Updated Draft

Guttrum Forest & Benwell Forest

Operating Plan

Draft: July 2020

North Central CMA

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Acknowledgment of Country

The North Central Catchment Management Authority acknowledges Aboriginal Traditional Owners within the region, their rich culture and spiritual connection to Country. We also recognise and acknowledge the contribution and interest of Aboriginal people and organisations in land and natural resource management.

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Front cover photo: Environmental water delivered to Reed Bed Swamp, Guttrum Forest October 2019

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Document control

Revision and distribution

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1	Draft prepared by P. Beattie	North Central CMA SDL team	2 October 2014
2	Revised draft prepared by P. Beattie. Feedback from SDL team meeting included, along with DHI modelling results.	North Central CMA SDL team	6 November 2014
3	Final draft prepared by P. Beattie. Feedback included from Operating Plan Workshop held in Tatura on 10 November and final DHI modelling results.	North Central CMA SDL team	17 November 2014
4	Final draft (version 2) prepared by P. Beattie. Includes business case DEPI feedback	North Central CMA SDL team	11 December 2014
5	Updated draft (version 3) prepared by G. Smith to align with refined concept designs since business case development. Changes as a result of revised / updated hydraulic modelling outcomes added by C. Corr.	Tim Shanahan, VMFRP	17 July 2020

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1. Introduction

1.1. Background

The Guttrum and Benwell Forests Environmental Works Project is a supply measure project being developed by the North Central Catchment Management Authority (CMA) for consideration under the Basin Plan. The project aims to address flooding deficiencies and achieve environmental watering outcomes using less water than required under the benchmark conditions outlined in the Basin Plan. This project is one of nine sites proposed under the Victorian Murray Floodplain Restoration Project (VMFRP).

This document outlines the proposed operating plan for infrastructure to be built under the project in order to achieve the ecological objectives. It brings together relevant information from a large body of work that exists for the Guttrum and Benwell Forests (e.g. concept designs, hydraulic modelling, ecological investigations and risk assessments) including lessons learnt from past watering events managed elsewhere by the North Central CMA. It does not include information on roles and responsibilities, pre-operation planning, accounting and other administrative information. Much of this information is covered by the *Operating Arrangements for the Environmental Water Holdings of the Victorian Murray System*, updated in June 2020 by the Victorian Environmental Water Holder with input from key operational stakeholders.

The contents herein are intended to support the approvals process for the Guttrum and Benwell Forests Environmental Works Project and if successful, will be updated over time as part of ongoing adaptive management at the site.

Note: this document was first developed in 2014 and subsequently updated in 2020 following significant changes to the concept designs (i.e. shift from gravity-fed off the irrigation system to pump stations off the Murray River). The ecological principles of the environmental water operations remain largely the same. However, at the time of writing there is still further work to be completed on hydraulic modelling and preliminary designs so this document will need to be updated again to accurately reflect the final designs and capabilities of the project prior to operations commencing.

1.2. Design principles

The Guttrum and Benwell Forests package of works has been designed to:

- mimic the extent of a natural 26,000ML/day flood event in Guttrum Forest, which would have occurred about 80 times per 100 years for 90 days (median duration) prior to river regulation and now occurs about 41 times per 100 years for 70 days (median duration) (Gippel 2014).
- mimic the extent of a natural 24,000ML/day flood event in Benwell Forest, which would have occurred about 87 times per 100 years for 109 days (median duration) prior to river regulation and now occurs about 45 times per 100 years for 83 days (median duration) (Ecological Associates 2013).
- enable watering of the full range of flood-related habitats within the forests from semi-permanent wetlands through to River Red Gum forests with flood dependent understorey.
- enable top-up water to be provided to the semi-permanent wetland complexes so that flood duration requirements are met, even if River Murray flood durations are inadequate.
- allow water to be held on the floodplain so that flood duration requirements are met for the River Red Gum forests, if River Murray flood durations are inadequate and as part of blackwater risk mitigation, to enable gradual release of blackwater when River Murray flows and conditions are appropriate.
- prevent flooding of private land from environmental water deliveries.
- enable native fish movement off the floodplain (for those fish entering the forest via natural flooding) as water levels recede.
- provide operational flexibility to meet the various water requirements of the flora and fauna communities.

In doing so, the works aim to inundate about 1,150 hectares of floodplain, including about 676 hectares in Guttrum Forest and 471 hectares in Benwell Forest (1,147 ha total).

1.3. Overview of scenarios

Three scenarios have been identified for water delivery to the Guttrum and Benwell Forests, each of which is designed to meet the ecological objectives defined for these areas. The relationship between these scenarios and the ecological objectives is shown below.

The operating scenarios include:

- Forest floodplain (River Red Gum and wetland) watering
- Semi-permanent wetland watering
- Hybrid events – enhancing unregulated flow events e.g. extending the duration of flooding and/or supplementing the inflow rate, supporting bird breeding events.

Table 1 Summary of operating scenarios and their link to the ecological objectives[1]

Ecological objective	Operating scenario: Forest floodplain watering	Operating scenario: Semi-permanent wetland watering	Operating scenario: Hybrid event
Semi-Permanent Wetlands			
Overarching: Improve the health of semi-permanent wetlands			
Achieve an appropriate cover and diversity of species characteristic of the Plant Functional Groups found in the semi-permanent wetlands.			
Reduce River Red Gum encroachment in semi-permanent wetland areas.			
Provide suitable habitat for the threatened (EPBC listed) Growling grass frog.			
Maintain and where possible increase the current diversity of threatened flora species.			
Reduce the area of high threat weed species.			
Native Birds			
Overarching: Healthy wetland bird community across Guttrum and Benwell Forests through improved access to food and habitat that promotes breeding and recruitment			
Support a suite of waterbirds including waterfowl, colonial waterbirds and other wetland dependent species.			
Provide foraging areas for colonial nesting waterbirds in Guttrum and Benwel Forest and potentially elsewhere (e.g. lower Gunbower Forest).			
Provide suitable habitat for the threatened (EPBC listed) Australasian Bittern in the Guttrum Forest.			
Maintain and where possible increase the current diversity of threatened wetland bird species.			
River Red Gum Forest			
Overarching: Healthy River Red Gum communities.			
Achieve an appropriate cover and diversity of species characteristic of the Plant Functional Groups found in the River Red Gum forest understorey.			
Maximise the proportion of trees with healthy canopy condition in the River Red Gum forests.			
Maintain and where possible increase the current diversity of threatened flora species.			
Reduce the area of high threat weed species.			

[1] The objectives in Table 1 are those developed for the business cases in 2014. The Arthur Rylah Institute has undertaken a review of the objectives and is in the process of updating them, though further review from key stakeholders is required. It is expected that any new objectives will not vary greatly from the business case objectives, but that the wording will be updated to accommodate the proposed monitoring methods and relate back to key state and Commonwealth strategic programs (i.e. Basin Plan, WetMAP).

Ecological objective	Operating scenario		
	Forest floodplain watering	Semi-permanent wetland watering	Hybrid event
Native Fish			
Overarching: Promote recruitment of the local River Murray channel specialist native fish community by increasing opportunities to access productive floodplain water exiting Guttrum and Benwell Forests.			

1.4. This document

This document has been divided into a series of chapters (one per operating scenario) which documents the following information for each:

- Overview – a description of those parts of the forests (ecological components) that are relevant to the operating scenario.
- Purpose – the intention of the operating scenario from an ecological perspective.
- Hydrological requirements – the water regime needed for the ecological components in order to achieve the objectives. This is based on scientific evidence where possible and/or practical experience.
- Infrastructure operations to achieve the hydrological requirements.

Additional chapters have also been provided regarding other important considerations for operating the works:

- Fish exit strategy (during hybrid or natural events)
- Climate and water availability conditions.

1.5. Risk management

A detailed risk assessment process has highlighted a number of ecological, socio-economic and geotechnical risks that can potentially be mitigated through operational measures. These are summarised here, along with their potential implications for how the infrastructure can be operated to deliver environmental water:

Table 2 Summary of risks with operational mitigation measures

Risk	Implications for operation of infrastructure
ECOLOGICAL	
Blackwater	In cases where there is a higher risk of blackwater (e.g. large organic matter loads due to a longer period since the previous flood), the forests may be inundated in mid-May (start of the off-irrigation season) as a way of leaching the organic matter prior to the start of the formal/complete forest watering event in July. The leaching water would be returned to the River Murray prior to hypoxia developing. Blackwater that does develop on the floodplain can only be released to receiving waterways when there is an adequate flow within these waterways to effectively dilute the blackwater and any associated low dissolved oxygen levels. This is only applicable to the forest floodplain watering scenarios (fully managed and hybrid events), as the other wetland delivery scenarios are not intended to have connectivity with the River Murray. Any floodplain water entering the River Murray from the Guttrum or Benwell Forests will occur following careful analysis of the extent/degree of any blackwater present and the capacity of the river to receive these flows without being negatively impacted. Close consultation with River Murray Water, ecologists and other stakeholders will occur in each case. In terms of blackwater within the semi-permanent wetlands, minimum inflows will be used to top-up the wetlands, reduce stratification and freshen water held within each system, during the delivery period in mid to late spring. This will help reduce the risk of low dissolved oxygen during the warm spring months when there is an increasing chance of low dissolved oxygen. Dissolved oxygen levels will reduce over the summer months as the wetlands evaporate and remaining water rises in temperature.
River Red Gum encroachment	River Red Gum encroachment of wetlands will be minimised by providing conditions that are not conducive to mass germination of River Red Gum seedlings i.e. where possible top-up flows will be provided to wetlands following broader forest flooding so that draw down of water in the wetlands occurs during the natural period of late summer/autumn

Risk	Implications for operation of infrastructure
	(Ecological Associates 2013), rather than late spring/early summer (North Central CMA 2014c). Successive years of inundation will also assist in drowning any unwanted seedlings that may germinate.
Waterbird breeding – abandoning of chicks	Where significant colonial waterbird breeding is evident, operations will be carefully managed to maintain a stable water level within the wetland supporting the breeding colony and in the surrounding foraging area. This includes a gradual drawdown from peak flows to minimum inflows and a continuation of minimum inflows until chicks have fledged. See the waterbird breeding scenario for further details.
Fish stranding	Under managed events only, as the method of delivery is via pump stations with fish exclusion screens, limited numbers of fish will be present on the floodplain. However, in hybrid events fish may have moved from the river to the floodplain, and environmental water can be delivered to maintain water quality. Under hybrid events, a plan is required to cue fish to move off the floodplain on the recession. A sharp drop in water level will be provided during the drawdown phase of hybrid forest watering events, as a way of cueing native fish to exit the floodplain and enter the River Murray. Following the sharp drop, flows will be increased for a short period and a second drop provided to cue any remaining fish to exit the floodplain. During this period, it is important that inflows continue for a time to retain connectivity across the floodplain so that fish are able to migrate to outlet points before inflows cease and connectivity across the floodplain is lost. See fish exit strategy for further details.
Domination of flora by one species e.g. *Typha*	Variability in environmental water deliveries to wetlands is needed to avoid any one species being favoured at the expense of others. This includes varying the timing, depth, duration and frequency of watering in response to climatic conditions and the results of ecological monitoring. A variable water regime will mimic the variability inherent in natural flood events.
GEOTECHNICAL	
Bank slumping and levee failure	Changes in water levels through both inflows and outflows will occur gradually, particularly during draining to lower the risk of bank slumping or levee failure as per the North Central CMA Levee Breach and Risk Assessment and Strategy (Water Technology 2014).
SOCIO-ECONOMIC	
Economic impact and negative community perception about the project due to reduced access for forest uses - recreation, bee-keeping for honey production, domestic firewood collection, forestry, minor sand quarrying, cattle grazing.	Stakeholder engagement will be ongoing. Plans for environmental water delivery will be communicated with the Department of Environment, Land, Water and Planning (DELWP) well in advance, so that the various forest users can be alerted to periods when environmental watering is likely to occur in a given year and what alternative options there are for their respective activities during these periods e.g. alternative access locations. Any new licenses to access the forest for extractive or other activities are likely to include conditions that reference the need to water the forests to maintain wider ecological outcomes.

Further comment on operational mechanisms to address the above risks are made in each operating scenario chapter where applicable. Detailed descriptions of each risk are available in the risk register developed for the project and in the risk related chapters and appendices of the business case.

2. Forest floodplain watering

2.1. Overview

Watering the forest floodplain includes inundating the River Red Gum forests with flood dependent understorey and the lower lying semi-permanent wetland systems. Hydraulic modelling suggests River Red Gum forests with flood tolerant understorey are largely unaffected by the project (outside the inundation footprint).

River Red Gum forests with flood dependent understorey occur in areas with a low flooding threshold that do not retain deep water when floods subside (Ecological Associates 2013). In the Guttrum and Benwell Forests, the River Red Gum with flood dependent understorey areas generally relate to the Riverine Swamp Forest and Floodway Pond Herbland/Riverine Swamp Forest Complex Ecological Vegetation Classes (Ecological Associates 2013).

2.2. Purpose

The forest floodplain watering scenario aims to reinstate the natural water regime of the River Red Gum forests with flood dependent understorey in both the Guttrum and Benwell Forests. Water will be delivered to meet the shortfall in frequency and duration of natural flooding, and to target the water requirements of River Red Gum communities. Some of the lower-lying River Red Gum communities will be flooded more frequently as a result of management interventions in the semi-permanent wetlands. This is seen as a positive outcome and mimics the more frequent flooding of the low-lying areas that would have occurred under natural conditions.

The scenario will contribute towards achievement of the project's ecological objectives for the river red gum forests, the semi-permanent wetlands, native birds, and carbon and nutrient input to the Murray River system (Table 1). It is therefore an important scenario for achieving a range of ecological outcomes.

This scenario relates to watering the forest floodplain from dry conditions in order to achieve the desired frequency (and duration) of watering in addition to that supplied by natural events. The flooding will mimic approximately a 26,000ML/day natural event in Guttrum Forest and a 24,000ML/day natural event in Benwell Forest in terms of area and location of inundation (DHI 2014) (see below). The hybrid scenario (Section 5) includes top-up watering of the forest floodplain following natural flow peaks, and/or flood capture where appropriate, to achieve required flooding duration and extent where it is inadequate.

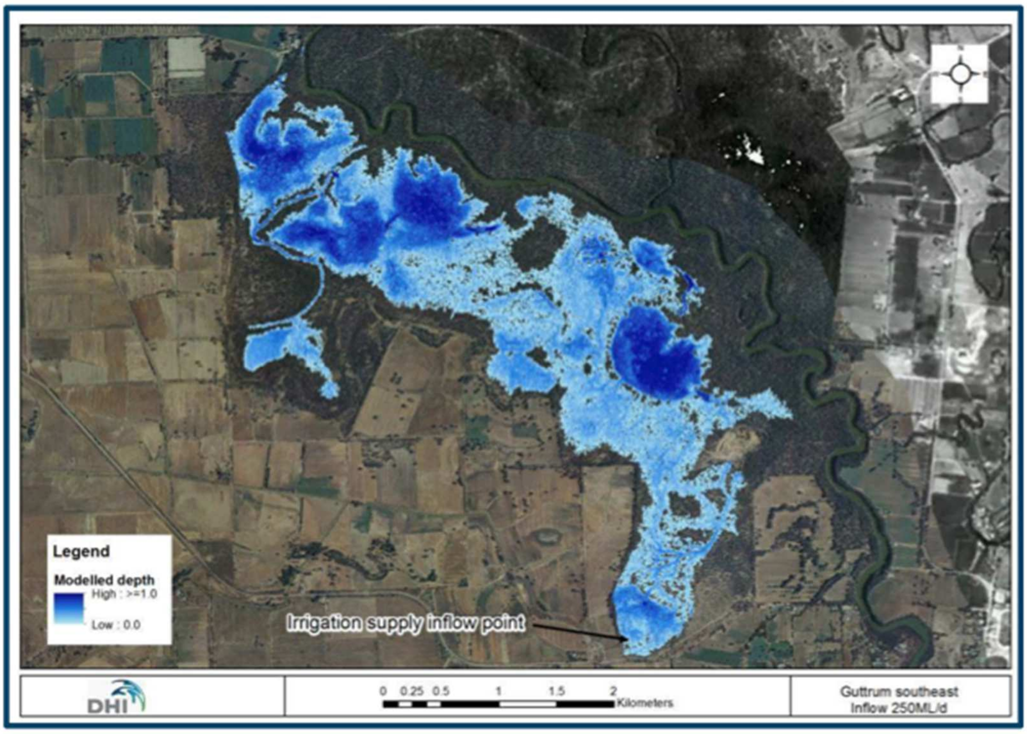

Figure 1: Guttrum Forest modelled inundation extent – 250ML/day inflow from two pump stations (125 ML/d each) in the east and west ends.

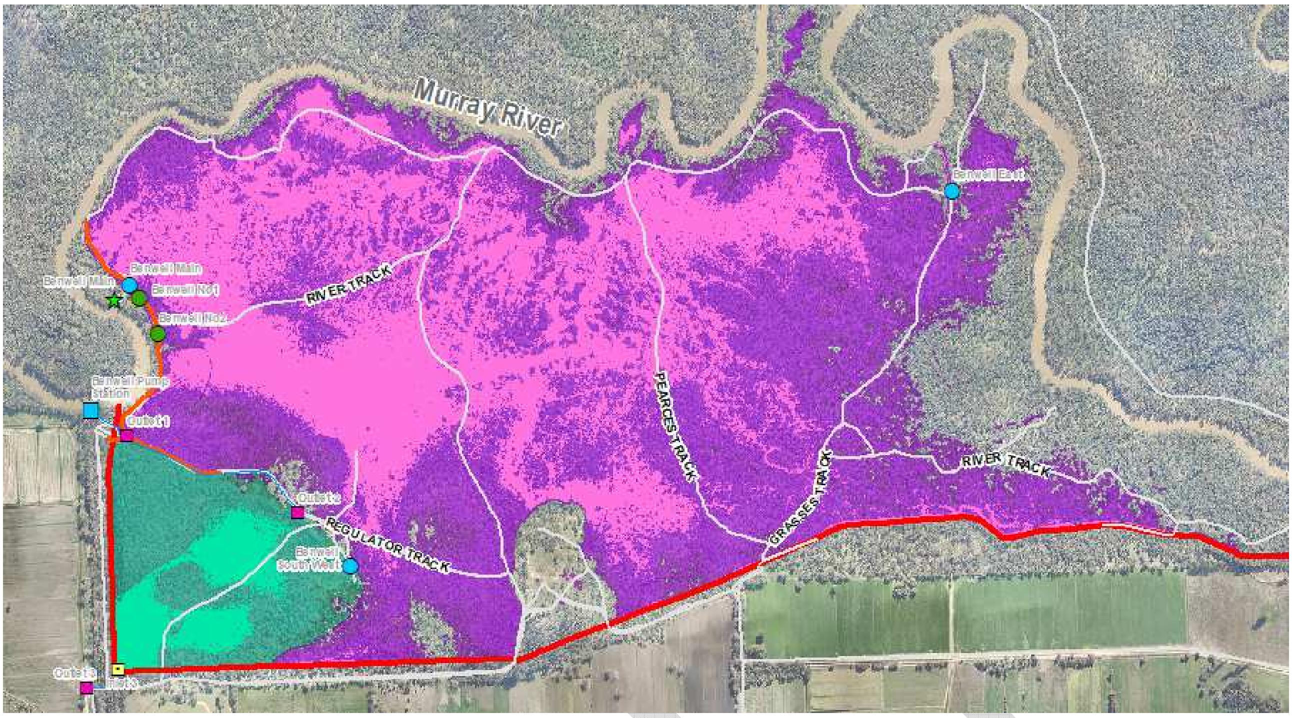

Figure 2 Benwell Forest modelled inundation extent at 74.9 m AHD– 125 ML/d inflow from western end (blue square on map).

2.3. Hydrological requirements

Pre-regulation water regime

Hydraulic modelling suggests flooding of the River Red Gum forest with flood dependent understorey commences at Benwell Forest at flows above 18,000ML/day and at Guttrum Forest at flows above 20,000ML/day (DHI 2014; Ecological Associates 2013). Flooding of these areas is mostly complete in both forests at River Murray flows of 26,000ML/day (DHI 2014; Ecological Associates 2013).

Under natural conditions, inflows of 26,000ML/day would have occurred in about 8 out of 10 years with events lasting 1.5 to 4.5 months (interquartile range) (Gippel 2014).

Hydrological requirements

The hydrological requirements needed to achieve the ecological objectives specific to the forest floodplain watering scenario are shown below. Supporting evidence for these requirements is provided in the Guttrum and Benwell Forest Ecological Objectives and Hydrological Requirements Justification Papers (North Central CMA 2014a; North Central CMA 2014b).

Note: The River Red Gum forest with flood dependent understorey across both sites is predominantly Riverine Swamp Forest (EVC 814). In Benwell Forest, a substantial portion of the eastern floodplain is Grassy Riverine Forest (106), with Riverine Swamp Forest dominating the western portion (Biosis & Bennetts 2014). The water regime has therefore been based on the Riverine Swamp Forest EVC, with the optimum duration of ponding reflecting that suitable for both the Riverine Swamp Forest and Grassy Riverine Forest EVCs.

Access to outflows from the forest floodplain for native channel specialist fish and other aquatic biota is provided through release of carbon and nutrient rich water from the broad inundation of the River Red Gum forests. The hydrological requirements for this objective therefore reflect that defined for River Red Gum forest with flood dependent understorey (discussed above).

Table 3 Hydrological requirements to achieve the ecological objectives specific to forest floodplain watering. Requirements for other ecological values are also covered by this scenario, but are described in relevant sections.

Overarching ecological objectives	Hydrological requirements										
	Recommended number of events in 10 years			Tolerable interval between events once area is dry (months)			Duration of ponding (months)			Preferred timing of inflows	Depth
	Min	Opt	Max	Min	Opt	Max	Min	Opt	Max		
River Red Gum with flood dependent understorey (Healthy River Red Gum communities)	6	7	8	-	-	36	4	4	7	Winter/ spring	Not critical for adult River Red Gums. Varies for understorey. Some understorey sp. prefer shallow depths <10cm during active growth but can tolerate deeper immersion for short periods.
Native fish[2] (Promote recruitment of the local River Murray channel specialist native fish community by increasing opportunities to access productive floodplain outflows from Guttrum and Benwell Forests.)	6	7	8	-	-	36	4	4	7	Outflows to River Murray in spring/ summer after temperature and flow cued spawning occurs in the channel.	Sharp drop in water level required to provide a fish exit cue in late spring/summer for any fish that have entered the floodplain. Hypothesis: 0.3m over 48 hrs. This will also promote organic matter transport.

Water delivery requirements

Based on the above hydrological requirements, the flooding frequency for River Red Gum forests with flood dependent understorey is up to 8 years in 10. Modelling shows under current conditions (benchmark with TLM model run), flows required to achieve substantial floodplain inundation (26,000ML/day) occur 4 years in 10 (Gippel 2014). These flows occur about 5 years in 10 under Basin Plan 2750 conditions (Gippel 2014). It is important to note that this model run uses data from 1895 to 2009 and does not capture the changes to water availability that are expected under a drying climate. Data from the last two decades alone shows that natural inflows have occurred only 5 times to the wetlands over 20 years as opposed to the 'current conditions' modelling of 4.5 years in 10 by Gippel 2014. For the purposes of this project, however, the Basin Plan 2750 (2750 gigalitres of environmental water recovered) scenario has been assumed, until the full effects of the Basin Plan implementation can be analysed.

This leaves a current flooding frequency deficit of 4 years in 10 and a Basin Plan deficit of 3 years in 10 where watering the dry forest floodplains is required.

2.4. Infrastructure operation (from dry)

Note: Further refinement of the concept designs and hydraulic modelling is being undertaken at the time of writing. Once final design and modelling reports are complete, this section will need to be updated to accurately reflect these reports.

[2] Note this objective is likely to be updated to focus on carbon loads and/or stream metabolism rather than native fish.

Guttrum Forest

Water will be delivered via two pump stations situated on the Murray River in both the east and west of the forest. Two pump stations are required to be operated under a full forest watering event as high ground in the middle of the forest means that the time-to-fill would be too long if only one pump station was used (DHI 2017). In addition, the two pump stations enable independent watering of the semi-permanent wetland complexes. The eastern pump station (Guttrum East) will have three outlet points that facilitate filling of the eastern semi-permanent wetlands as well as the forest floodplain. All of these outlets would typically be used to fill the forest from dry, with a maximum inflow capacity of 125 ML/d. An additional 125 ML/d will be delivered from Guttrum West pump station, totalling 250 ML/d flow rate to fill the forest from dry.

The inflow capacities of each inlet point are:

- Little Reed Bed Swamp = max 15 ML/d
- Reed Bed Swamp North = max 80 ML/d
- Reed Bed Swamp South = max 30 ML/d

To achieve an equivalent inundation extent of an approximate 26,000ML/day River Murray inflow, the pump stations would be allowed to run until the level at the forest outlet (Guttrum Main Regulator) reaches 75.8 m AHD (DHI 2020). At this level, hydraulic modelling shows there are no return flows to the River Murray via the other inlet points along the River Murray (i.e. G1, G2 and G3) (DHI 2014). Therefore only the Main Regulator would need to be closed during the operation (assuming water levels remain at 75.8 m AHD at the outlet). However, depending on which environmental water inlets are utilised during a full forest watering event, three small regulators (Little Reed Bed Swamp Regulator, Reed Bed Swamp North Regulator and Reed Bed Swamp South Regulator) will be built on these effluents along River Track in the eastern part of the forest. These regulators would be closed if required to contain water on the floodplain and direct it into the forest.

Once the maximum environmental watering level of 75.80 mAHD is reached at the Guttrum Regulator, the Guttrum West Pump Station would be turned off and the Guttrum Regulator would commence automatic modulation to maintain the desired water level. The Guttrum East Pump Station would continue to operate at a high to maximum flow rate to maintain the maximum inundation extent possible for the east and south parts of the forest. The Guttrum East Pump Station would then reduce its flow rate to provide "maintenance flows" and the forest will be operated as a through-flow system. Maintenance flows aim to maintain the extent for the optimal duration to support the ecological objectives; provide freshening inflows that will assist with managing water quality; and return continuous carbon and nutrient-rich outflows to the Murray River. Outflows would occur through the Main Regulator and water would drain from the forest floodplain to the River Murray as occurs naturally.

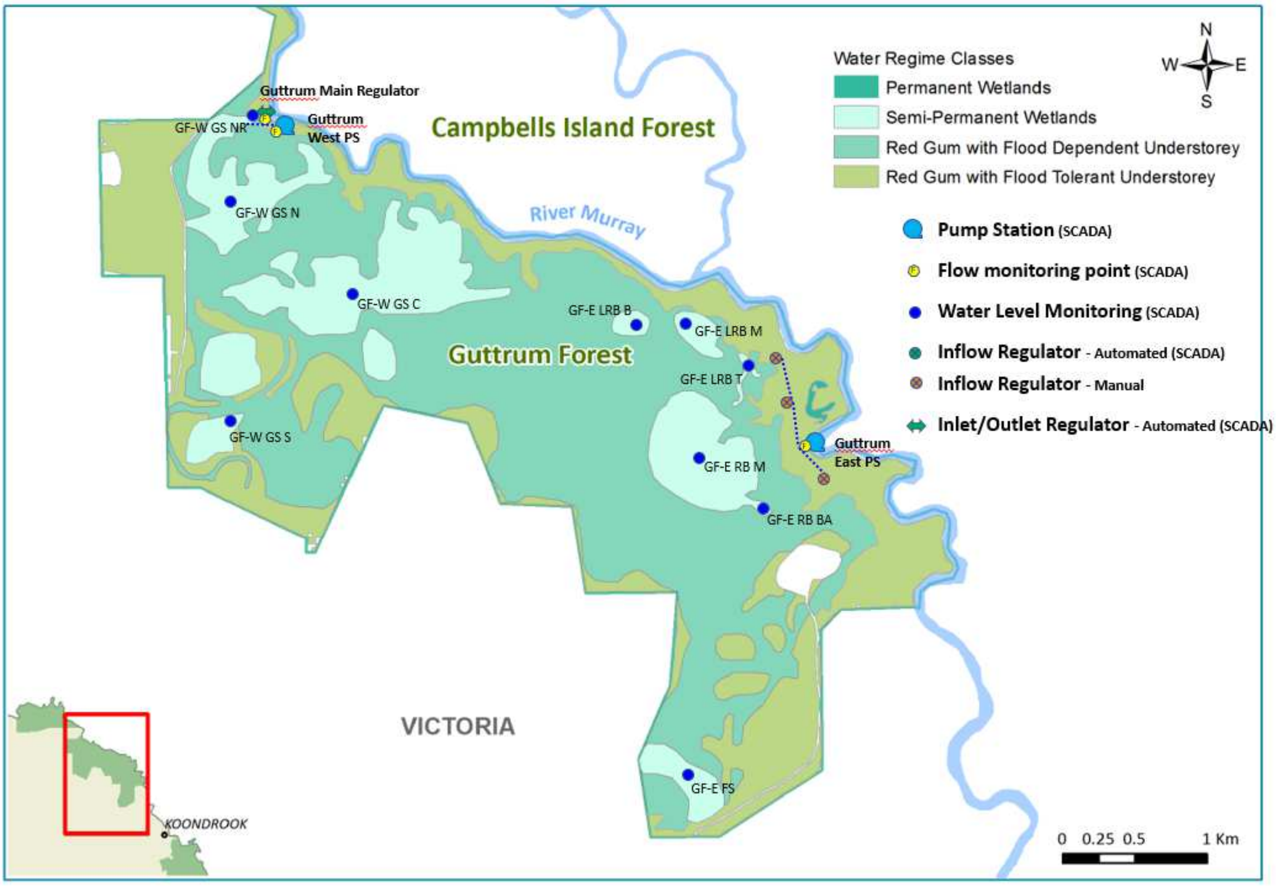

Figure 3 Location of Guttrum Forest Infrastructure (as of July 2020, produced by NCCMA)

The table and hydrograph below summarises the proposed infrastructure operation to deliver water to the Guttrum Forest floodplain under this scenario. This represents the maximum use of the infrastructure i.e. water delivery to a dry forest with the aim of creating the maximum possible flood extent within the River Red Gum with flood dependent understorey water regime class.

In summary, the indicative inflow pattern will be:

- **Filling phase:** Gradual ramp up with filling at peak flows of 250 ML/day from both pump stations for 16 days to achieve the desired inundation extent (75.8 m AHD at the forest outfall)
- **Maintenance phase:** opening the Guttrum Main Regulator and reducing inflows from 250 ML/day to between 65 and 90 ML/day from the Guttrum East Pump Station only to offset losses and provide return flows to the Murray.
- continue providing maintenance inflows at 90ML/day for about 110 days to meet the duration requirements of the River Red Gum forests (with approx. 25 ML/day return flows to the River Murray during this period)
- **Ramp down phase:** gradual ramp down of inflows.

Further explanation is provided below.

Table 4 Operating plan summary for the maximum forest floodplain watering scenario – Guttrum Forest. Figures are provided from a number of

Component of operating plan	Proposed operation for forest floodplain watering scenario
Frequency of delivery	3 years in 10 (inundation in other years provided through Basin Plan inflows to achieve the 8 in 10 flooding frequency)
Timing	Winter/spring *[Late winter inflows and spring drawdown so floodplain water is available in River Murray at time of in-channel spawning.]*
Inundated area	676 ha (DHI 2020)
Peak inflow rate	250 ML/day (DHI 2017 & 2020)
(A) Delivery time (days to fill from dry)	16 days (DHI 2020)
(B) Drying time (days to dry for RRG forests once outflows to the River Murray cease)	14 days (DHI 2014) *[Guttrum River Red Gum forest DHI drainage tables]*
(C) Desired duration of inundation for RRG forests (from hydrological requirements)	124 days (i.e. 4 mths)
(D) Duration of delivery once floodplain full (maintenance phase)	110 days (i.e. 3.5 mths)* *[D = C – B)* *[E = 124 days required duration minus 14 (drying time)]*
(E) Total length of event (excluding ramp up and ramp down)	140 days (i.e. 4.5 mths approx.) *[E = A + D + B]* *[F = 16 (fill time) plus 110 (duration of delivery) plus 14 (drying time)]*
Estimated total water inflow (ML) (excluding ramp up, ramp down and contingencies)	13,900 ML *[X = 16 days filling @ 250 ML/day plus 110 days maintenance @ 90 ML/day]*
Estimated total water return flows to Murray River (ML)	2,750 ML (20% of total pumped water)

*Does not take into account fill time (16 days), so that forest areas further from the inlets also receive their duration requirements. i.e. takes 16 days for water to reach this location.

Note: this scenario will include wetlands retaining some water for a further 4 months after throughflows (at up to 90 ML/day) cease.

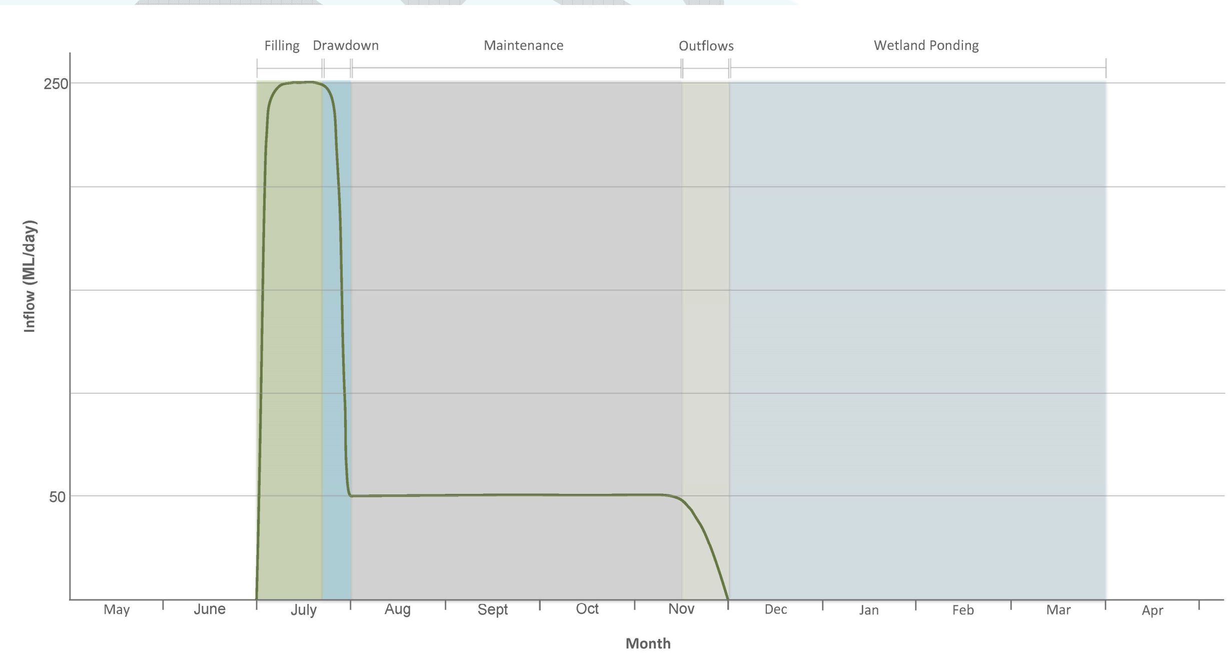

Figure 4 Conceptual diagram of the maximum forest floodplain watering scenario – Guttrum Forest. Note that with the shift to pump stations, there is increased flexibility for commencing inflows so the hydrograph may shift later in the season in a given year, if beneficial.

Benwell Forest

Note: hydraulic modelling and concept designs for Benwell Forest, including the management of levees and levee risk, are still undergoing refinement and extent and water levels may change. Once final design and modelling reports are complete, this section will need to be updated to accurately reflect these reports. For the purposes of this document, the maximum water levels and extent are used here to reflect, as far as possible, the original intent of the project. For this purpose, a preliminary full supply level of 74.9 mAHD has been adopted across the whole Benwell Forest.

Water will be delivered via a pump station situated on the Murray at the western end of Benwell forest at a maximum rate of 125 ML/d.

To achieve an equivalent inundation extent of a 24,000 ML/day River Murray inflow, water would be delivered from the pump station via two outlets (one main one to central and eastern forest, and one smaller one to south west area) while regulators at low points along the River Murray would be closed during the filling stage (i.e. Benwell Main Regulator and Benwell East Regulator (formerly known as B13 and B7 respectively)) (DHI 2014; R8 in prep.). The ground profile along the western bank of the river at the downstream end of the forest mostly utilising the existing alignment of River Track will be raised as part of infrastructure works, which will contain water on the floodplain and prevent outflows during delivery (DHI 2014). Further investigation is ongoing to determine if additional infrastructure is required within the containment bank along River Track so that natural flow paths remain uninhibited as much as possible.

Once the maximum desired inundation extent and depth is achieved, the Benwell Main Regulator and Benwell East Regulator will be opened (partially or fully, depending on river conditions) to create a throughflow, with maintenance flows provided at lower flow rates to match losses within the forest and enable return flows. The regulators would actively operate to maintain the target water level. This water delivery would continue to maintain the area of inundation for the required duration. Towards the end of the watering event, larger volumes of outflows would be released by opening the outlet regulators, and water would drain from the forest floodplain to the River Murray as occurs naturally.

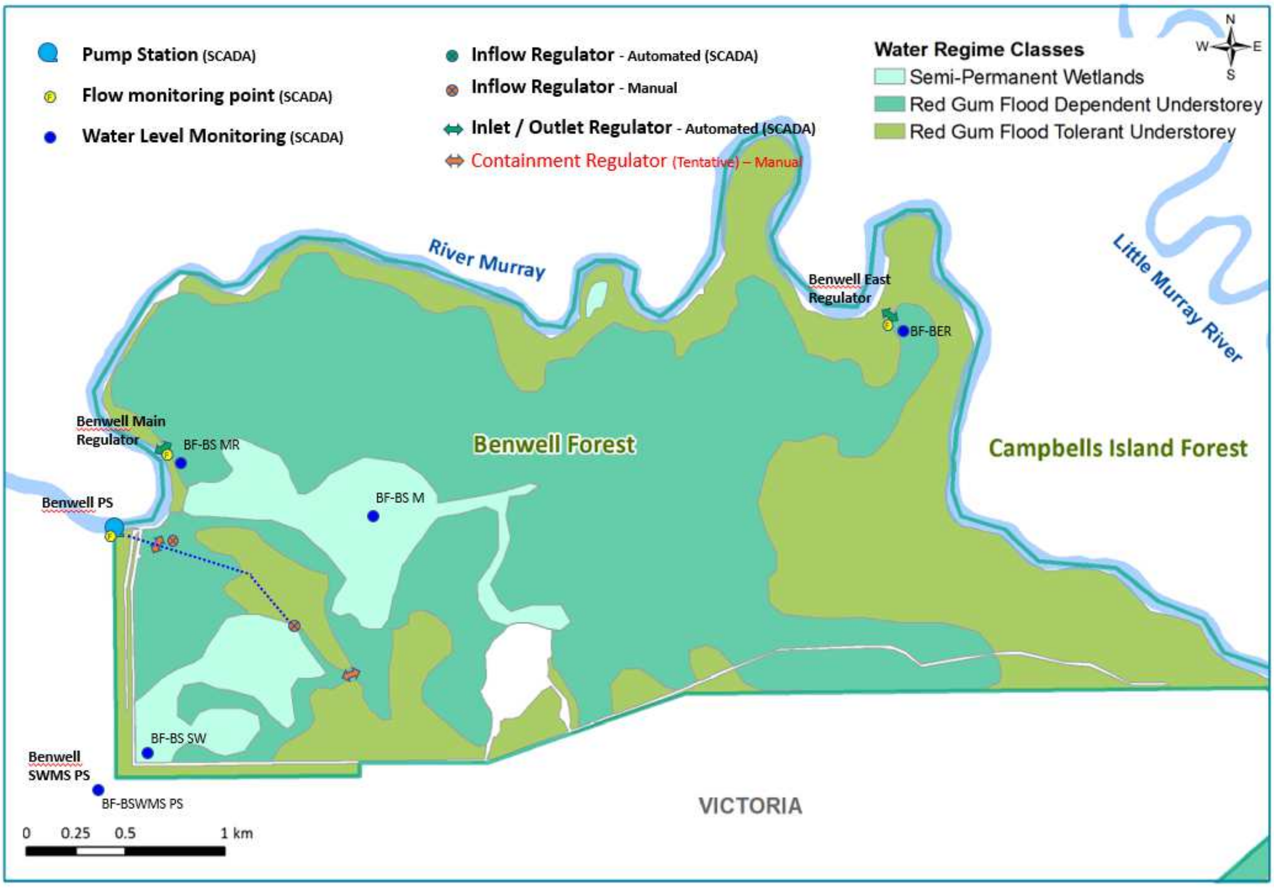

Figure 5 Location of Benwell Forest infrastructure (Source: as of July 2020, produced by NCCMA)

The table below summarises the proposed infrastructure operation to deliver water to the Benwell Forest floodplain under this scenario. This represents the maximum use of the infrastructure i.e. water delivery to a dry forest with the aim of creating the maximum possible flood extent within the River Red Gum with flood dependent understorey water regime class. Refer to the hydrograph for this scenario in Guttrum Forest as an indication of how water is intended to be delivered over time.

In summary, the indicative inflow pattern will be:

- Gradual ramp up with filling at peak flows of 125 ML/day for 20 days to achieve the desired inundation extent (74.9 mAHD at Benwell Main Regulator)
- Opening the Benwell Main and/or Benwell East Regulators (partially for fish exit) and reducing inflows from 125 ML/day to 45-70 ML/day to offset losses and provide return flows to the Murray.
- holding inflows at 70 ML/day for about 110 days to meet the duration requirements of the River Red Gum forests (with approx. 25 ML/day return flows to the River Murray during this period)
- gradual ramp down of inflows.

Further explanation is provided below.

Table 5. Operating plan summary for the maximum forest floodplain watering scenario – Benwell Forest

Component of operating plan	Proposed operation for forest floodplain watering scenario
Frequency of delivery	3 years in 10 (inundation in other years provided through Basin Plan inflows to achieve the 8 in 10 flooding frequency)
Timing	Winter/spring *[Late winter inflows and spring drawdown so floodplain water is available in River Murray at time of in-channel spawning.]*
Inundated area	471 ha (NCCMA calculated from R8 2020)
Peak inflow rate	125 ML/day (NCCMA calculated from R8 2020)
(A) Delivery time (days to fill from dry)	20 days (DHI 2017; NCCMA calculated from R8 2020)
(B) Drying time (days to dry for RRG forests once outflows to the River Murray cease)	14 days (DHI 2014) *[Benwell River Red Gum forest DHI drainage tables]*
(C) Desired duration of inundation for RRG forests (from hydrological requirements)	124 days (i.e. 4 mths)
(D) Duration of delivery once floodplain full (maintenance phase)	110 days (i.e. 3.5 mths)* *[D = C – B)* *[E = 124 days required duration minus 14 (drying time)]*
(E) Total length of event (excluding ramp up and ramp down)	144 days (i.e. 4.75 mths approx.) *[E = A + D + B]* *[F = 20 (fill time) plus 110 (duration of delivery) plus 14 (drying time)]*
Estimated total water inflow (ML) (excluding ramp up, ramp down and contingencies)	10,200 ML *[X = 20 days filling @ 1250 ML/day plus 110 days maintenance @ 70ML/day]*
Estimated total water return flows to Murray River (ML)	2,750 ML (27% of total pumped water)

*Does not take into account fill time (20 days), so that forest areas nearer to the outlet also receive their duration requirements. i.e. takes 20 days for water to reach this location.

Note: this scenario will include wetlands retaining some water for a further 4 months after throughflows cease.

Discussion

Timing of deliveries

There are two important ecological drivers regarding the timing of deliveries under this scenario. Firstly, to maximise outcomes for in-channel native fish recruitment it will be important to provide floodplain outflows to the River Murray in spring/summer and/or after variable River Murray channel flows. This will optimise the provision of phytoplankton and zooplankton (food for fish larvae) after spawning has occurred by flow-cued spawners (e.g. golden perch and silver perch) and/or temperature-cued spawners (all other native fish species) (Mallen-Cooper et al. 2014). The proposed operating regime will deliver maintenance flows over four months from August to November, resulting in outflows to the River Murray during this period of some 50 ML/day in total (North Central CMA internal workings).

Secondly, it will be important to avoid draw down of water in the wetlands during spring to early summer (Ecological Associates 2013), which will promote germination of River Red Gums and potentially further encroachment. Instead draw down in late summer/autumn is preferable (North Central CMA 2014c). Following the inflows ceasing at the end of November, the wetlands will pond water for up to four months, with substantial reductions in area occurring after the first two months (DHI 2014). This means the draw down period will reflect that which occurred under natural conditions.

The four-month duration of delivery plus the four-month ponding period for the wetlands in this scenario, will result in a total inundation duration of six to eight months approximately (depending on how quickly each portion of the wetlands drain). This is within the tolerance limits for semi-permanent wetlands (see duration requirements under Table 3.

Filling, maintenance and flushing flows

The supply points will be operated to mimic a variable flooding regime for River Red Gums, in terms of flood extent, timing and number of flood peaks. By lowering the inflow rate through the pump stations, extensive inundation of the River Red Gums can still be achieved.

The maintenance flows provide throughflows and will be important to help mitigate water quality risks (such as blackwater events and algal blooms that are more common during warmer temperatures). At an inflow of 90 ML/day in Guttrum Forest, outflows to the River Murray have been modelled at around 25 ML/day (DHI 20) during the August to November maintenance flow period. At an inflow of 50ML/day in Benwell Forest, outflows to the River Murray have been modelled at 19-33ML/day (DHI 2014internal workings) during the August to November period. These outflow rates are well within the design criteria of the concept design and pose a low risk of erosion. To achieve a throughflow at Guttrum Forest, inflows will be maintained from the eastern pump station, with the Guttrum Main Regulator opened. For Benwell Forest, if only the Benwell Main Regulator is opened, then only the western end of the forest will be influenced by the throughflows due to the inflow and outflow points both being located at the western end of the forest. As shown below, the inundation area to the east of the throughflow path will be stagnant and is at higher risk of having low dissolved oxygen blackwater. This could be managed through flushing flows (refer under Figure 4) if the Benwell East Regulator was not operational. However, the ideal operational practice will involve opening the Benwell East Regulator (potentially in conjunction with opening the Benwell Main Regulator), so that throughflow is maximised across the floodplain. This operation will require testing to confirm water movement pathways once operational.

In cases where there is a higher risk of blackwater (e.g. large organic matter loads due to a prolonged period since the previous flood), the forests may be inundated in mid-May (start of the off-irrigation season) as a way of leaching the organic matter prior to the start of the formal/complete forest watering event in July. The ‘flushing flow’ water would be returned to the River Murray prior to hypoxia developing. The pre-leached organic matter on the floodplain would mean there is little chance of blackwater developing in the July water delivery event and therefore the stagnant water to the east of the throughflow pathway would be less of an issue. However, it is acknowledged that removing the Dissolved Organic Carbon from the organic matter (through leaching) prior to a July event, would result in some loss of floodplain productivity and therefore ecological benefit. With the reinstatement of more regular flooding, however, it is expected that these types of ‘flushing flows’ would be required less often.

If a blackwater event in the main river channel does occur and River Murray flows are inadequate to safely receive the blackwater off the floodplain, then it would be retained on the floodplain until adequate dilution flows became available.

Return flows

Outflows from the proposed forest floodplain watering scenario are only expected during the maintenance flow and drawdown periods (August to November at 90 ML/d in Guttrum and 70 ML/day in Benwell Forests respectively) and will be around 25 ML/day for each site during these months (DHI 2014). These outflows will vary with evaporation and seepage rates within the forest and rainfall events as well as pump station flow rates and will thus reduce as the inflow rate declines at the end of a watering event. Such outflow rates pose a low risk of erosion both within the forest and at the outlet points.

Outflows during the filling phase (125 or 250 ML/day inflows as applicable) are not intended as this inflow rate will only be held until the forest reaches the desired supply level, after which it will reduce to 90 / 70 ML/d as maintenance and throughflows begin. However, the maximum possible outflows to the River Murray that could occur under a fully managed event are in the order of 200 ML/day for Guttrum Forest, and approximately 75 ML/day and up to 1500ML/day at the Benwell East and Benwell Main outlets in Benwell Forest, respectively (DHI 2014)[3]. These would occur if the outlets were fully opened while the floodplains were fully inundated up to the desired supply levels (75.8 mAHD at Guttrum Forest and 74.9 mAHD at Benwell Forest). While this situation is not currently part of any proposed operating scenarios, it is important to note that this is within the design limits of the outfall structures and secondary spillways (the latter of which have been designed to pass much higher flows than the primary outlets in line with natural flooding flows).

The most likely scenario for a sudden and maximum flow discharge from the inundated forests to a low river water level is for risk management purposes. For example, if a levee weakness, or potential or actual failure were to occur, the water level and pressure may need to be reduced as quickly as possible.

The concept design includes suitable reinforcement at the outfall locations (e.g. rock beaching) so that the full range of outflow rates possible under the project can be safely received and transported to the River Murray. This equates to a low risk of erosion (such as scouring) from the return flows. The concept design for the outfall locations also enables safe fish passage to the River Murray during outflow periods through the provision of plunge pools (as informed by an expert fish ecologist).

Monitoring return flows at both sites will be important for calculating net water use (total ML) in each forest and therefore any water delivery credits. The project includes a combination of acoustic Doppler devices in channels and rated weirs (e.g. the overflows) with readings taken from the nearby water level sensors. See below for proposed monitoring arrangements.

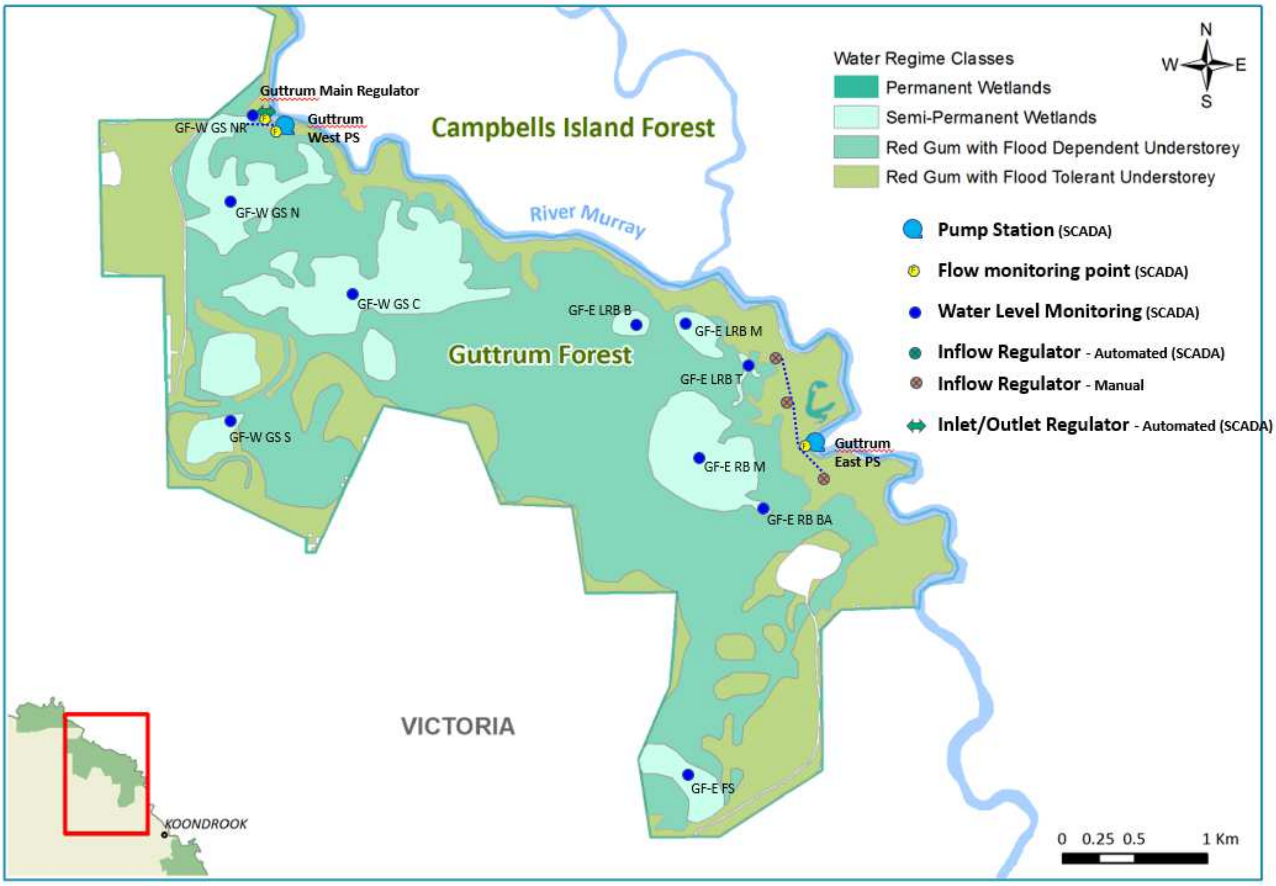

Figure 6. Proposed water monitoring locations across Guttrum Forest (blue dots)

[3] These figures are currently under investigation to confirm and may change.

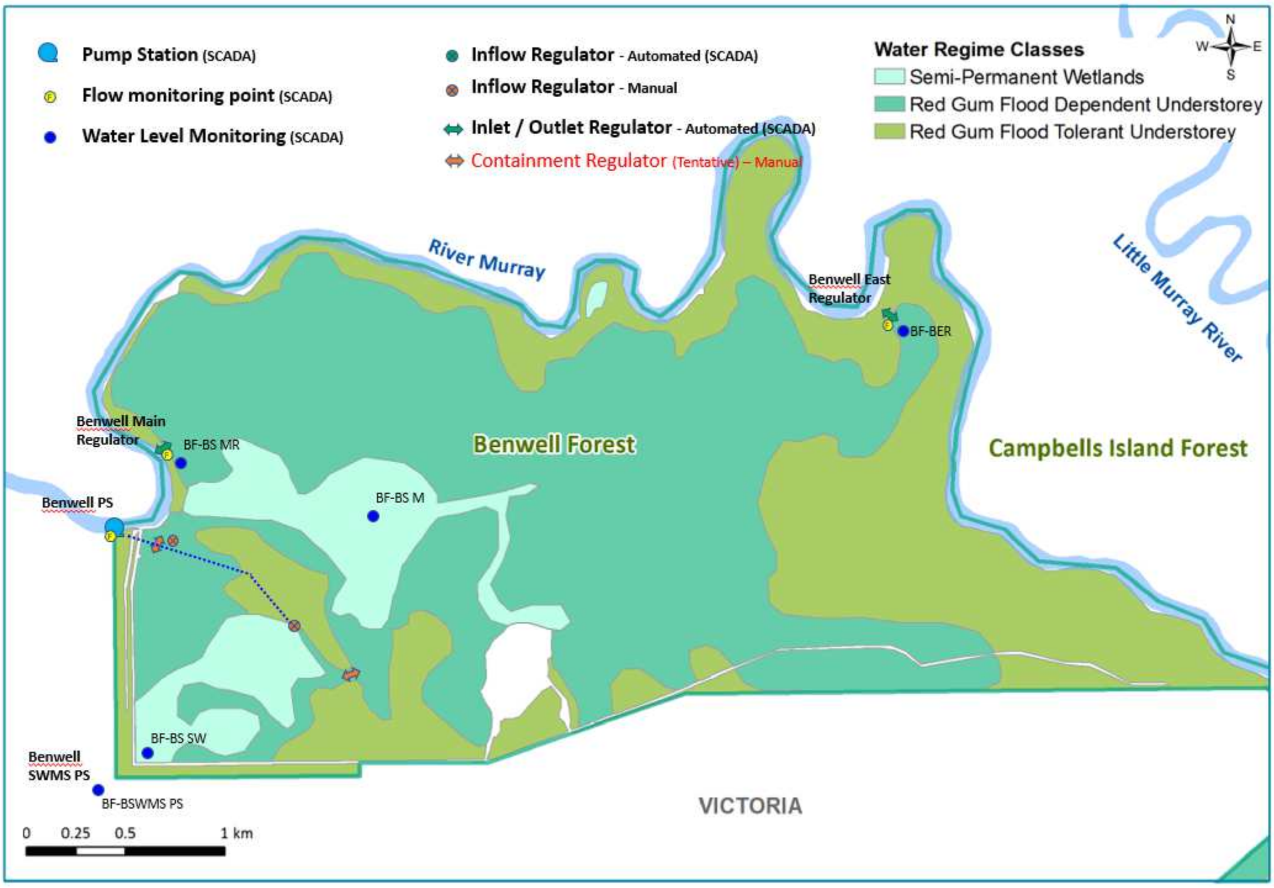

Figure 7. Proposed water monitoring locations across Benwell Forest

2.5. Constraints to operations

With the shift from gravity-fed infrastructure off the irrigation system to pump stations off the Murray River, the potential for constraints to operations is greatly reduced. However, there is increasing risk that the existing capacity constraints of the Barmah Choke may impact the reliability of supply for River Murray customers at certain times of the year due to competition for supply. The greatest risk exists in the months of December – March inclusive; and during periods of extreme heat. This has the potential to impact deliveries if environmental water requirements coincide with these periods (NCCMA 2020).

3. Semi-permanent wetland watering

3.1. Overview

Semi-permanent wetlands can be defined as those areas where water is retained to less than one metre deep and therefore have the potential to dry out in autumn, even if annual flooding occurs (Ecological Associates 2013). In the Guttrum and Benwell Forests, the semi-permanent wetland areas primarily consist of Floodway Pond Herbland/Riverine Swamp Forest Complex with smaller areas of Spike-sedge Wetland and Tall Marsh Ecological Vegetation Classes (Ecological Associates 2013; Biosis & Bennetts 2014). The semi-permanent wetlands in each forest include (see below for modelling maps):

- Guttrum Forest - Reed Bed Swamp, Little Reed Bed Swamp and the Guttrum Swamp wetland complex.
- Benwell Forest - Benwell Swamp and Southwest Benwell Swamp.

While the below maps show some areas outside the semi-permanent wetland boundaries holding water once forest draining to the River Murray has stopped, EVC mapping (Biosis and Bennetts 2014) of these areas has highlighted vegetation more indicative of Riverine Swamp Forest with temporary wetlands within the understorey i.e. they are not classed as semi-permanent wetlands as they do not retain water long enough to support vegetation indicative of semi-permanent wetlands.

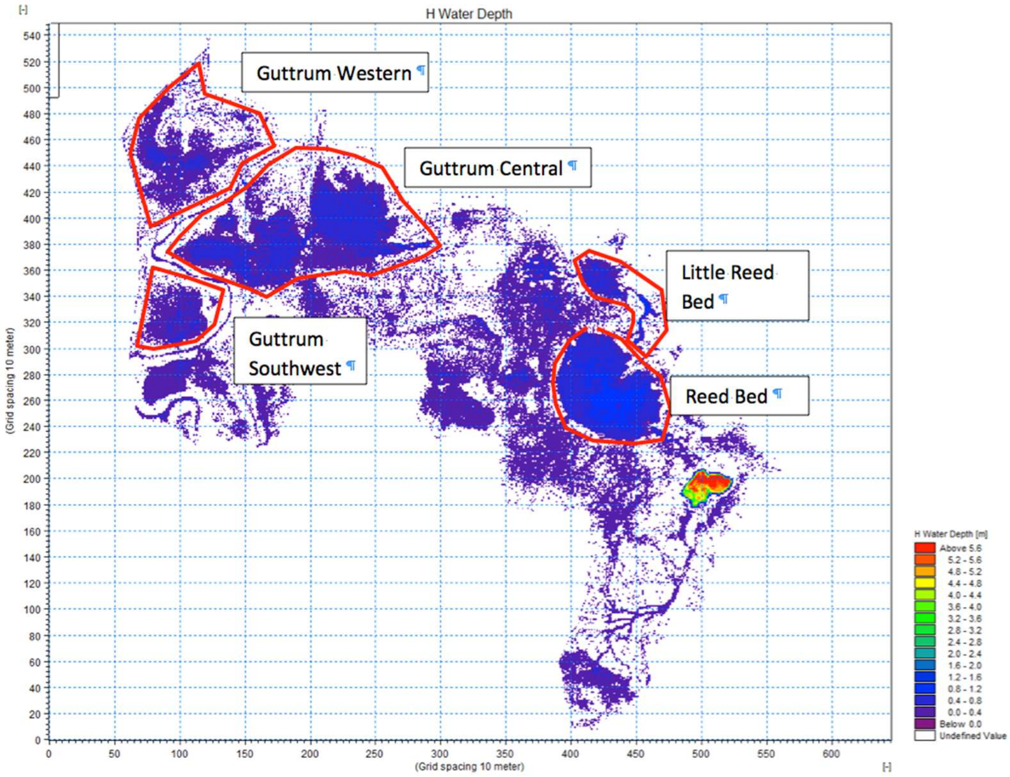

Figure 8. Guttrum Forest wetlands modelled by DHI (2014)

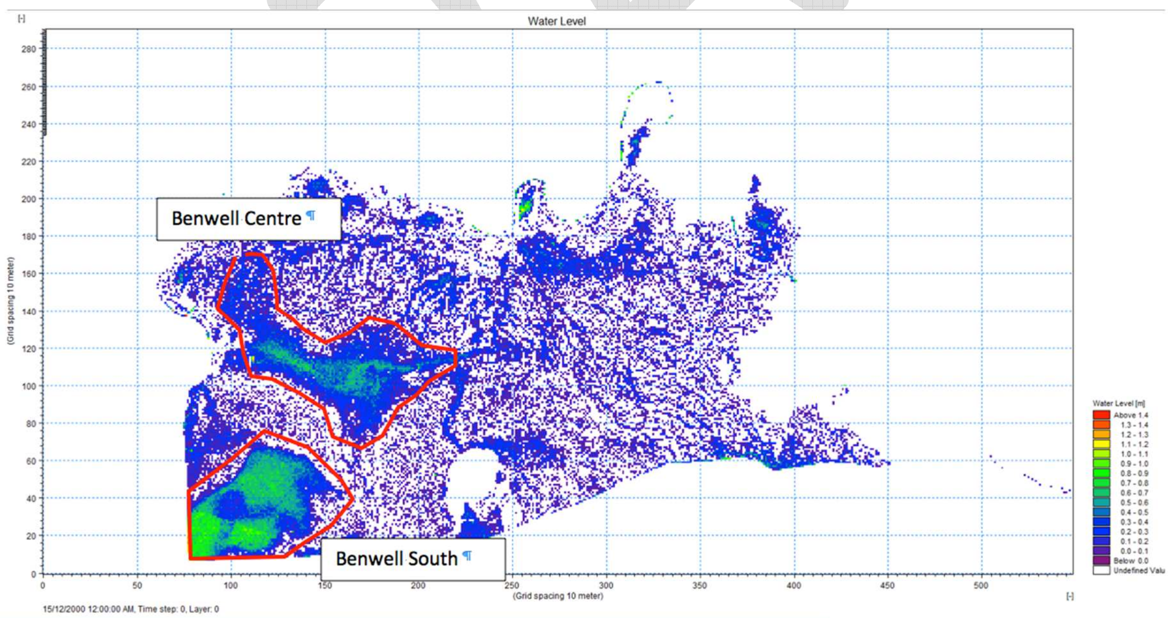

Figure 9. Benwell Forest wetlands modelled by DHI (2014)

3.2. Purpose

The semi-permanent wetland watering scenario aims to reinstate the natural water regime of the semi-permanent wetlands in both the Guttrum and Benwell Forests. This will contribute towards achievement of the project's ecological objectives for wetland vegetation and waterbirds, as well as other wetland-dependent biota (Table 1).

The scenario relates to watering the semi-permanent wetlands from dry conditions in order to achieve the desired frequency (and duration) of watering in addition to that supplied by natural events. It will mimic a 21,000 to 23,000 ML/day natural event in Guttrum and Benwell Forests in terms of the area and location of inundation (DHI 2014; Ecological Associates 2013). The hybrid scenario (discussed ahead) includes top-up watering of the semi-permanent wetlands following natural flow peaks to achieve required flooding duration where natural flood event duration is inadequate.

3.3. Hydrological requirements

Pre-regulation water regime

Hydraulic modelling suggests the semi-permanent wetlands across the forests share a similar hydrology with River Murray inflows commencing between 17 - 23,000ML/day (Ecological Associates 2013). The modelling indicates the following inundation relationships for each wetland regarding River Murray flows (DHI 2014):

- Guttrum Swamp wetland complex is inundated at 20,000 ML/day.
- Little Reed Bed wetland and Reed Bed Swamp in Guttrum Forest are inundated at 22,000 ML/day.
- Benwell Swamp is inundated at 16,000 ML/day.
- Southwest Benwell Swamp is inundated at 22,000 ML/day.

Under natural conditions, inflows of 23,000ML/day would have occurred about 9 out of 10 years with events lasting 3 to 5 months (interquartile range) (Gippel 2014). The depth of retained water in the wetlands is generally shallow (0.5 to 0.7m) and water would usually remain over summer with drying in autumn. However, in wet years water may remain until the following winter, especially for Reed Bed Swamp which retains water to a greater depth (0.85m) (Ecological Associates 2013).

Hydrological requirements

The hydrological requirements needed to achieve the ecological objectives relevant to the semi-permanent wetland watering scenario are shown below. Supporting evidence for these requirements is provided in the Guttrum and Benwell Forest Ecological Objectives and Hydrological Requirements Justification Papers (North Central CMA 2014a; North Central CMA 2014b).

Note: According to recent surveys (Biosis & Bennetts 2014), semi-permanent wetlands in Guttrum and Benwell Forest primarily consist of Floodway Pond Herbland/Riverine Swamp Forest Complex (EVC 945). The water regime for this objective therefore reflects that required by this EVC, which is within the tolerance range of the majority of the present wetland EVCs (North Central CMA 2014a; North Central CMA 2014b). An expert bird ecologist has confirmed the hydrological requirements outlined below for general waterbirds, during the Ecological Objectives refinement workshop (R. Webster, pers. comm. July 2014).

Table 6 Hydrological requirements to achieve ecological objectives relevant to semi-permanent wetlands

Overarching ecological objectives	Hydrological requirements										
	Recommended number of events in 10 years			Tolerable interval between events once area is dry (months)			Duration of ponding (months)			Preferred timing of inflows	Depth
	Min	Opt	Max	Min	Opt	Max	Min	Opt	Max		
Semi-permanent wetlands (Improve the health of semi-permanent wetlands)	6	9	10	1	6	36	3	6	8	Winter/ spring	Often <50cm. At Full Supply Level Guttrum Swamp is >0.7m and Reed Bed Swamp is 0.85m. The general depth of Benwell Swamp is 0.5m and 0.7m in Southwest Benwell Swamp.
Native birds* (Healthy wetland bird community across Guttrum and Benwell Forest through improved access to	3	5	10	12	18	24	4	6	12	Late winter/ spring/ early summer	Maximise area up to 30cm deep. Need to fluctuate depth over time to promote wetland productivity.

Overarching ecological objectives	Hydrological requirements: Recommended number of events in 10 years			Tolerable interval between events once area is dry (months)			Duration of ponding (months)			Preferred timing of inflows	Depth
	Min	Opt	Max	Min	Opt	Max	Min	Opt	Max		
food and habitat that promotes breeding and recruitment)											

* The native bird hydrological requirements are for general waterbirds. Requirements for colonial nesting species are discussed under the operating scenario for waterbird breeding support.

Water delivery requirements for semi-permanent wetlands

Based on the above hydrological requirements, the initial flooding frequency for semi-permanent wetlands is 9 years in 10. Modelling shows under current conditions (benchmark with TLM model run), flows required to achieve extensive wetland inundation (23,000 ML/day) occur 4.5 years in 10 (Gippel 2014). This increases to 7 years in 10 under Basin Plan 2750 conditions (Gippel 2014). It is important to note that this model run uses data from 1904 to 2009 and does not capture the changes to water availability that are expected under a drying climate. Data from the last two decades alone shows that natural inflows have occurred only 5 times to the wetlands over 20 years as opposed to the 'current conditions' modelling of 4.5 years in 10 by Gippel 2014. For the purposes of this project, however, the Basin Plan 2750 (2750 gigalitres of environmental water recovered) scenario has been assumed, until further information is available on projected streamflow in the Murray River in future.

If no other environmental watering occurred, this would leave a flooding frequency deficit of 2 years in 10 where watering dry wetlands would be required. However, the semi-permanent wetlands will also be watered when the broader floodplain (River Red Gum) watering occurs. Any floodplain watering provided to meet the River Red Gum requirements, will also meet the semi-permanent wetland requirements both in terms of frequency and duration.

Given that a fully managed event will be delivered 3 years in 10 to a dry forest floodplain (to achieve the River Red Gum objectives), the frequency of water requirements of the semi-permanent wetlands would also be met. See below:

Summary: Wetland inundation frequency achieved through forest floodplain watering scenario (dry forest)

- Wetland target frequency: 9 years in 10.
- Basin Plan 2750 frequency of natural inflows that inundate wetlands: 7 years in 10 (rounded for simplicity)
- Managed frequency through River Red Gum watering: 3 years in 10 (delivered to completely dry floodplain)
- Total frequency (current plus managed): 10 years in 10.

Action: no additional action required to achieve wetland flood frequency requirements. Duration requirements (6 months) are also met through wetland ponding after inflows to the River Red Gum floodplain cease- wetlands retain water for approximately 4 months.

This suggests that under the current defined water regime, environmental water delivery to semi-permanent wetlands in these forests (i.e. fully managed events to dry wetlands) may not be needed. However, if natural events do not occur at current modelled inflows and/or if environmental water availability is limited (see Table 11), then watering specifically to inundate the wetlands would be required. Therefore the scenario has been retained in this operating plan.

3.4. Infrastructure operation (from dry)

As stated above, this scenario is included as although under Basin Plan 2750 modelling it is assumed that the wetlands' water requirements will be met through natural inflows and the forest floodplain watering scenario, it is most likely under a drying climate that delivery from dry will be required for the wetlands.

Infrastructure

Guttrum Forest

For semi-permanent wetland watering into a dry system, independent of the River Red Gum forest floodplain, water will be delivered via the east and west pump stations. The east pump station will water Reed Bed Swamp and Little Reed Bed wetland. The west pump station will water the Guttrum Swamp complex (DHI 2017).

- To inundate the eastern wetlands, water will pumped through a pipeline following the alignment of River Track and will be released into three different flood runners to fill Reed Bed Swamp and Little Reed Bed Swamp (Figure 8).

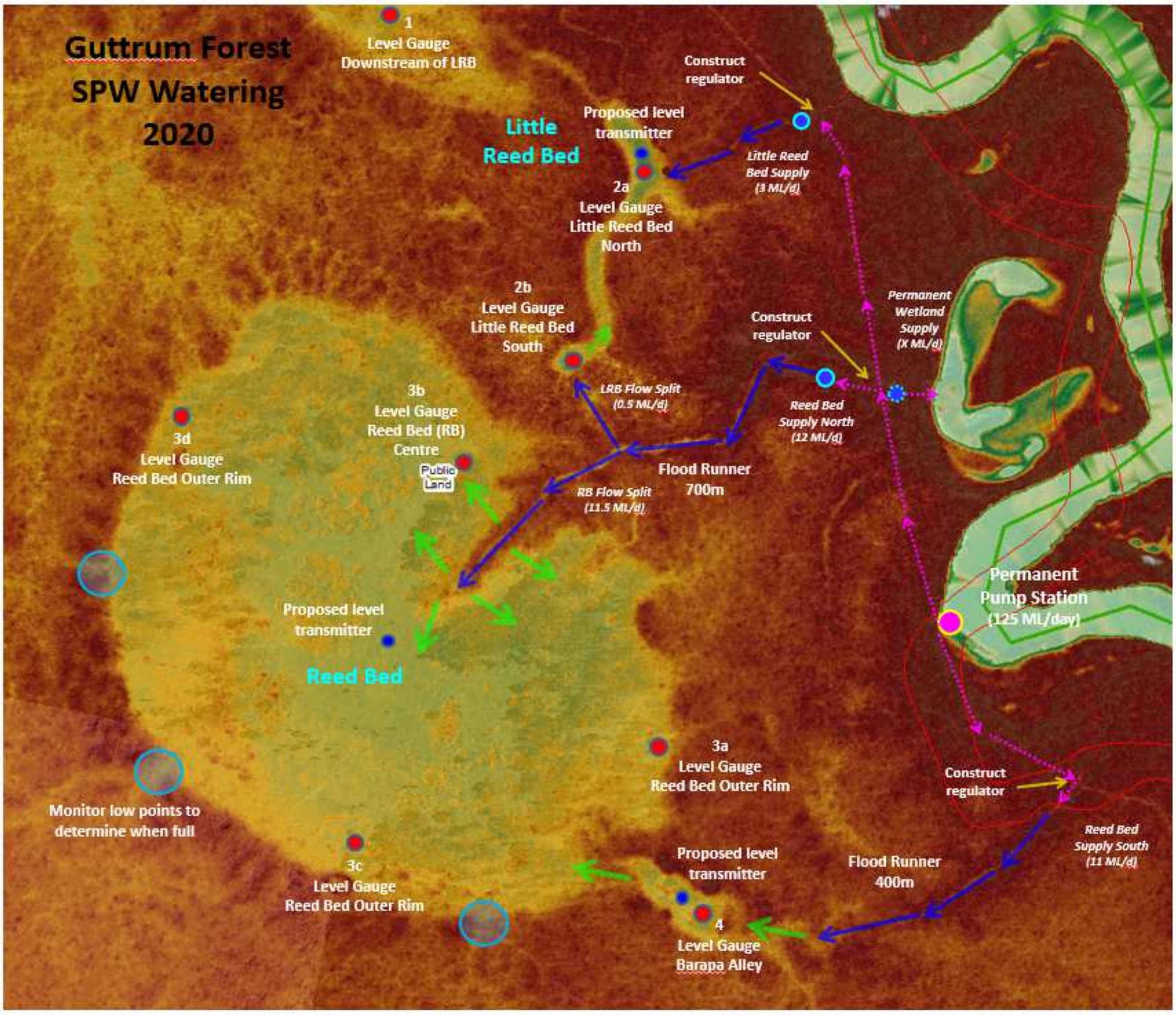

Figure 8. Locations of three inflow points to floodrunners that fill Reed Bed Swamp and Little Reed Bed Swamp

The expected flow rates to deliver to the semi-permanent wetlands are:

- Little Reed Bed Swamp = 1 to 3 ML/day
- Reed Bed Swamp North = 10 to 15 ML/day
- Reed Bed Swamp South = 10 to 15 ML/day

Small regulators are proposed for these flood runners to block water from running back towards the Murray River or inundating River Track, and instead will direct it west or southwest towards the wetlands and broader forest. These small regulators will be formed by gated culvert crossings of River Track at the locations of the existing flood runners. The Guttrum east pump station will provide for wetland fills up to a full supply level of 75.7 m AHD for the Reed Bed southern inlet (DHI 2020) and 75.5 mAHD for the main Reed Bed Swamp (DHI 2020). As water is held within the wetlands, the outlet (Main Regulator) would not be required. Water would eventually infiltrate and evaporate until the wetlands dried out.

To inundate the western wetlands, water will be pumped from the Guttrum west pump station and follow the natural flow paths to fill Guttrum Swamp complex. The wetland system would gradually fill from the north to the central / eastern and then southern end. The Main Regulator outlet is located close to the east pump station, and will be closed during filling of the wetlands to full supply level. According to DHI 2017, a full supply level of 75.7 m AHD can be targeted across the Guttrum Swamp complex.

Benwell Forest

For semi-permanent wetland watering into a dry system, independent of the River Red Gum forest floodplain, water will be delivered via the Benwell west pump station. Water will travel via a short pipeline to two outfall locations that target the central Benwell Swamp and the Southwest Benwell Swamp, enabling the two wetlands to be filled independently (R8 2020). Water will be delivered at a flow rate of approximately 50 ML/d in total, with 22 ML/d directed to the central Benwell Swamp and 28 ML/d towards the Southwest Benwell Swamp (DHI 2017).

Both wetlands will be filled to a full supply level of approximately 74.6 mAHD. At this level, some water will pool against the containment bank along River Track for central Benwell Swamp and against a section of the outer levee for Benwell South West Swamp. The Benwell Main Regulator would be closed prior to operations commencing, but may be opened again if a high river peak was expected that would result in natural inflows. The wetlands would gradually evaporate and infiltrate over a four to six-month period. Flows to top-up the wetlands or maintain water levels may be delivered if required to meet ecological objectives, such as supporting a waterbird breeding event (see section 4.5).

Operation of infrastructure

Guttrum Forest

The table below summarises the proposed infrastructure operation to deliver water to the Guttrum Forest semi-permanent wetlands under this scenario. This represents filling from dry to full supply level – the maximum watering option. Further explanation is provided below.

In summary, the indicative inflow pattern (eastern wetlands) will be:

- **Filling phase:** In winter or early spring, gradual ramp up with filling at peak flows of 25 ML/day for 15 days to achieve the desired inundation extent in Reed Bed Swamp and Little Reed Bed Swamp
- **Maintenance phase:** In late spring, deliver one or more top-ups to the wetlands (as required) by ramping up again to up to 25 ML/d until desired water level is reached. Flows can be held steady to maintain water levels under nests if required. This flow rate will depend on climatic conditions and will need to account for losses through evaporation.

In summary, the indicative inflow pattern (western wetlands) will be:

- **Filling phase:** In winter or early spring, gradual ramp up with filling at peak flows of 100 ML/day for 15 days to achieve the desired inundation extent in Guttrum Swamp and the associated wetlands in the west of Guttrum Forest.
- **Maintenance phase:** In late spring, deliver one or more top-ups to the wetlands by gradually ramping up again to around 50 ML/d until desired water level is reached. Flows can be held steady to maintain water levels under nests if required. This flow rate will depend on climatic conditions and will need to account for losses through evaporation.

Table 7. Operating plan summary for the maximum semi-permanent wetland watering scenario – Guttrum Forest

Component of operating plan	Proposed operation for semi-permanent wetland watering scenario
EASTERN WETLANDS – REED BED SWAMP AND LITTLE REED BED	
Frequency of delivery	2 years in 10 to fill from dry - if required under modelled 'current conditions' (inundation expected to be provided in other years through natural inflows and forest floodplain watering to achieve the 9 in 10 flooding frequency) 7 years in 10 to provide top-ups - under Basin Plan 2750 modelling, only the top-up component is expected to be required 7 years in 10 (i.e. natural inflows that fill the wetlands are expected 7 years in 10).
Timing	Spring (to reduce risk of further River Red Gum encroachment)
Inundated area	64 ha (DHI 2020) – approx. 45 ha in Reed Bed Swamp and 6 ha in southern Reed Bed floodrunner = 51 ha; and 13ha in the Little Reed Bed tiers
Peak inflow rate	25 ML/day (DHI 2020)
(A) Delivery time (days to fill from dry)	15 days (DHI 2020)
(B) Drying time (days to dry for wetlands once inflows cease)	70 days (DHI wetland drying tables 2014 & NCCMA internal workings). (i.e. approx. 1.4 months) - Reed Bed Swamp – approx. 70 days to dry to 10% of full volume - Little Reed Bed Swamp – approx. 52 days to dry to 10% of full volume
(C) Desired duration of inundation for wetlands (from hydrological requirements)	183 days (i.e. 6 mths)
(D) Duration of maintenance phase	113 days (i.e. 3.8 mths) (note this is the duration of inundation required, not 'holding' flows. Flows are most likely to be delivered as top-ups to meet the required duration of inundation) *[D = C – B)* *[D = 183 days required duration minus 70 (drying time)]*
(E) Total length of event (excluding ramp up and ramp down)	198 days (i.e. 7 mths approx.) *[E = A + D + B]* *[E = 15 (fill time) plus 113 (duration of maintenance phase) plus 70 (drying time)]*
Estimated total water inflow (ML) (excluding ramp up, ramp down and contingencies)	1,116 ML *[X = 15 days filling @ 25 ML/day followed by the equivalent of 7 ML/day for 113 days]*[4]

[4] Note that 7 ML/d is the volume required to offset evaporation and seepage if the aim was to hold the wetland at a stable water level. However, in practice the wetland will most likely be allowed to partially draw down before a top-up flow is delivered. More than one top-up may be required to provide the target duration of inundation. It is expected that the volumes required for the top-up will be approximately the equivalent of the 7 ML/d flow rate, but delivered in a larger volume over a shorter period e.g. 30 days x 7 ML/d = 210 ML that could be delivered over ~8 days at 25 ML/d.

Component of operating plan	Proposed operation for semi-permanent wetland watering scenario
WESTERN WETLANDS – GUTTRUM SWAMP COMPLEX	
Frequency of delivery	2 years in 10 to fill from dry - if required under modelled 'current conditions' (inundation expected to be provided in other years through natural inflows and forest floodplain watering to achieve the 9 in 10 flooding frequency) 7 years in 10 to provide top-ups - under Basin Plan 2750 modelling, only the top-up component is expected to be required 7 years in 10 (i.e. natural inflows that fill the wetlands are expected 7 years in 10).
Timing	Late winter or spring
Inundated area	330 ha (DHI 2017)
Peak inflow rate	100 ML/day (DHI 2017)
(A) Delivery time (days to fill from dry)	15 days (DHI 2014) – based on 50ML/day taking 15 days (DHI 2014)
(B) Drying time (days to dry for wetlands once inflows cease)	42 days (DHI wetland drying tables 2014 & NCCMA internal workings). (i.e. approx. 1.4 months) - Guttrum Swamp - North – approx. 28 days to dry to 10% of full volume - Guttrum Swamp - Central – approx. 42 days to dry to 10% of full volume - Guttrum Swamp - South – approx. 28 days to dry to 10% of full volume
(C) Desired duration of inundation for wetlands (from hydrological requirements)	183 days (i.e. 6 mths)
(D) Duration of maintenance phase	141 days (i.e. 4.7 mths) (note this is the duration of inundation required, not 'holding' flows. Flows are most likely to be delivered as top-ups to meet the required duration of inundation) *[D = C – B]* *[D = 183 days required duration minus 42 (drying time)]*
(E) Total length of event (excluding ramp up and ramp down)	198 days (i.e. 7 mths approx.) *[E = A + D + B]* *[E = 15 (fill time) plus 141 (duration of delivery) plus 42 (drying time)]*
Estimated total water inflow (ML) (excluding ramp up, ramp down and contingencies)	3,615 ML *[X = 15 days filling @ 100 ML/day followed by 15 ML/day for 141 days[5]]*

*Does not take into account fill time, so that the full wetland inundation areas receive their duration requirements. The maintenance phase is designed to provide the fastest draining wetland area (south western wetland) with the required duration of flooding (as per the hydrological requirements. This results in an inundation period of about 7.6 mths for the slower draining wetlands which is within the tolerance limits for semi-permanent wetlands (Fitzsimons et al. 2011).

Benwell Forest

The table below summarises the proposed infrastructure operation to deliver water to the Benwell Forest semi-permanent wetlands under this scenario. This represents filling from dry to full supply level – the maximum watering option.

In summary, the indicative inflow pattern will be:

- **Filling phase:** Gradual ramp up with filling at peak flows of up to 50 ML/day for approximately 8 days to achieve the desired inundation extent in Benwell Swamp and Southwest Benwell Swamp

[5] Note that 15 ML/d is the volume required to offset evaporation and seepage if the aim was to hold the wetland at a stable water level. However, in practice the wetland will most likely be allowed to partially draw down before a top-up flow is delivered. More than one top-up may be required to provide the target duration of inundation. It is expected that the volumes required for the top-up will be approximately the equivalent of the 15 ML/d flow rate, but delivered in a larger volume over a shorter period e.g. 30 days x 15 ML/d = 450 ML that could be delivered over ~4.5 days at 100 ML/d.

- **Maintenance phase:** In late spring, deliver one or more top-ups to the wetlands by gradually ramping up again to around 25 ML/d until desired water level is reached. Flows can be held steady to maintain water levels under nests if required. This flow rate will depend on climatic conditions and will need to account for losses through evaporation.

Further explanation is provided below.

Table 8. Operating plan summary for the maximum semi-permanent wetland watering scenario – Benwell Forest

Component of operating plan	Proposed operation for semi-permanent wetland watering scenario (Benwell Swamp and Southwest Benwell Swamp)
Frequency of delivery	2 years in 10 to fill from dry - if required under modelled 'current conditions' (inundation expected to be provided in other years through natural inflows and forest floodplain watering to achieve the 9 in 10 flooding frequency) 7 years in 10 to provide top-ups - under Basin Plan 2750 modelling, only the top-up component is expected to be required 7 years in 10 (i.e. natural inflows that fill the wetlands are expected 7 years in 10).
Timing	Late winter or spring
Inundated area	60 ha (DHI 2014) – approx. 20ha in Benwell Swamp and 40ha in Southwest Benwell Swamp
Peak inflow rate	50 ML/day, with 22 ML/d directed to Benwell Swamp and 28 ML/d directed to Southwest Benwell Swamp) (DHI 2017)
(A) Delivery time (days to fill from dry)	8 days at 50 ML/day (DHI 2017)
(B) Drying time (days to dry for wetlands once inflows cease)	56 days (DHI wetland drying tables 2014 & NCCMA internal workings) (i.e. approx. 2 months) - Benwell Central – approx. 35 days to dry to 10% of full volume - Benwell Southwest – approx. 56 days to dry to 10% of full volume
(C) Desired duration of inundation for wetlands (from hydrological requirements)	183 days (i.e. 6 mths)
(D) Duration of maintenance phase	127 days (i.e. 4 mths) (note this is the duration of inundation required, not 'holding' flows. Flows are most likely to be delivered as top-ups to meet the required duration of inundation) *[D = C – B)* *[D = 183 days required duration minus 56 (drying time)]*
(E) Total length of event (excluding ramp up and ramp down)	198 days (i.e. 7 mths approx.) *[E = A + C + D]* *[E = 8 (fill time) plus 127 (duration of delivery) plus 56 (drying time)]*
Estimated total water inflow (ML) (excluding ramp up, ramp down and contingencies)	1,416 ML *[X = 8 days filling @ 50 ML/day followed by 8 ML/day for 127 days[6]]*

[6] note that 8 ML/d is the volume required to offset evaporation and seepage if the aim was to hold the wetland at a stable water level. However, in practice the wetland will most likely be allowed to partially draw down before a top-up flow is delivered. More than one top-up may be required to provide the target duration of inundation. It is expected that the volumes required for the top-up will be approximately the equivalent of the 15 ML/d flow rate, but delivered in a larger volume over a shorter period e.g. 30 days x 8 ML/d = 240 ML that could be delivered over ~4.8 days at 50 ML/d.

Discussion

Filling and maintenance flows

Managed floods delivered to the semi-permanent wetlands will aim to replicate a dynamic natural flooding regime that varies in depth, duration, frequency and season. Therefore the operation will vary from event to event, depending upon the antecedent conditions.

The desired variation in the watering regime may be achieved by:

- using different pump station outfalls in different events to vary the part of the forest being inundated.
- varying the inflow rate delivered through the pump stations.
- varying the timing and duration of inflows.
- Varying the depth of flooding from year to year and during a watering event to maximise wetland productivity - full supply level would be the maximum.
- providing inflows on more than one occasion during a particular event to mimic the rise and fall of natural inflows to these areas.
- Increasing the available habitat for aquatic fauna by extending the flooding into the River Red Gum with flood dependent understorey.

Once wetlands are filled, delivery of top-up flows will occur over the maintenance phase to achieve the required duration of inundation over the largest wetland area possible. This aims to maximise the ecological outcomes from the project. Top-up flows may need to be provided shortly after wetlands fill to account for the rapid decline in area inundated in some wetlands. For example, the wetlands reduce in modelled area inundated by 50% after 30 days in Little Reed Bed Wetland and after about 60 days in Reed Bed Swamp (DHI 2014). To the west of Guttrum Forest, the wetlands reduce in area inundated substantially (by 50%) after 14 days in the southwest and northwest wetlands, and after about 60 days in Guttrum Swamp (DHI 2014). For Benwell Swamp, the inundated wetland extent reduces by almost 50% after about 30 days in Southwest Benwell Swamp and by about 40% in Benwell Swamp after only 2 weeks (DHI 2014). See below for wetland drying graphs.

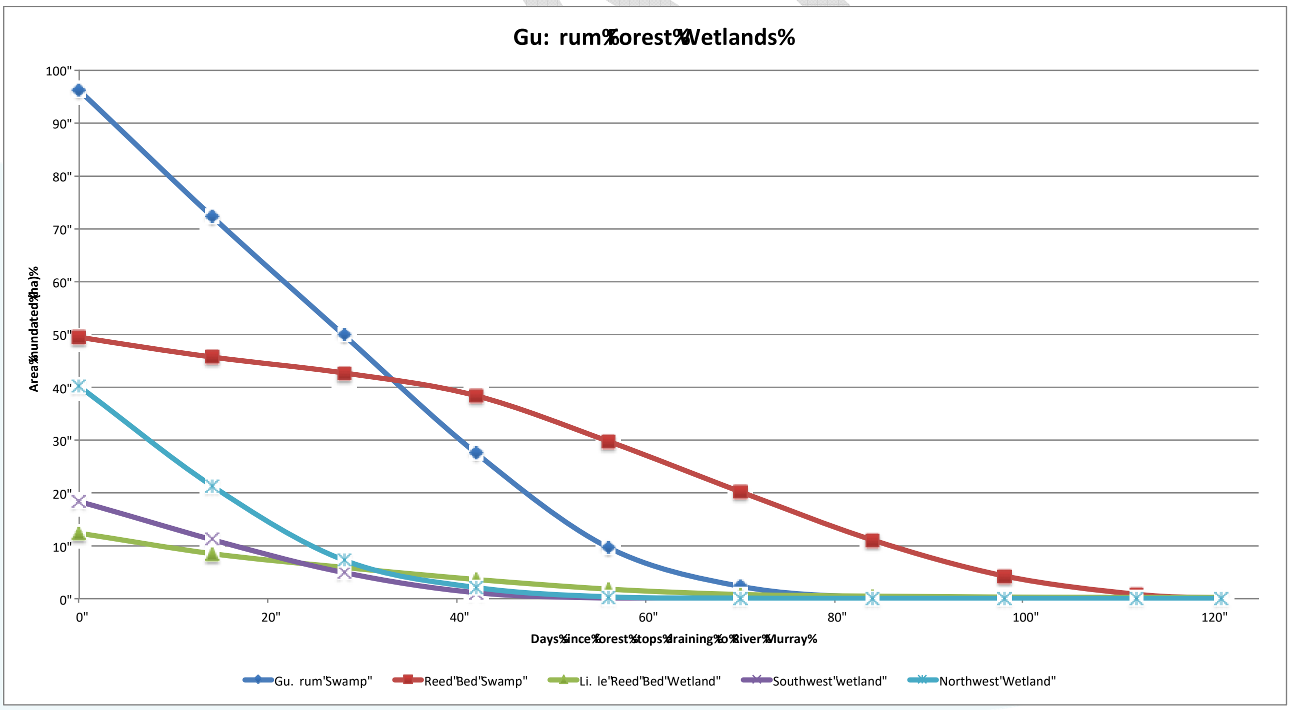

Figure 9 Wetland drying simulation results – Guttrum Forest (DHI 2014)

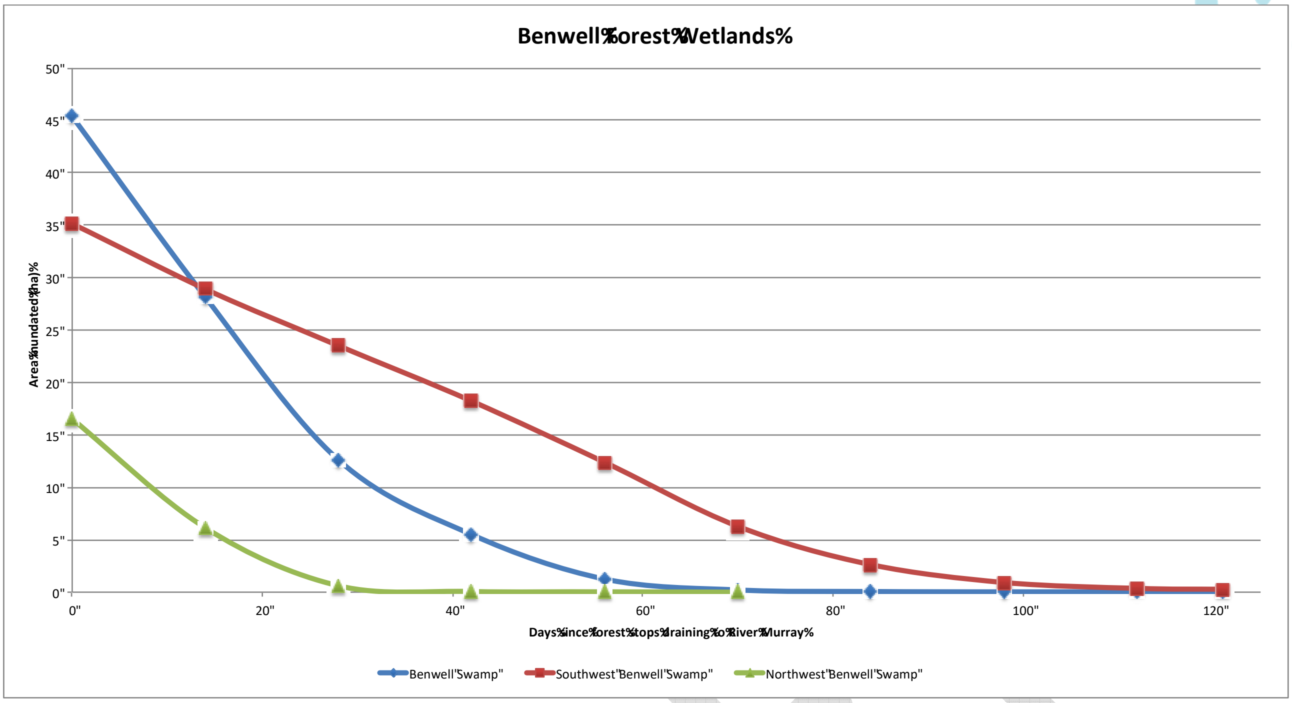

Figure 10. Wetland drying simulation results – Benwell Forest (DHI 2014)

Timing of deliveries

The semi-permanent wetlands in Guttrum Forest have experienced extensive River Red Gum encroachment due to inappropriate water regimes. Further colonisation is possible through germination of saplings if the water drawdown in the wetlands occurs during spring to early summer (Ecological Associates 2013) instead of the natural draw down period of late summer/autumn (North Central CMA 2014c). The operating strategy for the semi-permanent wetlands needs to ensure that optimal conditions for River Red Gum establishment are not provided too frequently, to prevent further encroachment in the wetlands. This will occur primarily through water deliveries in winter or spring with top-ups delivered in late spring or early summer to enable wetland drawdown in autumn. Opportunities to manage River Red Gum encroachment will be an ongoing consideration in the operating strategy for semi-permanent wetlands.

Colonial waterbird breeding

The Reed Bed Swamp semi-permanent wetland in Guttrum Forest and the Southwest Benwell Swamp in Benwell Forest contain important colonial bird breeding sites (Ecological Associates 2013; G. Smith, pers. comm. October 2014). Therefore it is possible that managed floods in the semi-permanent wetlands of Guttrum and Benwell Forest may result in a bird breeding event. However, an event stimulated under this operation is likely to be significantly smaller than an event stimulated by the forest floodplain watering scenario, and is also likely to attract a restricted range of species (e.g. less likely to attract egrets due to a limited food supply) (North Central CMA 2010). Furthermore, the forest and wetland habitats will be undergoing a period of rehabilitation over the coming years and large bird breeding events in response to environmental watering may eventuate in the medium-term, rather than short-term.

4. Hybrid events

4.1. Overview

Hybrid events are defined as the delivery of environmental water to supplement natural inflows that enter the forests from the River Murray. All opportunities to use natural inflows will be sought, as they are likely to result in a greater environmental benefit compared to fully managed events. Benefits of using natural inflows include (North Central CMA 2010):

- Opportunities to extend the duration of flood events that are greater in magnitude than can be replicated through artificial delivery (i.e. >26,000ML/day).
- Opportunities to increase the extent of inundation provided by natural inflows. Greater floodplain inundation creates a greater food resource for waterbirds, along with other benefits.
- Maximising the chance of successful bird breeding events by making use of climatic cues.
- Enabling use of the floodplain by native fish – an outcome that is limited through artificial delivery via pumping.
- Use of less environmental water allocation volume to achieve ecological outcomes.
- Greater connectivity between the forest and River Murray – important for maximising ecosystem functions.

4.2. Purpose

The hybrid scenario will vary greatly depending on the natural inflow event and what opportunity is available to maximise environmental outcomes.

Three hybrid opportunities have been identified previously in this operating plan based on possible natural flood duration deficits. These are discussed under this scenario, however, it is important to note that other hybrid water delivery opportunities will arise. The three options discussed herein include:

- Follow up watering of the forest floodplain following natural flow peaks and/or flood capture to achieve required flooding extent and/or duration where natural flood event extent or duration is inadequate to achieve ecological objectives.
- Top-up watering of the semi-permanent wetlands following natural flow peaks to achieve required flooding duration where natural flood event duration is inadequate to achieve ecological objectives.
- Delivering a waterbird breeding scenario in association with environmental cues including topping up wetlands to support natural bird breeding events when required.
- Delivery events under the hybrid scenario could potentially contribute towards achievement of any one of the project's ecological objectives or indeed multiple objectives (Table 1).

4.3. Extending forest floodplain inundation

Hydrological requirements and water delivery needs

The duration of ponding required by River Red Gums with flood dependent understorey in Guttrum and Benwell Forest is in the order of four months (target regime). See the forest floodplain watering scenario for further details.

Under natural conditions, inflows of 26,000 ML/day (that achieve broadscale flooding of this vegetation) (Ecological Associates 2013) would have occurred in about 8 out of 10 years with events lasting about 90 days (median duration) and ranging from 1.5 to 4.5 months (interquartile range) (Gippel 2014).

Modelling shows under current conditions (benchmark with TLM model run), flows of this size last about 70 days (median duration) and range from 1 to 3.5 months (interquartile range) (Gippel 2014). Under Basin Plan 2750 conditions, flows of this size last about 80 days (median duration) and range from about 1 to 3.5 months (interquartile range) (Gippel 2014).

This leaves a current median flooding duration deficit of 54 days and a Basin Plan median duration deficit of 44 days (assuming a four month duration is needed), indicating that some natural floods will require intervention to extend the effective duration of flooding if the forest floodplain vegetation is to achieve its hydrological requirements.

While these model runs provide an indication of the changes to Murray River flows since regulation, the data is representative of the period from 1895 to 2009 (Gippel 2014). This does not factor in changes to the climate and associated declines in run-off that have been observed in the last 25 years. Therefore, realistically, natural events of a magnitude and duration that will inundate the whole forest are likely to be even less frequent than estimated under the Basin Plan 2750 or 2100 model runs.

Infrastructure operation

There are two mechanisms that can be used concurrently for extending the duration of natural floods that inundate the broader forest:

- Flood capture – closing the main forest regulators on the low-lying flood runners from the River Murray after the river flow peak has passed to retain floodwater on the floodplain for the required duration. This includes the Guttrum Main Regulator (G5) at Guttrum Forest and the Benwell Main Regulator (B13) and Benwell East Regulator (B7) at Benwell Forest (DHI 2014). The outlets/inlets would then be opened after the desired period and floodwater returned to the River Murray.
- Pumped deliveries – up to 125 or 250 ML/day delivered into the relevant forests via the pump stations discussed in detail under the forest floodplain watering scenario.

Regarding the use of flood capture, the timing of natural flooding will be an important consideration. Modelling suggests River Murray flows of 26,000 ML/day at Barham frequently begin in mid winter (median timing) but tend to occur anywhere from late autumn to mid spring (interquartile range) (Gippel 2014). A similar pattern is modelled under Basin Plan conditions (Gippel 2014). Considering these floods often last slightly over 2 months (median duration) (Gippel 2014), some floods of this size would extend into the summer months. Therefore, capturing flood water and ponding it over a given period during the warmest months is likely to increase the risk of low-oxygen levels in the water developing through both stratification and water temperature increases. In this instance, the outlets may be opened and throughflow maximised through environmental water deliveries using the pump stations.

Another flood capture consideration is food availability for native fish temporarily trapped on the floodplain and whether holding fish for the chosen period will have implications for the River Murray native fish community e.g. disruption of ecosystem processes associated with natural flood events (fish migration, spawning). This risk will be assessed on an event-by-event basis with advice sought from expert ecologists.

In terms of returning flood water to the River Murray (post flood capture), the water levels in the forest that are capable of being retained by the outlets will be the same as those levels retained during fully managed events. Therefore the return flows to the River Murray will be in line with those described under the forest floodplain watering scenario and will pose a low risk of erosion. Release of any blackwater from the floodplains will occur only when adequate dilution flows in the River Murray are available.

4.4. Extending wetland inundation

Hydrological requirements and water delivery needs

The duration of ponding required by the semi-permanent wetlands in Guttrum and Benwell Forest is in the order of 6 months. See the semi-permanent wetland watering scenario for further details.

Under natural conditions, inflows of 23,000 ML/day (that achieve broadscale wetland inundation) would have occurred in about 9 out of 10 years with events lasting about 3.8 months (median duration) and ranging from 2 to 5 months (interquartile range) (Gippel 2014).

Modelling shows under current conditions (benchmark with TLM model run), flows of this size last about 3 months (median duration) and range from 1.5 to 3.8 months (interquartile range) (Gippel 2014). They have even less duration under modelled Basin Plan conditions (73 days) (Gippel 2014). The wetlands generally pond water for a month before substantial areas of each wetland dry out. This is a general guide as some wetlands pond water for longer than others.

This leaves a current median flooding duration deficit of about two months, indicating that many natural floods will require intervention to extend the effective duration of flooding if the semi-permanent wetlands are to achieve their duration requirements.

As discussed above, under the Basin Plan 2750 scenario, a forest floodplain watering scenario (delivery to a dry forest) will be required in about 3 years in 10 to cover the flood frequency deficit for River Red Gums with flood dependent understorey. This will also contribute towards meeting the hydrological requirements of the wetland systems, through the combination of delivery times and ponding times.

Infrastructure operation

There are three wetland systems across Guttrum and Benwell Forests that may require topping-up of natural inflows:

- Guttrum Forest eastern wetlands – including Reed Bed Swamp and Little Reed Bed Swamp.
- Guttrum Forest western wetlands – including Guttrum Swamp complex .
- Benwell Forest western wetlands – including Benwell Swamp and Southwest Benwell Swamp.

Guttrum eastern wetlands

To top-up wetland water levels in the east of Guttrum Forest water will be delivered via the Guttrum East pump station via one or more of the outlets into flood runners that fill the Reed Bed Swamp complex, as described under the semi-permanent wetland watering scenario. Water may be delivered either by ramping up flows to the maximum capacity of each outlet until the desired water level is reached; or flows may be delivered at a lower flow rate over an extended period if required to maintain water levels, such as if a waterbird breeding event takes place.

Modelling suggests a continuous inflow of about 7 ML/day would maintain water levels in Reed Bed Swamp and Little Reed Bed wetland by covering evaporation and seepage losses in late spring and summer (DHI 2014), which would be important if a waterbird breeding event was initiated. In practice, the delivery rate and timing would be adapted to meet the needs of each individual situation including changes in evaporation over time.

Water would eventually infiltrate and evaporate until the wetlands dried out.

Guttrum western wetlands

To top-up wetland water levels in the west of Guttrum Forest, water would be delivered from the Guttrum West pump station as described under the semi-permanent wetland watering scenario. The Guttrum Main Regulator (G5) would be closed for the duration of delivery to build water levels and push water towards the wetlands.

Modelling suggests a continuous supply of about 15 ML/day would maintain water levels in Guttrum Swamp and the associated wetlands to the southwest over a 0.2m range (DHI 2014). In practice, the delivery rate and timing would be adapted to meet the needs of each individual situation including changes in evaporation over time.

Water would eventually infiltrate and evaporate until the wetlands dried out.

Benwell western wetlands

To top-up the Benwell wetlands, water will be delivered via the Benwell West pump station as described under the semi-permanent wetland watering scenario, directing water to either the Benwell Swamp or Southwest Benwell Swamp.

Modelling suggests a continuous inflow via the pump station of about 8 ML/day would maintain water levels in Benwell Swamp at about 74.2 m AHD (DHI 2014). In practice, the delivery rate and timing would be adapted to meet the needs of each individual situation including changes in evaporation over time.

Water would gradually evaporate and infiltrate.

4.5. Waterbird breeding support

Hydrological requirements and water delivery need

The duration of ponding required for colonial waterbird breeding in Guttrum and Benwell Forest is between 7 to 10 months, with 9 months chosen for the purposes of this operating plan as this duration would support the majority of colonial nesting waterbird species.

Under natural conditions, inflows of 26,000 ML/day (that achieve broadscale flooding of forests and wetlands required to provide adequate foraging areas to support breeding colonies) (Ecological Associates 2013) would have occurred in about 8 out of 10 years with events lasting about 3 months (median duration) and ranging from 1.5 to 4.5 months (interquartile range) (Gippel 2014).

Modelling shows under current conditions (benchmark with TLM model run) and Basin Plan 2750 conditions, flows of this size last about 70 days (median duration) and range from 1 to 3.5 months (interquartile range) (Gippel 2014).

Hydraulic modelling indicates Reed Bed Swamp (as an example) holds water over most of its area for a further month (with ongoing drawdown over at least 4 months) after floods subside (DHI 2014). Therefore, under natural conditions it appears the longer flood events of this size (4.5 to 5 months at 75th-95th percentiles) (Gippel 2014) would have resulted in large areas of ponded water in the wetland for about 7 to 9 months (meeting the ponding requirements for colonial waterbird breeding).

Under current conditions modelling, the duration deficit means the 2 month median duration of current floods, combined with the further month of ponding (before large areas of ponding reduce) does not meet the required 9 months ponding duration for colonial waterbird breeding. Even the upper limit for current flood duration of 26,000 ML/day events (3.5 months, 75th percentile and 5.5 months, 95th percentile) (Gippel 2014) combined with a month of widespread ponding in the wetlands is inadequate for colonial waterbird breeding.

This indicates that many natural floods suitable for colonial waterbird breeding will require intervention to extend the effective duration of flooding if successful breeding is to occur. However it is important to acknowledge that the forest and wetland habitats will be undergoing a period of rehabilitation over the coming years and large bird breeding events in response to environmental watering may eventuate in the medium-term, rather than short-term.

Infrastructure operation

Guttrum Forest

To top-up wetland water levels in Reed Bed Swamp, water will be delivered via the Guttrum East pump station. See semi-permanent wetland scenario for further details.

Modelling suggests a continuous inflow of 7 ML/day would maintain water levels in Reed Bed Swamp by covering evaporation and seepage losses in late spring and summer (DHI 2014). This is critical to avoid chick abandonment.

In practice, the delivery rate and timing would be adapted to meet the needs of each individual situation including changes in evaporation over time and the stage of waterbird breeding.

Any water required for maintenance or top up of the Guttrum Swamp complex on the west side of the forest would be additional.

Benwell Forest

To support large bird breeding events in Southwest Benwell Swamp, water levels would be maintained using a continuous inflow of about 8 ML/day into the forest. The inflow rate would be adjusted as required to account for changes in environmental conditions over time e.g. increasing evaporation over warmer months.

Discussion

Presence and activity of waterbirds in the forest will be actively monitored in spring to determine the need to continue inflows for later breeding species (e.g. egrets).

Minimum inflows intend to provide the basic water requirements to allow late-season breeding species to rear and successfully fledge their young through the summer period. It aims to maintain an area of inundation for feeding and depth under nests by offsetting high summer evaporation rates. Evaporation has a greater impact during a fully managed event, as food resources may not be available elsewhere (North Central CMA 2010).

Detailed monitoring and advice from specialist ecologists will be used to determine the water requirements of each colony. Past observations from Gunbower Forest suggest the need for minimum inflows to support bird breeding will be apparent in about October when birds show signs of breeding preparations (e.g. breeding plumage, courting behaviour and nest construction). Breeding of egrets generally begins in November or early December, with the following three months incorporating egg laying, hatching and fledging young (Scott 1997). It is therefore essential that adequate inflows be provided from November to early February or in some cases, as late as March (North Central CMA 2010).

Maintaining water depth in nesting areas and feeding areas will be important for breeding success. The centre of Reed Bed Swamp has been modelled at up to 1.1m deep during maintenance flows, with much of the wetland ranging from 0.6-0.9m (DHI 2014). At minimum inflows of 7 ML/day, this depth will be maintained (DHI 2014). Southwest Benwell Swamp has been modelled at up to 1m deep during maintenance flows, with much of the wetland ranging from 0.4-0.8m (DHI 2014), which will be maintained under minimum inflows of about 4 ML/day.

Note: While summer inflows are rarely observed due to river regulation, they would have occurred under natural conditions. For example, spells analyses conducted for mean daily flow data at Barham (Gippel 2014) showed a range of flows of varying size beginning and continuing in the summer months.

5. Fish exit strategy

5.1. Native fish entry to and use of floodplain

Given there is limited permanent wetland habitat in these forests (one small wetland near the River Murray bank in Guttrum Forest), the project focuses on providing benefits to in-channel native fish, rather than encouraging fish to enter the floodplain during managed events. Food (organic matter) for fish larvae will be available in floodplain outflows to the river, which will promote recruitment of in-channel fish, in conjunction with other factors outside the project scope.

However, fish will still enter the Guttrum and Benwell Forest floodplain primarily through natural River Murray inflows. These fish may move into deeper wetland areas (e.g. Reed Bed Swamp) or remain on the inundated River Red Gum floodplain. The average depth across the forests for flows similar to 26,000 ML/day events has been modelled as around 50cm (DHI 2014), which should be adequate for a range of fish sizes (North Central CMA 2010). It is recognised that opportunistic use of the floodplain by native fish has many benefits regarding access to food and habitat resources (Mallen Cooper et al. 2014).

Given fully managed events will be delivered from via pump stations with fish exclusion screens (rather than a natural waterway) and carp screens will be installed on the inlet regulators (to prevent adult carp access), it is unlikely that large-bodied native fish will enter the floodplain from the river during fully managed environmental water deliveries. A very limited number of small fish and fish larvae may enter via the pump stations and these will provide an important food source for supporting the waterbird community and achieving the ecological objectives for the project regarding wetland birds e.g. the Australasian bittern (*Botaurus poiciloptilus*) predates on fish amongst other aquatic fauna (ARKive 2012).

A priority risk identified for the project is native fish stranding on the floodplain, if the forest drains quickly after watering. Fish stranding (of small and large fish) is a risk applicable to natural and hybrid events. This section describes operational mitigation measures to help alleviate this risk for natural and hybrid events.

5.2. Native fish exit from floodplain

The primary fish exit routes at both the Guttrum and Benwell forests are the outlet points (Guttrum Main Regulator at Guttrum Forest and Benwell Main and Benwell East Regulators at Benwell Forest). During natural events and hybrid events, some fish exit may also occur through the low-lying inlets along the River Murray bank of both forests, as river levels drop and the forests drain back to the river through these inlets. This will depend on the size of the flood and whether water levels in the forests are high enough to engage the inlets.

During hybrid events, operations during the draw down phase will be managed to provide a fish exit cue for those fish that have entered the floodplain. This may include:

- operating the outlet regulators to create a sharp drop in water level sufficient to cue native fish to leave the floodplain (e.g. 0.15 m to 0.2 m in 48 hours). Experience using The Living Murray infrastructure at Gunbower Forest indicates that providing a sharp drop followed by a steady rise and a second sharp drop is sufficient to cue native fish to exit the floodplain. This should be implemented over approximately two weeks. On a smaller floodplain such as Guttrum or Benwell forests, this may take less time.
- following the initial water level drop, inflows through the pump station(s) will be reduced to ensure a slow water recession (e.g. 2–5 cm/day) allowing fish to exit the floodplain (North Central CMA 2010).

It is important to note that hydraulic modelling suggests connectivity across Guttrum Forest is quickly lost during forest draining. Therefore, to reduce fish stranding the provision of fish exit cues shortly followed by minimum inflows through the pump station will be important. Benwell Forest by comparison has a slower and steadier decline in inundated area and the Benwell Central forest area mostly drains back to the Benwell Main Regulator (DHI 2014) (see diagrams below).

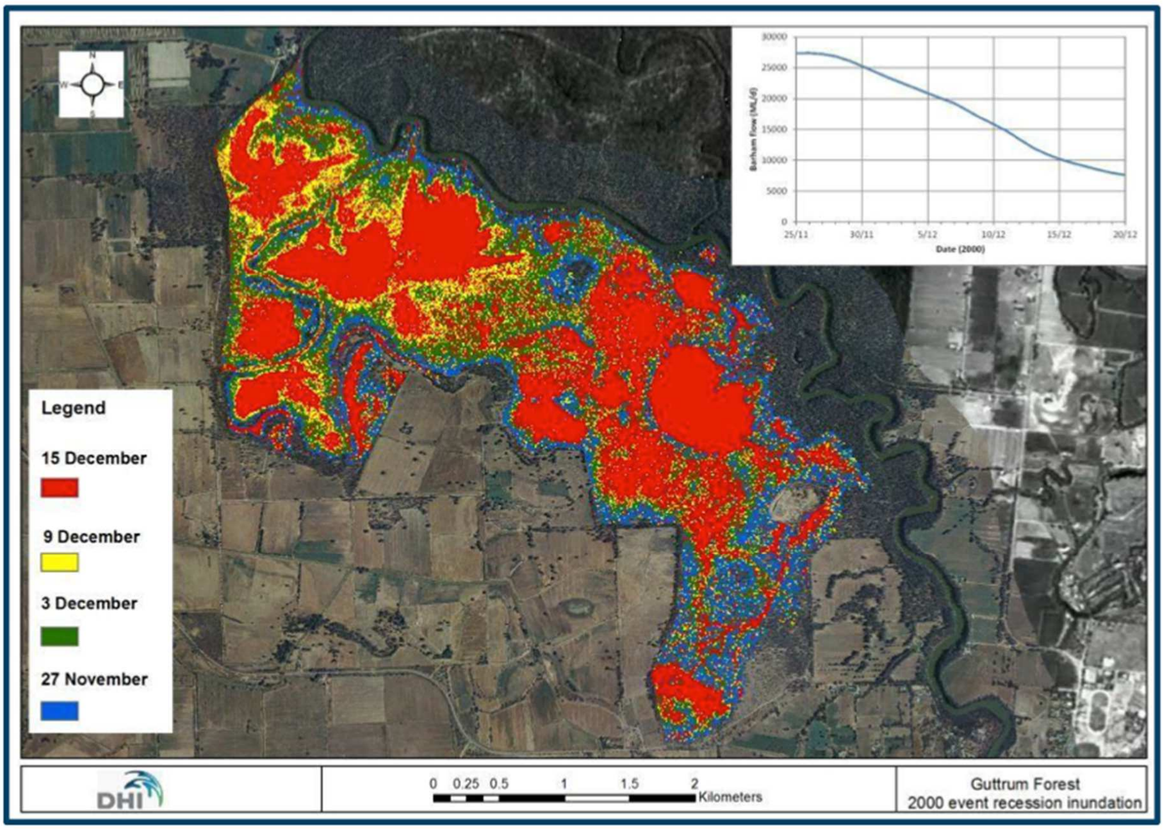

Figure 11. Guttrum Forest 2000 event recession (DHI 2014)

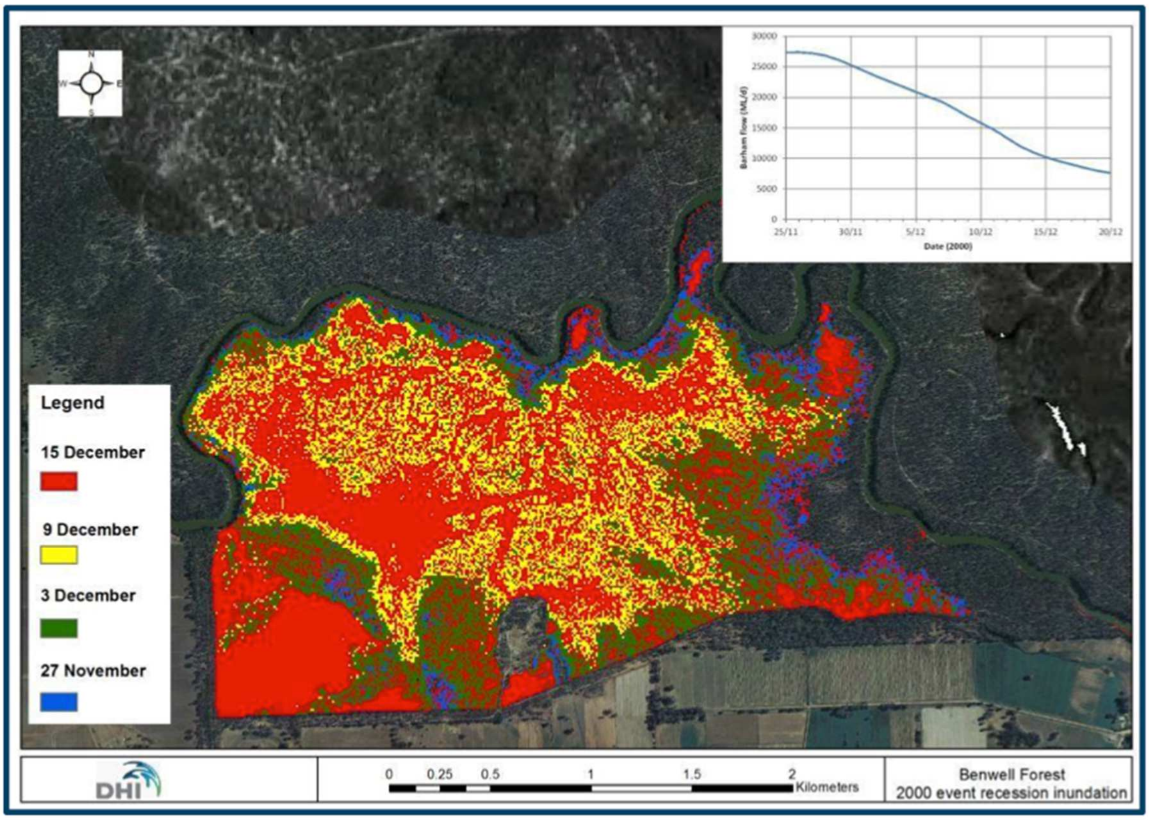

Figure 12. Benwell Forest 2000 event recession (DHI 2014)

Minimum inflows during the draw down phase intend to provide the basic water requirements to allow native fish to exit the floodplain via the primary outlets. This includes connectivity across the floodplain, adequate depth for fish migration and adequate velocities.

Detailed monitoring and advice from specialist ecologists will be used to inform the fish exit strategy. This includes lessons learnt through operations of the Hipwell Road Channel in Gunbower Forest and the associated fish exit strategy.

Depending on the scenario, during the draw down phase inflow rates may reduce from a maximum of 125 or 250 ML/day as applicable to a minimum inflow of 50 ML/day at Guttrum Forest and 10 ML/day at Benwell Forest. At these minimum inflows, outflows of 19-33 ML/day through the G5 outlet and 5 ML/day through the B13 outlet have been modelled though may taper off fairly quickly (DHI 2014). Depths across the primary drainage pathways during the minimum inflow period are generally at least 0.2-0.3m at Guttrum Forest and 0.1-0.3m at Benwell Forest. These depths are expected to be adequate for most small and medium fish to move off the floodplain. Greater depths may be required for large-bodied fish. Therefore, the minimum inflows during the draw down phase of hybrid events may be higher and will be determined on an event-by-event basis.

While flow velocities have not been investigated specifically through modelling, these will be observed during operations and amendments to inflow rates made where necessary.

Refinement of the fish exit strategy will be ongoing in response to monitoring results and consultation with fish ecologists. Reed Bed Swamp in Guttrum Forest and Benwell Swamp in Benwell Forest are known colonial waterbird breeding sites. If birds are breeding within these wetlands, the fish exit strategy cannot be implemented until breeding has been completed, which may occur as late as February. Timing of implementation for the fish exit strategy will be determined on an event-by-event basis.

6. Climate and water availability conditions

6.1. Overview

The need and ability to implement this operating plan is dependent upon both the climate scenario forecast for a given watering season and the availability of environmental water for deliveries to the Guttrum and/or Benwell Forests. This section captures some of the considerations for operating infrastructure under the project.

6.2. Seasonally adaptive approach

In recent years, the Victorian Government has developed the ‘seasonally adaptive approach’ to guide environmental watering decisions. This approach has been described in sustainable water strategies and in the revised Victorian Waterway Management Strategy (DEPI 2014), and water managers are required to plan each year using this framework.

The seasonally adaptive approach identifies priorities for environmental watering under different climatic conditions, depending on the amount of environmental water that is likely to be available in any given year. It is a flexible way to deal with short-term climatic variability and helps to guide annual priorities and manage the site through extended dry periods. The approach is outlined below.

In drier periods, restricted water resource availability will potentially limit the number of ecological objectives that can be targeted through environmental water management. However, these ecological objectives can be achieved in wetter periods as water resource availability increases. Depending on the conditions and amount of water available, watering actions at the Guttrum and Benwell forests in any year will range between the minimum and preferred operating regimes.

Figure 1.3.2 Example planning scenarios for a river system under a range of climatic conditions

Planning scenario	Drought	Dry	Average	Wet to very wet
Expected Conditions	No or negligible contributions from unregulated flows. Waterways may stop flowing at times, more likely during summer/autumn	Minor contributions from unregulated reaches and tributaries, more likely in winter/spring	Unregulated flows provide extended low flows and multiple freshes, more likely in winter/spring. Minor storage spills may occur	Extended unregulated high flows, multiple large storage spills and overbank flooding, more likely in winter/spring but possible any time of year
Management Objectives	Protect	Maintain	Recover	Enhance
	• Avoid critical loss • Maintain refuges • Avoid catastrophic events	• Maintain river functioning with reduced reproductive capacity • Maintain key functions of high-priority wetlands • Manage within dry-spell tolerances	• Improve ecological health and resilience • Improve recruitment opportunities for key plant and animal species	• Restore key floodplain wetland linkages • Maximise recruitment opportunities for key animal and plant species
Example watering actions to support management objectives	Provide low flows and trigger-based freshes to maintain water quality in deep refuge pools	Provide summer/autumn low flows to manage water quality and maintain connectivity	Provide year-round low flows to maintain habitat connectivity to support fish movement	Maintain year-round low flows and seasonal freshes to improve the quality of in-stream and bank vegetation and trigger the spawning and movement of native fish
		Extend the duration of flow peaks to freshen water quality in deep pools	Extend the duration and/or magnitude of peaks to provide spawning cues for fish	Maintain connectivity and the exchange of nutrients between the river and floodplain
			Provide seasonal freshes to support the establishment and maintenance of bank vegetation	Slow the recession of natural peaks to avoid bank slumping and erosion
				Top up natural flows if needed, to meet targets for winter low flows and spring peaks

Figure 13. The seasonally adaptive approach to environmental watering (VEWH 2020)

6.3. Infrastructure operation guide

Four climatic scenarios have been developed to guide the management of environmental watering in the Guttrum and Benwell Forests. The four scenarios are classified as extreme dry (90% POE), dry (75% POE), median (50% POE) and wet (25% POE). These scenarios align with those developed for water resource management undertaken by Goulburn-Murray Water.

The below matrix is based on Baumgartner et al. (2013) and identifies when to deliver environmental water to certain ecological components for different climate and water availability scenarios. This should be used to guide environmental water decisions in Guttrum Forest and Benwell Forest.

Table 9. Possible operating scenarios under various climate and water availability conditions

		Anticipated climate conditions^			
		Extreme dry (90% POE)	Dry (75% POE)	Median (50% POE)	Wet (25% POE)
River flows & natural inundation		Murray River inflows not expected	Murry River inflows not expected	Minor inflows from Murray River expected	Major flooding from Murray River expected
		No natural inundation	No natural inundation	Minor floodplain inundation including semi-permanent wetlands. Small waterbird breeding events possible.	Broad floodplain inundation including semi-permanent wetlands. Large waterbird breeding events likely.
Anticipated environmental water availability*	High	N/A	Forest floodplain watering Semi-permanent wetland watering	Extend forest floodplain inundation Extend wetland inundation Top ups to support bird breeding	Extend forest floodplain inundation Extend wetland inundation Top ups to support bird breeding
	Low	Semi-permanent wetland watering	Semi-permanent wetland watering	See above – where possible given volumes available	N/A

Source: based on Baumgartner et al. (2013)

* Volumes chosen to reflect delivery volumes for various operating scenarios, excluding ramp up, ramp down and contingency volumes. ^ Murray River inflow descriptions are estimates and would be confirmed every year though the seasonal watering proposal process.

Note: Use of the infrastructure will depend on the volume of natural flooding and therefore if and how much environmental water delivery is required for a given event.

N/A refers to the situation where the described environmental water volume would not be available.

7. References

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