pig)	Severe grazing and trampling of vegetation; poor water quality and habitat value in wetlands	Control of pest animals	Annual population counts of pest mammals Annual analysis of pest risk based on seasonal conditions and planned watering events	To what extent do watering events promote pest animals? Under what conditions (seasonal, pest animal abundance, habitat type) do pest animals have significant impacts on watered areas?

7. NYAH

PROJECT DESCRIPTION

The Nyah Floodplain Management Project is a Supply Measure project located in Nyah Park on the River Murray floodplain, 30 km north of Swan Hill in northwest Victoria. The floodplain includes wetland, forest and woodland areas and the Parnee Malloo anabranch.

The purpose of the project is to restore the integrity and productivity of the ecosystem by increasing the frequency and duration of floodplain inundation. The project concept is to use structures to retain and regulate water over the floodplain. The project inundates up to 476 ha of intact floodplain habitat.

WATER DELIVERY, USE AND SALINITY IMPACTS

Water level monitoring is required to record the forest water regime and to identify priorities for future watering. Water regime monitoring will include discharge in Parnee Malloo Creek to evaluate effectiveness in promoting flowing habitat in this channel.

Water level monitoring is also required to evaluate the effectiveness of watering in achieving ecological outcomes. Ecological responses can be related to watering events to test assumptions and improve the effectiveness and efficiency of water use.

Managed watering events involve capturing flow peaks and storing pumped water. These events will result in water losses to evaporation and seepage. Water use will be calculated using a water balance model informed by local monitoring data. It is expected that after a number of watering events have been completed, general rules of thumb for water use will be developed to estimate water use and water balance modelling will no longer be required.

Nyah is located in a region of the River Murray that recharges the aquifer. Floodplain inundation presents a low risk of increased salt loads to the River Murray. Monitoring of salinity impacts involves a low-level surveillance program using existing resources.

Table 16. Water delivery, use and salinity monitoring at Nyah

Factor	Requirement	Monitoring
Operations	Records of structure operation and use are required to confirm hydraulic relationships.	All structure settings will be recorded during watering events.
Water regime	The water levels in the forest will be monitored to record the water regime. The data will be used - to determine future watering needs and - to relate environmental outcomes to water regimes	River discharge Floodplain water level Discharge (depth and velocity) in Parnee Malloo Creek
Net water losses from watering events	The net loss of water to evaporation and seepage must be quantified to determine return flows of environmental water and to budget for future environmental watering events.	Net water use will be quantified indirectly using a water balance model informed by: - hydraulic modelling - records of operational settings (pumping volumes, regulator opening and closing) - river discharge - flows and water levels at gauged locations on the floodplain
Net salinity impacts from watering events	The net salinity impact of environmental watering must be quantified to estimate the EC impact at Morgan.	Nyah is located in a losing reach of the River Murray and environmental watering is not expected to generate a salt load. The potential for salinity impacts will be monitored by measuring river EC upstream and downstream of Burra Creek and relating salinity levels to watering events.

OUTCOME MONITORING

The ecological objectives for Nyah are described by Ecological Associates (2014). The objectives centre on the restoration of vegetation communities, floodplain productivity and aquatic habitat through environmental water management. The water regime delivered to Nyah will be a product of both local water management and flow management in the River Murray. Monitoring and evaluation will be required to inform both processes.

Outcome monitoring will measure progress towards the objectives. Initial monitoring will provide a baseline of the existing status of the objectives and future monitoring will report how well the objectives are achieved.

Outcome monitoring will feed directly back to operations at the site. Water regime and ecological data will be reviewed during and after watering events to identify opportunities to promote ecological objectives more effectively and efficiently.

Outcome monitoring will also be used to test assumptions. The ecological objectives are predictions of the future status of the site and are based on imperfect site data and ecological knowledge. Monitoring data will

refine the conceptual models on which the objectives are based by reporting how environmental conditions and species respond to water regimes.

Table 17. Outcome monitoring at Nyah

Objectives	Components	Measures	Evaluation	Knowledge Gaps and Investigations
Restoring the vegetation structure of wetland plant communities	Wetland vegetation	Extent of open water / submerged macrophyte habitat Extent of emergent macrophyte habitat	Pre-development structure of wetland habitat is restored	What is the time frame to reduce the cover of invasive red gum in wetlands?
Re-establishing resident populations of frogs and vegetation-dependent fish	Frogs	Number of frog species Frog abundance	Frog are present including in very dry years.	
	Vegetation-dependent fish	Number of fish species Fish abundance	Vegetation-dependent fish are present including in very dry years	
Providing seasonal feeding and reproductive opportunities for channel-dependent fish species	Channel-dependent fish species including murray cod and golden perch	Abundance of murray cod and golden perch in Parnee Malloo Creek	Murray cod and golden perch are present in Parnee Malloo Creek when it is flowing	
Providing reliable breeding habitat for waterbirds, including colonial nesting species	Waterbird species that breed readily - ducks, crakes, rails, waterhens and coots	Number of species breeding Number of breeding waterbirds Number of breeding sites	Species that breed readily breed 9 years in 10	
	Colonial nesting species - egret, ibis, spoonbills, cormorant	Number of species breeding Number of breeding waterbirds Number of breeding sites	Colonial nesting species breed 4 to 9 years in 10	What are the factors that promote breeding events: - local habitat quality and watering? - Seasonal conditions? - Regional flooding?
Restoring floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, sugar glider and grey-crowned babbler	Floodplain productivity	Organic matter load (kg dry weight per m^2) on floodplain	Organic matter load increases. Compare watered and unwatered areas.	
	Floodplain vertebrate fauna	10 yearly survey of vertebrate fauna distribution and abundance	Floodplain vertebrate fauna species are more abundant and diverse. Compare watered and unwatered areas.	Which floodplain vertebrate species are promoted by flooding? What are the energy pathways and habitat components that promote them?
Contributing to the organic carbon requirements of the River Murray channel ecosystem	Organic carbon export	Dissolved and particulate organic matter concentrations in water draining from floodplain	The average annual organic carbon export increases	Does the organic matter in the River Murray downstream of watered areas increase significantly?

RISK MONITORING

The environmental risks from the implementation of the proposed water regime have been identified by Lloyd Environmental (2014).

Monitoring data is central to the strategy for risk management. Monitoring data will identify emerging hazards so that managers can adapt operations to minimise risk.

Monitoring data will also improve knowledge of how watering events promote hazards. By reporting on water regimes and hazard responses, monitoring data will help develop practices that minimise hazard development and most effectively control them when they occur.

Table 18. Risk monitoring at Nyah

Risk	Consequences	Mitigation	Risk Management Variables	Investigations to Refine Risk Assessment
Red gum germinate at the fringes of managed watering areas including watercourses	Watercourses become choked creating blockages to flow and aquatic fauna	Vary water levels each event Periodically provide high water levels to drown seedlings Schedule watering to minimise germination	Distribution and density of red gum seedlings in watercourses	What conditions promote red gum germination? What flooding techniques most effectively kill red gum seedlings?
Episodic reduction in hydrodynamic diversity	Flowing habitat in Parnee Malloo Creek becomes blocked when the downstream regulator is operated to capture flood water. Flow-dependent fauna no longer benefit from the site.	Operate structures to minimise the loss of flowing habitat	Abundance of channel-specialist fish species in Parnee Malloo Creek when flowing and when blocked.	Do channel-specialist fish use Parnee Malloo Creek when it is flowing? How do these fish respond when the downstream regulator blocks flow?
Managed flood events increase carp abundance	Wetland and watercourse water quality; aquatic vegetation is degraded; carp impact on native aquatic fauna	Provide water regimes that promote native fish to increase resiliance to carp impacts and to compete with carp Operate structures to minimise benefits to carp	Carp abundance Carp size classes	What conditions promote carp recruitment and growth? What conditions impact on carp but not native fish species?
Changed flow regime favouring high risk weed species	Weeds that benefit from summer waterlogging such as noogoora burr and horehound will become established on the floodplain	Periodically inundate infested areas during the growing season of these weeds to eradicate populations	Extent and density of weed infestations	What seasonal and flooding conditions best promote weeds? What is the most efficient use of water to control weeds?
Blackwater events result from watering	Blackwater leads to the death of local populations of aquatic fauna.	Assess blackwater risk before watering events begin. Do not proceed if the risk of blackwater is high. Monitor risk factors during watering event and abort if risk becomes high.	When a watering event is planned evaluate risk in terms of: - time since last watered - time of year when watering event will take place - the depth of the watered area and likelihood of stratification - the accumulated organic matter in the target area During a watering event monitor: - vertical water temperature profile - vertical dissolved oxygen profile	How well do the identified hazards predict blackwater development? What are the impacts on watered areas when blackwater cannot be released and is retaine on the floodplain longer than planned?
Inability to discharge poor quality water	Managed flooding events are disrupted because water cannot be re-used in other wetlands and watercourses; water cannot be released to the River Murray	Monitor water quality during watering event and abort if risk becomes high. Transfer water to a low-value floodplain area, if possible. Retain a reserve of environmental water to dilute poor quality water outflows if necessary.	During a watering event monitor: - vertical water temperature profile - vertical dissolved oxygen profile - algal abundance - salinity	What conditions promote or mitigate against algal blooms?
Increase in native and non-native pest mammals (kangaroos, rabbits, pig)	Severe grazing and trampling of vegetation; poor water quality and habitat value in wetlands	Control of pest animals	Annual population counts of pest mammals Annual analysis of pest risk based on seasonal conditions and planned watering events	To what extent do watering events promote pest animals? Under what conditions (seasonal, pest animal abundance, habitat type) do pest animals have significant impacts on watered areas?

8. VINIFERA

PROJECT DESCRIPTION

The Vinifera Floodplain Management Project is located in Vinifera Park on the River Murray floodplain, 20 km northwest of Swan Hill in northwest Victoria. The floodplain includes wetland, forest and woodland areas.

The purpose of the project is to restore the integrity and productivity of the ecosystem by increasing the frequency and duration of floodplain inundation. The project concept is to use structures to retain and regulate water over the floodplain. The project inundates up to 340 ha of intact floodplain habitat.

WATER DELIVERY, USE AND SALINITY IMPACTS

Water management at Vinifera is designed to meet deficits in the ecological water requirements. Continuous water level monitoring is required to record the forest water regime and to identify priorities for future watering.

Water level monitoring is also required to evaluate the effectiveness of watering in achieving ecological outcomes. Ecological responses can be related to watering events to test assumptions and improve the effectiveness and efficiency of water use.

Managed watering events involve capturing flow peaks and storing pumped water. These events will result in water losses to evaporation and seepage. Water use will be calculated using a water balance model informed by local monitoring data. It is expected that after a number of watering events have been completed, general rules of thumb for water use will be developed to estimate water use and water balance modelling will no longer be required.

Vinifera is located in a region of the River Murray that recharges the aquifer. Floodplain inundation presents a low risk of increased salt loads to the River Murray. Monitoring of salinity impacts involves a low-level surveillance program using existing resources.

Table 19. Water delivery, use and salinity monitoring at Vinifera

Factor	Requirement	Monitoring
Water regime	The water levels in the forest will be monitored to record the water regime. The data will be used - to determine future watering needs and - to relate environmental outcomes to water regimes	Floodplain water level
Net water losses from watering events	The net loss of water to evaporation and seepage must be quantified to determine return flows of environmental water and to budget for future environmental watering events.	Net water use will be quantified indirectly using a water balance model informed by: - hydraulic modelling - records of operational settings (pumping volumes, regulator opening and closing) - river discharge - flows and water levels at gauged locations on the floodplain
Net salinity impacts from watering events	The net salinity impact of environmental watering must be quantified to estimate the EC impact at Morgan.	Vinifera is located in a losing reach of the River Murray and environmental watering is not expected to generate a salt load. The potential for salinity impacts will be monitored by measuring river EC upstream and downstream of Burra Creek and relating salinity levels to watering events.

OUTCOME MONITORING

The ecological objectives for Vinifera are described by Ecological Associates (2014). The objectives centre on the restoration of vegetation communities, floodplain productivity and aquatic habitat through environmental water management. The water regime delivered to Vinifera will be a product of both local water management and flow management in the River Murray. Monitoring and evaluation will be required to inform both processes.

Outcome monitoring will measure progress towards the objectives. Initial monitoring will provide a baseline of the existing status of the objectives and future monitoring will report how well the objectives are achieved.

Outcome monitoring will feed directly back to operations at the site. Water regime and ecological data will be reviewed during and after watering events to identify opportunities to promote ecological objectives more effectively and efficiently.

Outcome monitoring will also be used to test assumptions. The ecological objectives are predictions of the future status of the site and are based on imperfect site data and ecological knowledge. Monitoring data will refine the conceptual models on which the objectives are based by reporting how environmental conditions and species respond to water regimes.

Table 20. Outcome monitoring at Vinifera

Objectives	Components	Measures	Evaluation	Knowledge Gaps and Investigations
Restoring the vegetation structure of wetland plant communities	Wetland vegetation	Extent of open water / submerged macrophyte habitat Extent of emergent macrophyte habitat	Pre-development structure of wetland habitat is restored	What is the time frame to reduce the cover of invasive red gum in wetlands?
Re-establishing resident populations of frogs and vegetation-dependent fish	Frogs	Number of frog species Frog abundance	Frog are present including in very dry years.	
	Vegetation-dependent fish	Number of fish species Fish abundance	Vegetation-dependent fish are present including in very dry years	
Providing seasonal feeding and reproductive opportunities for channel-dependent fish species	Channel-dependent fish species including murray cod and golden perch	Abundance of murray cod and golden perch in Parnee Malloo Creek	Murray cod and golden perch are present in Parnee Malloo Creek when it is flowing	
Providing reliable breeding habitat for waterbirds, including colonial nesting species	Waterbird species that breed readily - ducks, crakes, rails, waterhens and coots	Number of species breeding Number of breeding waterbirds Number of breeding sites	Species that breed readily breed 9 years in 10	
	Colonial nesting species - egret, ibis, spoonbills, cormorant	Number of species breeding Number of breeding waterbirds Number of breeding sites	Colonial nesting species breed 9 years in 10	What are the factors that promote breeding events: - local habitat quality and watering? - Seasonal conditions? - Regional flooding?
Restoring floodplain productivity to maintain resident populations of vertebrate fauna including carpet python, sugar glider and grey-crowned babbler	Floodplain productivity	Organic matter load (kg dry weight per m^2) on floodplain	Organic matter load increases. Compare watered and unwatered areas.	
	Floodplain vertebrate fauna	10 yearly survey of vertebrate fauna distribution and abundance	Floodplain vertebrate fauna species are more abundant and diverse. Compare watered and unwatered areas.	Which floodplain vertebrate species are promoted by flooding? What are the energy pathways and habitat components that promote them?
Contributing to the organic carbon requirements of the River Murray channel ecosystem	Organic carbon export	Dissolved and particulate organic matter concentrations in water draining from floodplain	The average annual organic carbon export increases	Does the organic matter in the River Murray downstream of watered areas increase significantly?

RISK MONITORING

The environmental risks from the implementation of the proposed water regime have been identified by Lloyd Environmental (2014).

Monitoring data is central to the strategy for risk management. Monitoring data will identify emerging hazards so that managers can adapt operations to minimise risk.

Monitoring data will also improve knowledge of how watering events promote hazards. By reporting on water regimes and hazard responses, monitoring data will help develop practices that minimise hazard development and most effectively control them when they occur.

Table 21. Risk monitoring at Vinifera

Risk	Consequences	Mitigation	Risk Management Variables	Investigations to Refine Risk Assessment
Red gum germinate at the fringes of managed watering areas including watercourses	Watercourses become choked creating blockages to flow and aquatic fauna	Vary water levels each event Periodically provide high water levels to drown seedlings Schedule watering to minimise germination	Distribution and density of red gum seedlings in watercourses	What conditions promote red gum germination? What flooding techniques most effectively kill red gum seedlings?
Managed flood events increase carp abundance	Wetland and watercourse water quality; aquatic vegetation is degraded; carp impact on native aquatic fauna	Provide water regimes that promote native fish to increase resiliance to carp impacts and to compete with carp Operate structures to minimise benefits to carp	Carp abundance Carp size classes	What conditions promote carp recruitment and growth? What conditions impact on carp but not native fish species?
Changed flow regime favouring high risk weed species	Weeds that benefit from summer waterlogging such as noogoora burr and horehound will become established on the floodplain	Periodically inundate infested areas during the growing season of these weeds to eradicate populations	Extent and density of weed infestations	What seasonal and flooding conditions best promote weeds? What is the most efficient use of water to control weeds?
Blackwater events result from watering	Blackwater leads to the death of local populations of aquatic fauna.	Assess blackwater risk before watering events begin. Do not proceed if the risk of blackwater is high. Monitor risk factors during watering event and abort if risk becomes high.	When a watering event is planned evaluate risk in terms of: - time since last watered - time of year when watering event will take place - the depth of the watered area and likelihood of stratification - the accumulated organic matter in the target area During a watering event monitor: - vertical water temperature profile - vertical dissolved oxygen profile	How well do the identified hazards predict blackwater development? What are the impacts on watered areas when blackwater cannot be released and is retaine on the floodplain longer than planned?
Inability to discharge poor quality water	Managed flooding events are disrupted because water cannot be re-used in other wetlands and watercourses; water cannot be released to the River Murray	Monitor water quality during watering event and abort if risk becomes high. Transfer water to a low-value floodplain area, if possible. Retain a reserve of environmental water to dilute poor quality water outflows if necessary.	During a watering event monitor: - vertical water temperature profile - vertical dissolved oxygen profile - algal abundance - salinity	What conditions promote or mitigate against algal blooms?
Increase in native and non-native pest mammals (kangaroos, rabbits, pig)	Severe grazing and trampling of vegetation; poor water quality and habitat value in wetlands	Control of pest animals	Annual population counts of pest mammals Annual analysis of pest risk based on seasonal conditions and planned watering events	To what extent do watering events promote pest animals? Under what conditions (seasonal, pest animal abundance, habitat type) do pest animals have significant impacts on watered areas?

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