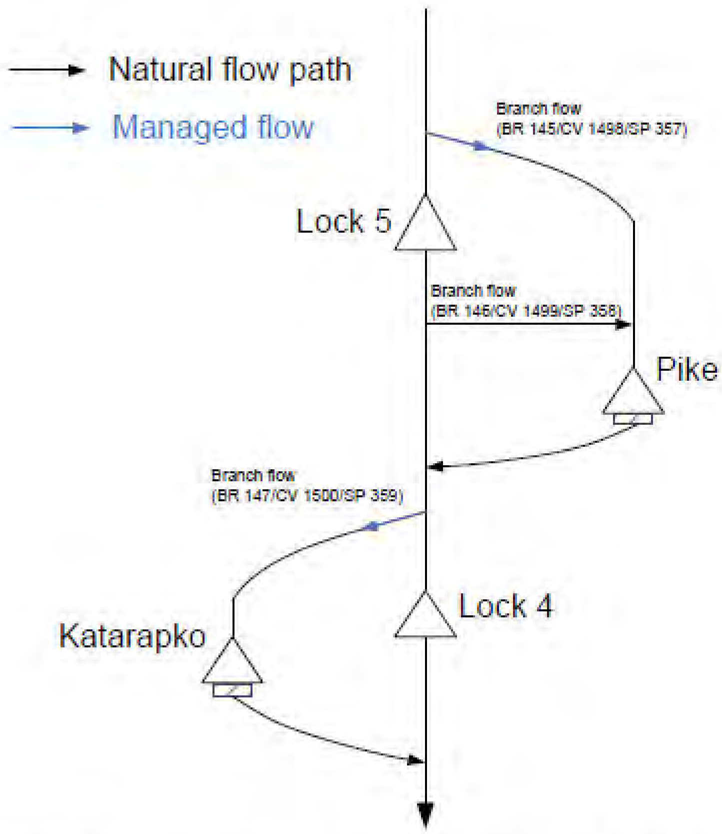
Amendment date: 28 June 2017

Environmental works and measures at point locations

Reference no.	Title of measure	South Australian Riverland Floodplain Integrated Infrastruture Programme
	Person undertaking the measure	**South Australia**
	Short description of measure	The South Australian Riverland Floodplain Integrated Infrastructure Programme (SARFIIP) aims to create an integrated and resilient floodplain along the South Australian River Murray, between the border and Lock 1, through a package of works and measures that enable floodplain inundation and freshening of groundwater lenses with particular focus on the Pike and Katarapko floodplains. Environmental works on the Pike and Katarapko Floodplains will optimise the frequency, duration and extent of inundation events to protect and restore these floodplain ecosystems and contribute to Basin Plan environmental outcomes. Salinity management measures will complement the floodplain inundation works to manage ecological risk, enhance ecological condition by maximising the area of soil salinity that is within the tolerances of target vegetation and to manage any long term and real time in-stream salinity risk.
1.	**Confirmation**	
	Capacity of the measure to operate as a supply measure *'Supply measure' is defined in section 7.03 of the Basin Plan to mean 'a measure that operates to increase the quantity of water available to be taken in a set of surface water SDL resource units compared with the quantity available under the benchmark conditions of development'.*	Yes - the SARFIIP meets the definition of a 'supply measure'.
	Confirmation that the measure entered into or will enter into operation by 30 June 2024 ***Basin Plan 7.12(3)(a)***	Yes - the SARFIIP will be operational by 30 June 2024.
	Confirmation that the measure is not an 'anticipated measure' ***Basin Plan 7.12(3)(b)*** *'Anticipated measure' is defined in section 7.02 of the Basin Plan to mean 'a measure that is part of the benchmark conditions of development'.*	Yes - it is a new project (not already included in the benchmark conditions).
	Confirmation that the proponent state(s)undertaking the measure agree(s) with the template ***Basin Plan 7.12(3)(c)*** *Joint proposals will need the agreement of all proponents*	Confirmed
2.	**Surface water SDL resource units affected by the measure** ***Basin Plan s 7.12(4)(b)***	
	This measure identifies all surface water resource units in the Southern Basin region as affected units for the purposes of notifying supply measures. The identification of affected units does not constitute an agreement between jurisdictions on apportioning the supply contribution, which will be required in coming months.	

3.	**Details of relevant constraint measures** ***Basin Plan s 7.12(4)(c)***
	This project is not reliant on other supply or constraint measures for implementation or operation.
4.	**Date on which the measure entered into, or will enter into, operation** ***Basin Plan s 7.12(4)(d))***
	30/06/2024
5.	**Details of the measure** ***Basin Plan 7.12(4)(a)***
	Description of the works *Pike Floodplain* Environmental works and measures proposed for the Pike Floodplain include: • A new environmental regulator and fishway at Tanyaca Creek. • A new environmental regulator and fishway at Pike River. • Blocking banks, and other ancillary structures, including new Bank E. • Lowering of the 'commence to flow' of Letton's flood runner. • Regulator at Bank H (upstream end of Snake Creek). • Regulator at 'Southern Mundic Creek Outlet'. • Removal of the Col Col regulator and embankment to a sufficient extent to allow unhindered flow and fish passage. • Complementary saline groundwater management scheme. *Katarapko Floodplain* Environmental works and measures proposed for the Katarapko Floodplain include: • Construction of 5.9 km of blocking bank to allow control of inundation regimes. • A new Lock 4 access track to enable all weather access to Lock 4 during periods of maximum inundation. • A major new outlet regulator at the downstream end of The Splash to enable manipulation of water levels and flows from the system. • A major new regulator at the downstream end of Piggy Creek to enable manipulation of water levels and be operated in conjunction with the new regulator at The Splash. • New ancillary regulators at the inlets of Piggy Creek to Katarapko Creek and an ancillary regulator near Lock 4. • One new Sawmill Creek Outfall Regulator and two ancillary Sawmill Creek Regulators. These structures are to be used in conjunction with The Splash and Piggy Creek regulators to raise water levels to the maximum target level. • Two new regulators at Carpark Lagoon, including one at the downstream end of Carpark Lagoon and one at the upstream inlet. These structures are to be used in conjunction with The Splash, Piggy Creek and Sawmill Creek regulators to raise water levels to the maximum target level. • Construction of Bank J, a new major inlet structure into the Eckerts Creek system. This project is not reliant on other supply or constraint measures for implementation or operation. Section of the Business Case presents dominant vegetation types in the Pike and Katarapko Floodplains, as well as the percentage area inundated for dominate vegetation types under proposed SARFIIP works (**Attachment 1**). A schematic of the new model representation of the Chowilla floodplain is below.



Note: Lock 4 and Lock 5 are currently represented in Bigmod as reaches (with storage routing), not as weirs

Hydrology and hydraulic relationships at the site.

River regulation has changed the flow regime of the River Murray, and has reduced the number and nature of the floods that occur at many sites, including the Pike and Katarapko floodplains. The pre-implementation hydrological and hydraulic nature of the sites, as described below, is post river regulation

Level-volume-area relationships for both sites are provided at **Attachment 2.** These relationships for Pike and Katarapko have been simplified and are attached at **Attachment 4.**

Pike Floodplain

Flow permanently enters the Pike anabranch complex upstream of Lock 5 through Margaret Dowling Creek and Deep Creek. Floodplain Inlets are fully regulated with the maximum capacity of 1400 megalitres per day (ML/d).

Water then discharges into Mundic Creek where the majority of flow would have naturally entered Tanyaca Creek at a range of locations (existing locations of Banks E, D, F and F1). Other permanent flow paths result in flow leaving Mundic Creek and entering Snake Creek and Pike River. Crude earthen and rock embankments (Bank E, D, F and F1) were constructed shortly after Locks 4 and 5 which currently prevent water from flowing into Tanyaca Creek from Mundic Creek. Water is instead diverted into the Pike River via two outlets (Mundic Creek southern and northern outlets). Similar embankments also restrict flow entering Snake Creek (Banks H and G, the former has since been removed).

Snake Creek re-enters Pike River upstream of Col Col. Col Col is another earthen embankment which also features a sluiced pipe culvert and a rock spill way. Col Col and the other earthen embankment further upstream act to keep water levels artificially elevated (14.35m AHD upstream of Col Col and 14.75m AHD upstream of the Mundic Creek embankments. This retains a mid-pool water level between Locks 4 and 5 (~2m less than Lock 5 and ~1m greater than Lock 4).

Flow enters downstream of Lock 5 via a range of locations, such as Banks B, B2 and C when flow to SA (QSA) exceeds 35,000ML/day; Swift Creek and Wood Duck Creek when QSA exceeds 15,000ML/d, Rumpagunyah Creek is permanently connected but can act as either an inlet or outlet depending on QSA and operation of Lock 4; and Letton's flood-runner which commences to flow at approximately 35,000ML/d QSA.

Banks B, B2 and C flow into Mundic Creek. Swift Creek and Wood Duck Creek flow into Tanyaca Creek. Tanyaca Creek flows into Rumpagunyah Creek. Rumpagunyah Creek typically (at flows >2,000ML/day QSA and "normal" Lock 4 pool) flows into the Lower Pike River. Letton's Floodrunner flows into Lower Pike River. Lower Pike River flows into the River Murray at Lyrup.

Due to the close proximity of Deep Creek and Margaret Dowling Creek to Lock 5, raising Lock 5 has only a marginal influence on flows into these Creeks. Conversely, raising Lock 4 has a significant influence on flows entering the Pike anabranch complex from downstream of Mundic Creek, with Swift Creek, Wood Duck Creek, Rumpagunyah Creek in particular providing significant additional flow during elevated flows to SA or elevated Lock 4 pool levels.

Katarapko Floodplain

The Eckert Creek system receives water directly from the River above Lock 4 at pool level through the Northern Arm and main Eckert Creeks. Katarapko Creek receives water directly from the River Murray below Lock 4 and from Sawmill Creek and The Splash. Below the mouth of Sawmill Creek there is a stone weir across Katarapko Creek to limit flows through the waterway.

The hydrological structures on both Eckert and Katarapko Creeks significantly restrict flows down both Creeks. The main Eckert Creek inlet structure (Bank J is estimated to overtop at above 45,000 ML/d). The main Katarapko Stone Weir starts to be overtopped at flows above 8,000 ML/d and is completely inundated at approximately 13,000 ML/d river flows. When River flows reach approximately 60,000 ML/d large areas of the floodplain become inundated and that there is large scale lateral connectivity with the floodplain. At flows of 60,000 ML/d a large percentage of temporary wetlands and large areas of floodplain shrubland and open and open plain become inundated.

Floodplain Inlets are fully regulated with following maximum capacities;

- 2,000 ML/d at Bank J
- 400 ML/d at Bank K
- 250 ML/d at Bank N

Refer to Section 10 of the Business Case for descriptions and figures representing flows under current conditions and the flows that result from the proposed changes (**Attachment 1**).

Proposed operating rules for the works and measures under full range of hydrological conditions experienced during 1895 to 2009 period, including any risk mitigation strategies.

Table 1 and 2 in **Attachment 3** provide a summary of the proposed operational regimes at Pike and Katarapko Floodplains.

6.	Representation of the project in the MDBA modelling framework

Interaction between river flows and site inflow

Inflows to the Pike floodplain are modelled using tables below. The inflow to Pike Offtake 1 (US Lock 5) is regulated to be 300 ML/d when the regulator is not operated and 1400 ML/d when the regulator is operated. The inflow to Pike Offtake 2 is not regulated (natural overbank flow) and is not dependent on operation. The model does not represent raising of Lock 5, but this is included in the ecological outcomes scoring.

Flow US Lock 5 (ML/d)	Flows into Pike Offtake 1 (ML/d)	
Pike Regulator not operated		Pike Regulator Operated
0	0	0
500	300	400
5000	300	1200
15000	300	1400
400000	300	1400

Flow DS Lock 5 (ML/d)	Flows into Pike Offtake 2 (ML/d)
0	0.0
30000	0.0
33708.6	1080.0
38706.4	1418.7
43867.9	1968.2
48565.9	2497.8
53693.2	2976.5
58689.3	3391.2
68683.6	3654.7
78682.0	3772.2

Flow into Katarapko Floodplain is modelled using the table below. The model does not represent raising of Lock 4.

Flow US Lock 4 (ML/d)	Katarapko inflow without ops (ML/d)	Katarapko inflow during operation (ML/d)
0	0.0	0.0
500	230.0	230.0
2000	230.0	230.0
6000	230.0	230.0
8000	230.0	230.0
10000	716.9	716.9
12000	724.3	2500.0
15000	735.4	2500.0
20000	761.8	2500.0
25000	796.1	2500.0
30000	836.2	2500.0
40000	1092.6	2500.0
50000	1740.6	2500.0
60000	4077.1	4077.1
70000	5759.8	5759.8
80000	7442.5	7442.5

Return flow from the site to the river
Once inflows to the site are calculated, the model applies hydrologic routing to calculate level, volume and inundation area. For a weir storage, flow behaviours are calculated by flow-level relationship at downstream of the weir. The model calculates storage volume or water level so that downstream level is lower than or equal to the weir pool level. The following relationships have been used by MDBA based on data provided by South Australia, but changes have been made to better match storage and area from hydrodynamic model results for Pike and Katarapko. A minimum flow requirement downstream Pike regulator of 400 ML/d has been used during operation.

Pike	
Flow (ML/d)	Level (mAHD)
0	12.0
362	13.22
1141.3	13.31
1165.5	13.38
1166.4	13.50
1166.4	13.67
1167.3	13.85
1168.1	14.07
2233.4	14.29
2482.3	14.48
3077.6	14.73
3545.0	14.98
4018.5	15.20
4400	15.42
4600	15.84
4700	16.18
4800	16.73
4900	16.90

Katarapko	
Flow (ML/d)	Level (mAHD)
0	9.8
229.6	9.92
230	10.02
712.2	10.23
730.5	10.73
745	11.21
770	11.59
820	11.95
1180	12.59
1600	13.14
5000	13.64
5900	14.11

Surface water loss relationships
A standard evaporation loss is applied by MSM–Bigmod with evaporation and rainfall calculated using monthly data from the Lake Victoria climate station and a pan evaporation factor of 0.830. Seepage is assumed to be zero.

7.	Representation of the operating strategy in the Murray Model

Only maximum floodplain inundation strategy has been included. Representation of Pike and Katarapko operating strategies in the Murray Model (MSM Rev 912) are below.

Lock 4 and 5 weir raising is not represented in the model.

Pike Floodplain	Max Inundation
Maximum Flow to SA (ML/d)	NA
Minimum Flow to SA (ML/d)	35,000 ML/d
Lock 5 Level (m)	16.8 m AHD*
Pike Regulator Level (m)	16.4 m AHD
Minimum flow DS Pike Reg.	400 ML/d
Maximum period between inundations	3 years
Time to raise	1 month
Minimum duration at target level	1 month
Drawdown time	1 month
Total duration	3 months
Earliest Start	July
Equivalent Natural Flow	80,000 ML/d

Katarapko Floodplain	Max Inundation
Maximum Flow to SA (ML/d)	NA
Minimum Flow to SA (ML/d)	20,000 ML/d
Lock 4 Level (m)	14.2 m AHD
Katarapko Regulator Level (m)	13.5 m AHD
Minimum flow DS Katarapko Reg.	NA
Maximum period between inundations	2 years
Time to raise	1 month
Minimum duration at target level	1 month
Drawdown time	1 month
Total duration	3 months
Earliest Start	July
Equivalent Natural Flow	70,000 ML/d

8.	Spatial data describing the inundation extent associated with the operation of the measure

The area of inundation associated with the operation of the works has been modelled with the hydrodynamic model. These areas have been combined with the necessary weir pool raising inundation extents. The total area of inundation for each of the operating strategies is given in the table below.

Operation strategy	Inundation area (ha)
Pike Maximum (PIK)	3886
Katarapko Maximum (KAT)	2050

For the purpose of calculating scaling factors for the Ecological Outcomes scoring method, the maps of the inundation areas associated with the works were combined with maps of SFI flow bands and maps representing the ecological elements used in the scoring method. The areas for the resulting hydrological assessment units (HAU) are provided in tables below.

Inundation area (ha) for HAU for PIK	SFI Flow Bands				
Ecological Element	**40,000**	**60,000**	**80,000**	**100,000**	**125,000**
General health and abundance - all Waterbirds	635.8	1113.5	1511.0	154.3	8.7
Bitterns, crakes and rails	409.0	96.8	73.6	22.8	0.3
Breeding - Colonial-nesting waterbirds	635.8	1113.5	1511.0	154.3	8.7
Breeding - other waterbirds	409.0	96.8	73.6	22.8	0.3
Redgum Forest	27.8	51.9	16.6	2.5	0.3
Redgum Woodlands	21.8	25.4	8.4	1.1	0.0
Forests and Woodlands: Black Box	86.5	303.8	330.6	51.1	3.0
Lignum (Shrublands)	63.3	591.3	863.2	25.6	0.6
Tall Grasslands, Sedgelands and Rushlands	46.2	69.9	71.4	22.5	0.2
Benthic Herblands	362.8	26.9	2.2	0.2	0.0
Short lived fish	409.0	96.8	73.6	22.8	0.3
Long lived fish	635.8	1113.5	1511.0	154.3	8.7

Inundation area (ha) for HAU for KAT	SFI Flow Bands				
Ecological Element	**40,000**	**60,000**	**80,000**	**100,000**	**125,000**
General health and abundance - all Waterbirds	436.6	532.7	817.0	61.5	7.3
Bitterns, crakes and rails	143.4	52.8	65.5	10.0	0.8
Breeding - Colonial-nesting waterbirds	436.6	532.7	817.0	61.5	7.3
Breeding - other waterbirds	143.4	52.8	65.5	10.0	0.8
Redgum Forest	7.3	3.6	3.1	1.2	0.1
Redgum Woodlands	2.9	3.6	2.4	0.5	0.1
Forests and Woodlands: Black Box	58.4	99.3	225.1	23.0	2.9
Lignum (Shrublands)	124.8	333.3	353.1	8.0	0.9
Tall Grasslands, Sedgelands and Rushlands	139.1	50.1	63.5	9.5	0.7
Benthic Herblands	4.3	2.7	2.0	0.5	0.1
Short lived fish	143.4	52.8	65.5	10.0	0.8
Long lived fish	436.6	532.7	817.0	61.5	7.3

Attachments:

1	DEWNR 2017	South Australian Riverland Floodplain Integrated Infrastructure Program (SARFIIP): Pike and Katarapko Floodplain Project Elements. Phase 2 Business Case
2	DEWNR 2017	Level-volume-area relationships for Pike and Katarapko Floodplains and Weir Pool 4 and 5
3	DEWNR 2017	Proposed operating rules for SARFIIP works and measures
4	MDBA	Level-Volume-Area relationships

South Australian Riverland Floodplain Integrated Infrastructure Program (SARFIIP): Pike and Katarapko Floodplain Project Elements

Sustainable Diversion Limit Adjustment Supply Measure

Phase 2 Business Case

Department of Environment, Water and Natural Resources

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Contents

1 Executive Summary

The South Australian Riverland Floodplain Integrated Infrastructure Program (SARFIIP) aims to create an integrated and resilient floodplain along the South Australian River Murray, between the border and Lock 1, through a package of works and measures that enable floodplain inundation, freshening of groundwater lenses, manipulation of weir pools and management of salinity risk with particular focus on the Pike and Katarapko floodplains (Figure 1).

The Pike and Katarapko floodplains have been identified as South Australian priority floodplains and Basin Plan key environmental assets (KEA's). Environmental works on the Pike and Katarapko Floodplains will optimize the frequency, duration and extent of inundation events to protect and restore these floodplain ecosystems and contribute to Basin Plan environmental outcomes.

Salinity management measures will complement the floodplain inundation works to manage ecological risk, enhance ecological condition by maximizing the area of soil salinity that is within the tolerances of target vegetation and manage any long term and real time in-stream salinity risk.

SARFIIP will also include measures to coordinate and optimize floodplain environmental watering between the border to Lock 1. This includes manipulation of weir pools to achieve environmental outcomes through additional areas inundated and/or evaporative savings.

SARFIIP is primarily an environmental works and measures program but also has potential through weir pool manipulation to produce additional inundation. The business case focuses on the adjustment potential of the floodplain inundation works while noting there is potential for outcomes to be enhanced in future as operating regimes for weir pool manipulation are developed.

SARFIIP is a seven year, $155 million investment program funded by the Commonwealth Government. Implementation of the program commenced in 2013/14 and is expected to continue until 2019/20.

This business case has been developed in accordance with the Phase 2 Assessment Guidelines for Supply and Constraint Measure Business Cases. As the program is already a fully funded some aspects of the Guidelines are not applicable.

A list of relevant document sections that address the Phase 2 Assessment Guidelines is provided at Appendix 1.

2 Project Details

2.1 Project Overview

SARFIIP is a seven year, $155 million investment program funded by the Commonwealth Government. Implementation of the program commenced in 2013/14 and is expected to continue until 2019/20. Further details on costs and project scheduling are outlined in Section 15.

River regulation and water extractions along the River Murray have reduced the volumes of water available to the environment, the frequency of wetting and drying events and the duration of higher flow events. This has also led to reduced interaction between the River Murray and its floodplain, resulting in a decline in the health of the floodplain environment.

SARFIIP aims to create an integrated and resilient floodplain along the South Australian River Murray, between the border and Lock 1, through a package of works and measures that enable floodplain inundation and freshening of groundwater lenses with particular focus on the Pike and Katarapko floodplains (Figure 1).

The Pike and Katarapko floodplains have been identified as South Australian priority floodplains and Basin Plan key environmental assets (KEA's). Environmental works on the Pike and Katarapko Floodplains will optimize the frequency, duration and extent of inundation events to protect and restore these floodplain ecosystems and contribute to Basin Plan environmental outcomes. The proposed works will introduce variability in patterns of flooding and mimic aspects of the natural water regime, providing efficient watering at a landscape scale with the intent to improve the condition of the floodplain biotic communities and to improve biological connectivity between the main River Murray channel and its floodplain environments. The infrastructure on the Pike and Katarapko Floodplain areas can also be operated to take advantage of the water level differentials across Lock 3 to 4 and Lock 4 to 5 to enable further floodplain inundation.

SARFIIP will also include measures to coordinate and optimize floodplain environmental watering between the border and Lock 1. This includes manipulation of weir pools to achieve environmental outcomes through additional areas inundated and/or evaporative savings. At this stage the operational regime for weir pool manipulation has not been fully developed, but it may have potential to enhance the sustainable diversion limit adjustment outcomes of the program as implementation proceeds.

Salinity management measures will complement the floodplain inundation works to manage ecological risk, enhance ecological condition by maximizing the area of soil salinity that is within the tolerances of target vegetation and to manage any long term and real time in-stream salinity risk.

Figure 1: Location of the Pike and Katarapko Floodplains in South Australia.

SARFIIP is comprised of four interlinked sub-programs as outlined below:

1. **Pike Floodplain Inundation Works:**

   Proposed environmental works and measures on the Pike Floodplain will inundate approximately 1971 hectares (ha) and consists of blocking banks at Pike Floodplain, a suite of new major and minor regulators, an upgrade to Margaret Dowling Creek inlet and bridge and new potential infrastructure to facilitate watering of lower Pike. This management option also involves the raising of the Lock and Weir No. 5 upper pool level by 500 mm (maximum) from its normal level to increase flows into the Pike anabranch through the numerous existing bank and weir structures and increase the area of floodplain inundated by approximately 1,134 ha (Appendix 2). Refer Section 2.2 for more information.

2. **Katarapko Floodplain Inundation Works:**

   Environmental works and measures on the Katarapko Floodplain will inundate approximately 1300 ha. Works include blocking banks, a new or upgraded Lock 4 access track, upgrade of a major structure at Eckerts Creek inlet (Bank J), a major new structure at the Eckerts Creek outlet (The Splash) and a suite of new major and minor regulators. This management option also involves the raising of the Lock and Weir No. 4 by 600 mm (noting this may increase up to 1140 mm) from its normal operation height to increase flow volumes and flow velocity into the Eckert Creek anabranch system and increase the area of floodplain inundated upstream of Lock 4 by approximately 885 ha (Appendix 3). Refer Section 2.3 for more information.

3. **Salinity Management Measures:**

   Salinity management measures (SMM) will investigate and construct, where required, Pike and Katarapko floodplain salinity management infrastructure to deliver environmental benefit and manage ecological and salinity risks as outlined in Section 9 and 12.

4. **Environmental Pathways:**

   The environmental pathways component of SARFIIP will enhance the outcomes from the works to be undertaken at Pike and Katarapko floodplains, as well as the existing Chowilla floodplain under The Living Murray (TLM) and the Riverine Recovery Project (RRP) environmental works. It will provide corridors or connectivity zones between these main sites to increase resilience and functionality of the floodplain through the exploration of further opportunities in site remediation and/or management. Investigations will be undertaken into coordination of environmental watering, including weir pool manipulation, wetland management and floodplain inundation. This coordination will consider cumulative risks and opportunities as well as resource and monitoring requirements in the management of multiple sites.

   The River Murray in South Australia is regulated by six weirs. The weir pool manipulation element is a continuation of previous weir operations investigations and trials aimed at mimicking the natural fluctuations in water level that wetlands and floodplains depend upon. Trials will continue to be undertaken to identify and address issues with the aim of enabling weir pool manipulation to become a standard operational practice.

SARFIIP infrastructure designed for floodplain inundation management at Pike and Katarapko floodplains, outlined as sub-programs 1 and 2 above, are proposed as environmental works at point locations under the Sustainable Diversion Limit (SDL) adjustment mechanism, and as such these items are the focus of this submission. Sub-program 3 is a key risk management measure which also enhances the projected environmental outcomes of the overall program. Sub-program 4 provides for environmental measures, including weir pool manipulation, which may enhance the SDL adjustment benefits in future. Some details are provided within this business case on the broad range of benefits that can be achieved through weir pool manipulation, particularly for Locks 4 and 5, which will be operated in conjunction with the Pike and Katarapko Floodplains works. However at this stage, further investigations are underway and operational details cannot be provided for the broader weir pool manipulation element.

Project delivery has commenced and the information contained in this business case is at a ‘point in time’ and new information is continually becoming available. This new information will be used to inform project delivery through the appropriate program governance mechanisms.

2.2 Environmental Works for the Pike Floodplain

Environmental works and measures proposed for Pike Floodplain are illustrated in Figure 2. Color coding in this figure shows that some infrastructure items have already, or are currently being funded under the RRP, with other items proposed under SARFIIP to enable managed inundation at the site. SARFIIP environmental works include:

- A new environmental regulator and fishway at Tanyaca Creek
- A new environmental regulator and fishway at Pike River
- Blocking banks, and other ancillary structures, including new Bank E

- Lowering of the ‘commence to flow’ of Letton's flood runner
- Regulator at Bank H (upstream end of Snake Creek)
- Regulator at ‘Southern Mundic Creek Outlet’
- Removal of the Col Col regulator and embankment to a sufficient extent to allow unhindered flow and fish passage
- Complementary saline groundwater management scheme (refer section 2.4).

2.3 Environmental Works for the Katarapko Floodplain

Environmental works and measures proposed for the Katarapko Floodplain are indicated in Figure 3 and include:

- Construction of 5.9 km of blocking bank to allow control of inundation regimes
- A new Lock 4 access track to enable all weather access to Lock 4 during periods of maximum inundation
- A major new outlet regulator at the downstream end of The Splash to enable manipulation of water levels and flows from the system.
- A major new regulator at the downstream end of Piggy Creek to enable manipulation of water levels and to be operated in conjunction with the new regulator at The Splash
- New ancillary regulators at the inlets of Piggy Creek to Katarapko Creek and an ancillary regulator near Lock 4
- One new Sawmill Creek Outfall Regulator and two ancillary Sawmill Creek Regulators. These structures are to be used in conjunction with The Splash and Piggy Creek regulators to raise water levels to the maximum target level
- Two new regulators at Carpark Lagoon, including one at the downstream end of Carpark Lagoons and one at the upstream inlet. These structures are to be used in conjunction with The Splash, Piggy Creek and Sawmill Creek regulators to raise water levels to the maximum target level
- Construction of Bank J, a new major inlet structure into the Eckerts Creek system.

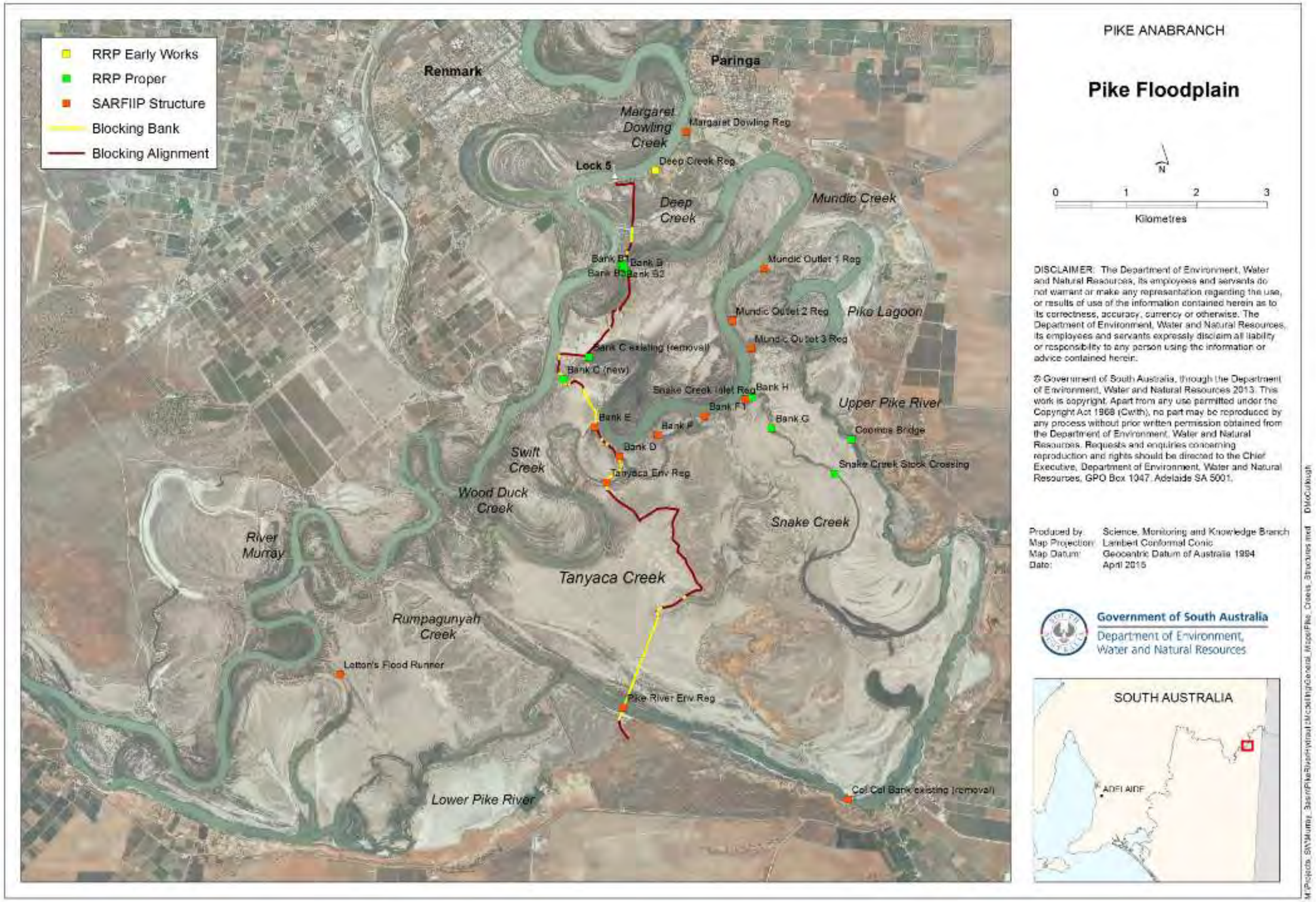


Figure 2: Works proposed and commenced at Pike Floodplain under the Riverine Recovery Project (RRP) and SARFIIP.

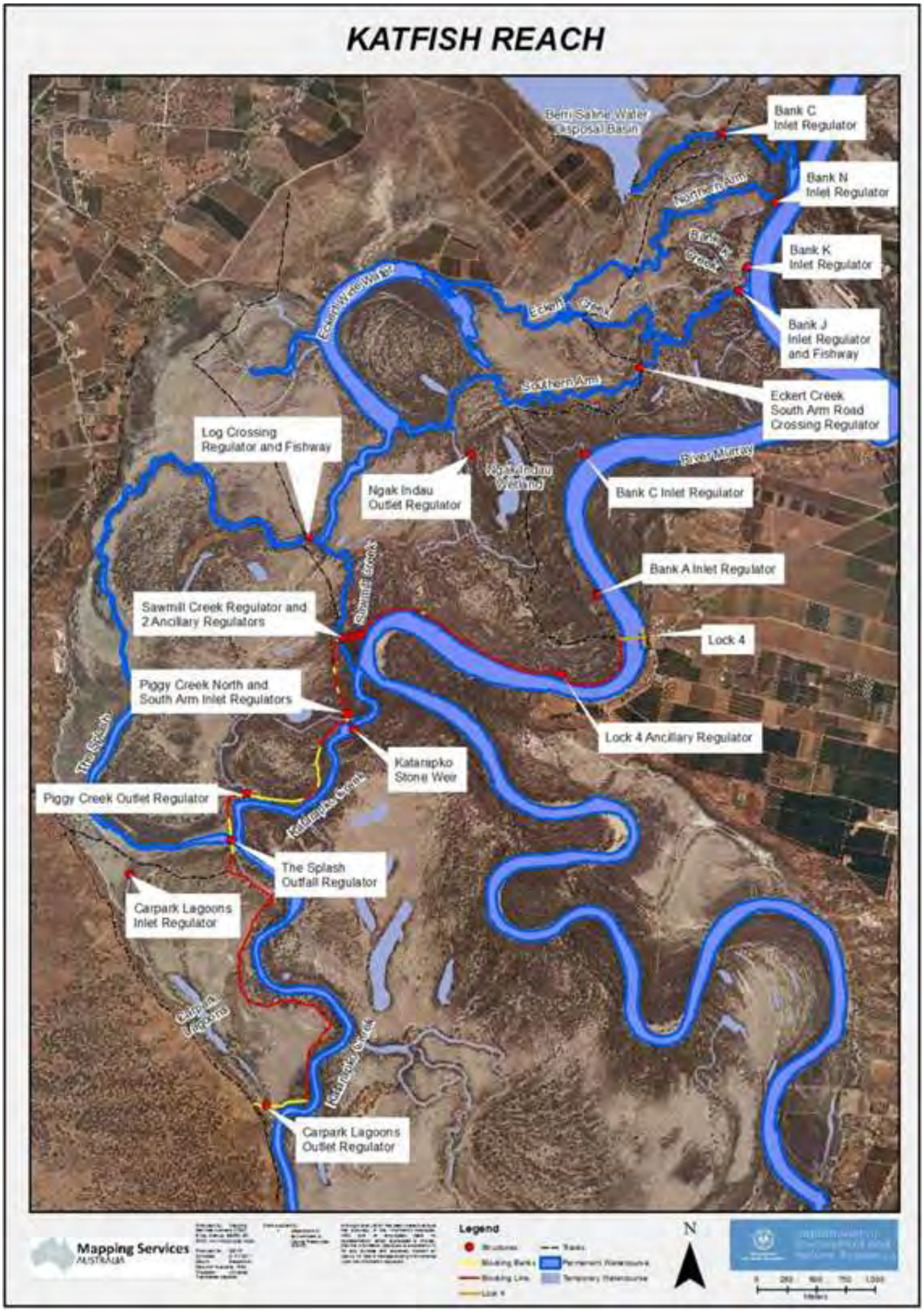


Figure 3: Works proposed under SARFIIP at Katarapko Floodplain

2.4 Associated Salinity Management Works

The salinity management measures (SMM) sub-program of SARFIIP involves the development of floodplain groundwater management schemes and salt interception infrastructure. This sub-program will enhance the ecological benefit and manage the salinity risks associated with more frequent inundation of the floodplains at both the regional and local scales. It complements the outcomes of constructing flow regulators and blocking banks at both Pike and Katarapko floodplains by:

- Ensuring a neutral salinity impact from any SARFIIP infrastructure constructed to control the inundation (flooding) of wetlands and floodplains.
- Protecting existing low salinity groundwater zones from potential saline groundwater intrusion caused by inundation events.
- Maximise the area suitable for vegetation by managing the groundwater condition in areas of potential benefit achieved by the inundation projects.
- Developing opportunities for further long-term salinity management in SA.

The proposed salinity management strategy involves production bores, pipelines and disposal options to recover saline groundwater and manage impacts to the floodplain ecosystem and the River Murray anabranches. Saline groundwater is likely to be recovered from two main areas: (1) the perimeter of the floodplains to reduce groundwater heads driving saline groundwater onto the floodplains and (2) internal floodplain areas where freshwater lenses could be extended and maintained, and where vegetation could be protected from saline groundwater migration caused by inundation events. It is expected that a combination of these two methods would also reduce the evapotranspiration of groundwater in the floodplain and thus reduce salt accumulation within the unsaturated zone soils.

The groundwater will be recovered from a series of production bores which will be installed and tested in stages. The final number will be dependent on aquifer testing and the bore capture zones. The bores will connect into a pipeline for offsite management of the saline water. The total length and capacity of the pipelines will vary depending on the exact number of bores and their aerial spread across the Floodplain. Based on current conceptual understanding, the estimated length of required pipeline is between 20 and 30 km. Figure 4 shows a possible alignment for the proposed SMM pipeline.

2.5 Complementary Actions

SARFIIP builds on works under the RRP which commenced in 2010. Through infrastructure and adaptive river management, RRP aims to restore wetting and drying cycles to key wetlands and improve floodplain inundation. Environmental works are being implemented on the Pike and Katarapko floodplains as part of RRP and are considered complementary actions for the purpose of this SARFIIP business case.

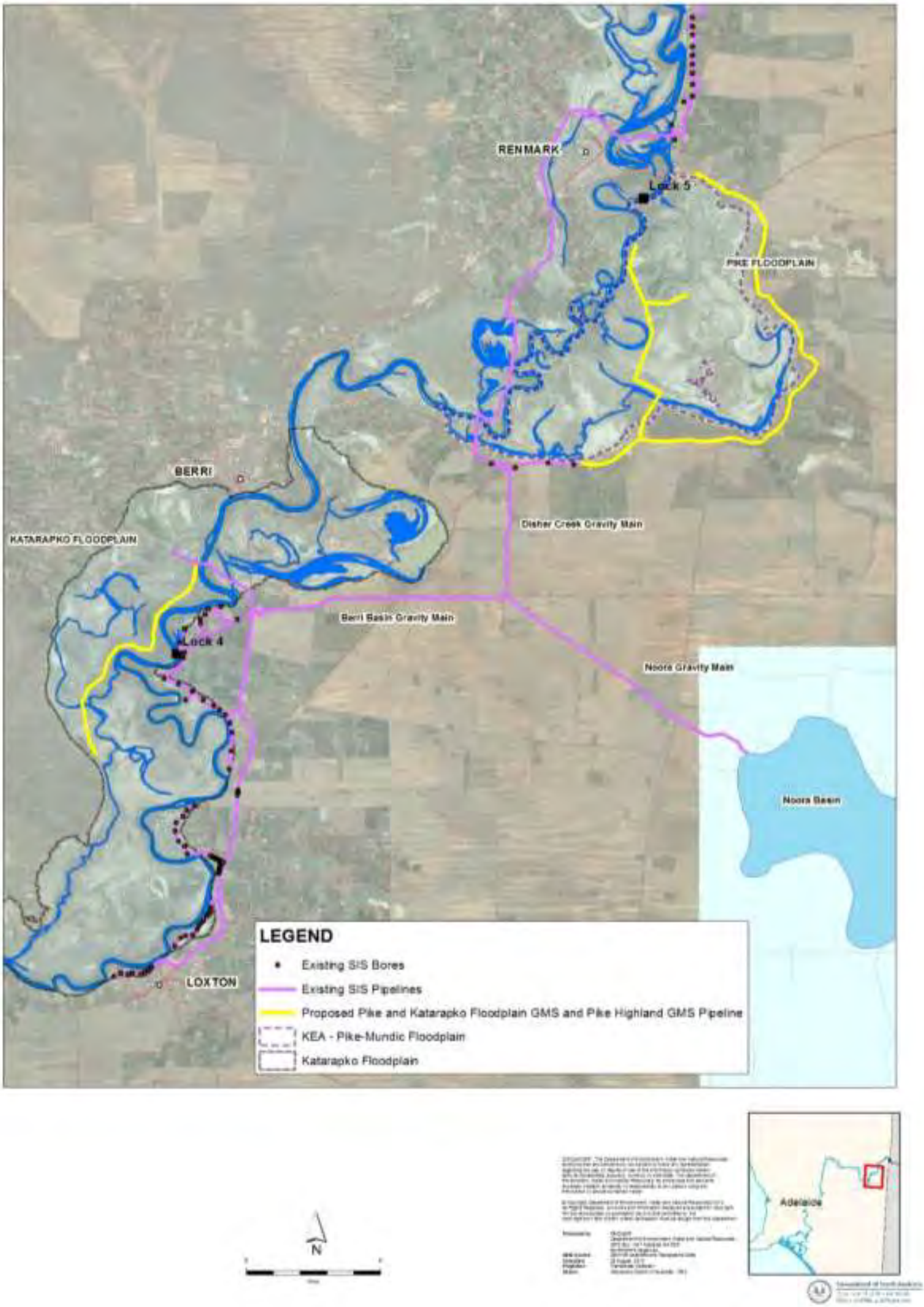


Figure 4: Map of Pike and Katarapko Floodplains proposed groundwater management scheme (prepared by DEWNR, 2015).

3 Eligibility

Eligibility criteria applicable to the SARFIIP Project as an SDL adjustment supply measure proposal are addressed below:

- *Reflects the definition of "Supply measure" under Basin Plan (cl.7.03 and cl.7.15)*

Installation and operation of new environmental surface water regulators in the Pike and Katarapko floodplains will enable beneficial use of River Murray flows in the order of 15 000 megalitres per day (ML/day) flows to South Australia (QSA) to generate an inundation extent which is currently only possible under "natural" flows of 60 000 – 80 000 ML/day.

The measure enables environmental water to be managed to deliver nearer natural frequency, duration and extent of inundation events that allow environmental outcomes to be achieved with a lower volume of water than would otherwise be required without SARFIIP infrastructure.

- *Measures not included in the benchmark conditions of development (cl.7.02 of the Basin Plan)*

SARFIIP is a new supply measure not included in the benchmark conditions of development.

- *Operational by 30 June 2024 (cl.7.12 of the Basin Plan)*

Construction of the first scope of works under SARFIIP are scheduled to commence in 2016 and are to continue through until June 2019. In the event that works are delayed, a contingency period of 12 months has been factored into the construction schedule, resulting in total construction completion by June 2020. The project is expected to be operational upon completion, demonstrating that the project meets the eligibility criteria of being operational by 30 June 2024.

This proposal is not seeking Commonwealth Supply funding.

4 Ecological values of the site

4.1 Ecological Values

The Pike and Katarapko floodplains are located within the South Australian River Murray (SARM) floodplain which is comprised of a mosaic of water-dependent and terrestrial habitats, including temporary wetlands, River Red Gum Woodlands, Black Box Woodlands, Lignum Shrublands, Terrestrial Shrublands and Samphire Shrublands (Kilsby and Steggles, 2015). The flow regime of the River Murray is the primary driver of the distribution and abundance of ecological communities in these habitats, interacting with the morphology of the channel and floodplain, shedding or retaining water and recharging groundwater (Kilsby and Steggles, 2015). The entire SARM floodplain (along with the river channel) supports many water-dependent biota, including 22 species of native fish, 11 species of frogs, water birds and macro invertebrates, as well as woodland-dependent birds, reptiles and mammals (Kilsby and Steggles, 2015).

Site specific details of the ecological values for the Pike and Katarapko floodplains are provided below. Floristic vegetation groups used to characterise the flora composition in both floodplain sites are based on over storey, understorey and structural similarity and are based on vegetation surveys carried out in 2002 (Smith and Kenny, 2005). Whilst these may not completely reflect current distributions, they are considered adequate for the purposes of presenting background information on the ecological values of these floodplain sites.

Pike Floodplain

The Pike Floodplain is a major floodplain and anabranch system within the SARM floodplain spanning approximately 6,700 ha (Ecological Associates and Tonkin Consulting 2015a). It is a priority floodplain for environmental flows within South Australia and comprises a range of floodplain and aquatic habitats, including permanent fast and slow flowing anabranch creeks, islands, billabongs, permanent and temporary wetlands, oxbow lakes, flood outs and lunettes (Wallace, 2009; Ecological Associates and Tonkin Consulting, 2015b).

The Pike Floodplain system provides a unique opportunity to preserve an important complex of inter-related habitats at one location, as many of the habitat features of the Pike Floodplain have been degraded elsewhere on the SARM floodplain.

Combined with the diverse range of aquatic and floodplain habitats, the Pike Floodplain supports diverse flora and fauna, including approximately 1257 ha of River Red Gum (*Eucalyptus camaldulensis*) woodlands and/or forests, 1540 ha of black box (*E. largiflorens*) woodlands, river Cooba (*Acacia stenophylla*), lignum (previously *Muehlenbeckia florulenta*, now *Duma florulenta*) shrublands, chenopod (*Atriplex spp.)* shrublands, herblands and dunes. Figure 5 presents the vegetation types and their distribution on the Pike Floodplain.

Seventeen plant species of conservation significance under the SA *National Parks and Wildlife Act (1972)* have been reported from the Pike Floodplain area in the Biological Database of South Australia as provided in Ecological Associates and AWE (2008).

The habitats found on the Pike Floodplain support a range of fauna, from micro and macro-invertebrates to fish, frogs and waterbirds. Terrestrial native mammals are also supported by these riparian environments. The Pike Floodplain potentially provides habitat for a number of animals listed under the Commonwealth *Environment Protection and Biodiversity Conservation Protection Act 1999* (Ecological Associates and AWE 2008). The site also provides habitat for waterbirds under international migratory bird agreements which are governed by the Act.

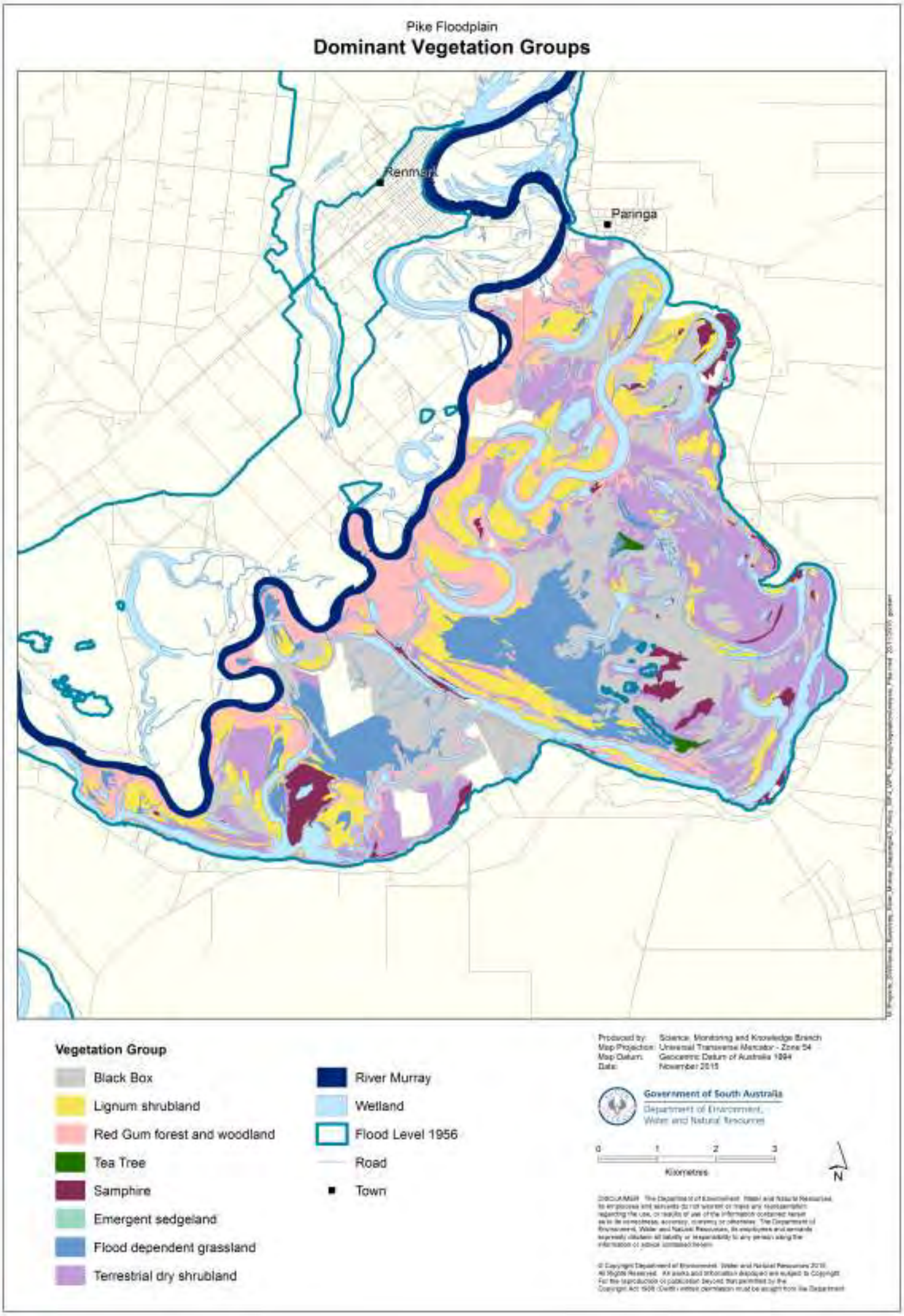


Figure 5: Dominant vegetation types in Pike floodplain area

Twenty one fauna species of state or national conservation significance have been reported to the Biological Database of South Australia from the Pike Floodplain area as discussed in Ecological Associates and AWE (2008). The four species of national significance are the Murray Cod, Golden Bell Frog, the Malleefowl and the Regent Parrot. The Golden Bell Frog (Figure 6) is found in permanently inundated reedy vegetation in the Renmark area and is likely to be associated with Mundic Creek where reedy vegetation is most abundant. Regent Parrot (Figure 6) feeds in mallee vegetation and relies on the hollows provided by large floodplain eucalypts to nest and shelter. Malleefowl is present in extensive mallee vegetation in highland areas near the floodplain, but is not a floodplain species.

Watercourses and wetlands within the Pike River Floodplain complex provide an extensive network of aquatic habitats, which include shallow water and mudflats for waterbirds, extensive reed beds used by a number of shy waterbirds for shelter, and open water habitats which are used by fish-eating birds such as Pelican and Cormorant and by dabbling ducks such as Teal.

The lowest-lying parts of the floodplain are located near the banks of the River Murray. These areas support relatively healthy River Red Gum woodland communities, which in places have a diverse understorey of native grasses and herbs. The River Red Gums play an important functional role within floodplain and wetland systems through provision of carbon (leaf litter) and habitat for a range of aquatic, floodplain and riparian fauna (Wallace, 2009). They provide habitat for a number of hollow-dwelling bats, birds, mammals and reptiles. The food provided by flowers and vegetation in the understorey and the canopy also sustains high levels of ecosystem productivity, particularly after floods.

Lignum shrublands occur in less frequently flooded areas. Between flood events Lignum shrublands are relatively simple plant communities with low species diversity. They provide shelter for kangaroos during the day and nesting sites for some bush birds. During floods, the shrublands and adjacent chenopod shrublands provide very productive habitats. Macro-invertebrates and zooplankton quickly populate vegetated and open water areas. Fish graze on decaying plant matter and spawn in the flooded vegetation. The lignum, which is relatively dormant during dry periods, grows new shoots and provides nesting platforms for waterbirds such as Ibis. Lignum can also be utilised by smaller terrestrial bird species (e.g. various wrens).

Black Box woodland occupies the most infrequently flooded parts of the floodplain. Like Red Gum, Black Box provides habitat for hollow-dependent animals. The understorey comprises grasses, chenopods, some low shrubs and herbs. This vegetation community has strong linkages to the surrounding mallee landscape, supporting ground foragers, canopy feeders and hollow nesting species (Wallace, 2009).

Figure 6: Regent Parrot and Golden Bell Frog are two species of national significance found on the Pike Floodplain.

Katarapko Floodplain

The Katarapko-Eckert Creek floodplain has long been recognised for having high conservation values, with the majority of the floodplain included in the Murray River National Park (Katarapko), with Katarapko Island being gazetted as a National Park since 1970. The Katarapko-Eckert Creek floodplain is also a priority floodplain complex for environmental flows within South Australia.

Katarapko Floodplain is a complex mosaic of habitats comprising numerous vegetation communities including floodplain woodland, shrublands and open plains, dune systems, over 40 km of permanent waterways and 27 temporary freshwater wetlands. This habitat diversity supports a range of terrestrial and aquatic animals.

Seventeen plant species considered threatened under State legislation are found on the floodplain (Katfish Reach Steering Group, 2008).

Figure 7 provides the distribution of dominant floodplain vegetation types at Katarapko Floodplain and indicates that Black Box is the most widespread vegetation class recorded, occupying approximately 2118 ha, followed by 1915 ha of River Red Gum forest, with Samphire, as well as Lignum and Lignum/Canegrass recorded across 642 ha and 562 ha of the floodplain, respectively.

According to Jacobs SKM (2014c) the diverse habitat supports 14 nationally threatened fauna species including the Southern Bell Frog, Murray Cod, Murray Hardyhead and Regent Parrot and a further 15 species that have a threatened rating at State level. There are also migratory bird species listed under international migratory bird agreements with Japan (JAMBA), China (CAMBA) and the Republic of Korea (RoKAMBA).

The area is a demonstration reach for native fish under the Native Fish Strategy (DENR, 2012a). Monitoring of the diverse population of native fish (15 species) shows that numbers are generally low, especially those with state or national conservation significance (Murray Cod, Freshwater Catfish and Silver Perch) (Bice et al., 2015).

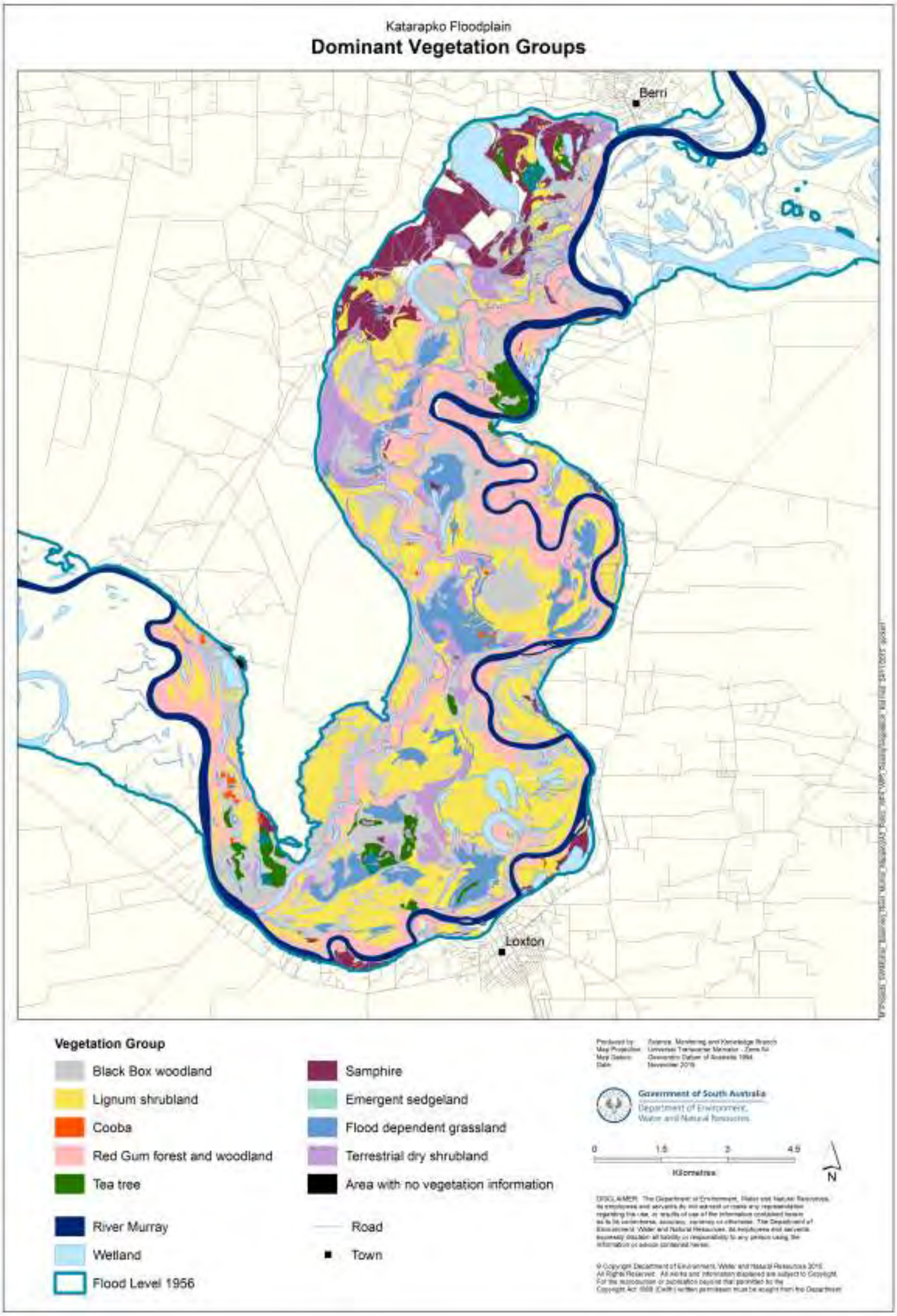


Figure 7: Dominant Floodplain vegetation types at Katarapko Floodplain

4.2 Current Condition

Pike Floodplain

Although the Pike Floodplain is currently experiencing a decline in health, the floodplain still retains significant ecological character and values. The site supports a high diversity of both terrestrial and aquatic habitats, including populations of rare, endangered and nationally threatened species (see Section 4.1). SARFIIP will help arrest the decline and protect and restore the ecology of the site.

There are a number of processes that are compromising the ecological integrity of the Pike floodplain. The key threats to the site are altered flow regimes, elevated highly saline groundwater, obstructions to fish passage, grazing pressure, and pest plants and animals (Wallace, 2011). Flow regulation in particular has reduced flooding frequencies and duration, and has resulted in saline groundwater levels increasing by up to 3m higher than under natural or pre-regulation conditions. This is having a significant impact on the native fauna and flora.

In order to maintain the 1257 ha of River Red Gum forest and woodland and 1540 ha of Black Box woodland on the floodplain in a healthy condition, flooding is generally required every 2-3 years for River Red Gums and every 4-8 years for Black Box. While floods are essential to many important conservation values of the floodplain, they have become less frequent as a result of the storage and diversion of water upstream (Ecological Associates and AWE, 2008). This lack of flooding, in conjunction with ongoing salt accumulation in the floodplain soils, has resulted in decline in the health of trees and understory vegetation throughout the Pike floodplain.

The salt and moisture-stress damage at the Pike Floodplain is predicted to get worse unless inundation events can be increased. CSIRO WINDS vegetation modelling has predicted that based on the continuation of flows typical of the last 15 years that dead trees (River Red Gum, Black Box and River Coobah) could increase from 39% currently to 49% of the floodplain area by 2035 (Hollis 2010).

An assessment of fish habitats within the Pike Anabranch concluded that the riparian habitat was generally in poor condition, however the in-stream habitat was deemed to be relatively good (Beyer et al., 2010). Few habitat associations were revealed in some fish species, which may be related to low habitat heterogeneity present under the current flow regime. It was considered that the Pike Anabranch system would provide a good template for a habitat restoration approach involving increasing connectivity and flowing habitats to increase the diversity of micro- and meso-habitats.

Overall, the Pike floodplain requires direct management intervention to retain the ecological character and attributes for which it has historically been valued. Ecological response associated with managed watering regimes elsewhere in the Basin provide strong evidence that if the frequency and duration of inundation can be closely aligned with the conditions encountered under without development conditions, extensive ecological recovery in the areas influenced through managed intervention can be expected.

Katarapko Floodplain

The Katarapko floodplain area is a modified system affected by river regulation and the cumulative effects of past local management actions. The variety of threats that are currently compromising the ecological integrity of key assets within Katarapko Floodplain include:

- Altered flow regimes with reduced flow variation;

- Maintenance of stable pool levels with limited level variation;
- Elevated highly saline groundwater and impacts from highland irrigation;
- Increased soil salinity from disposal basins;
- Floodplain flow restrictions and obstructions to fish passage;
- Past grazing pressure and subsequent land clearance;
- Inappropriate recreational use; and
- Pest plants and animals (Jacobs SKM, 2014c).

Tree health has declined due to reduced flooding frequency. In particular, due to the lack of flooding during the drought, the percentage of healthy trees (River Red Gum, Black Box and River Cooba) on Katarapko dropped from 43% in 2002 to 22% in 2007 (Ireland et al., 2012). Unless inundation frequency can be increased this decline will continue.

At the end of the Millennium Drought, only six of 25 temporary wetlands at Katarapko had healthy vegetation, which was attributed to past artificial watering (DEWNR, 2013b). The lack of flooding and increase in both soil and groundwater salinity were responsible for the decline in the health of non-watered sites.

At the other hydrological extreme is the Eckert Creek complex which has been permanently inundated since the construction of Locks 3 and 4 and has been impacted by elevated stable water levels, reduced flows and increased salinity (DEWNR, 2013b).

Sections of the littoral zone of the Eckert Creek system are affected by salt scalding due to the impact of past management of the Berri Saline Water Disposal Basin and the lack of significant flows through the system.

Direct management intervention and an improved watering regimes is needed to support recovery and maintenance of ecological values.

4.3 Past Management Activities and Actions

Pike Floodplain

Historically, both the upper and lower Pike floodplains supported areas of irrigated agriculture (Ecological Associates and AWE, 2008). Irrigated agriculture is now limited to small plots near Margaret Dowling and Deep Creeks. The Mundic Creek and Pike River is the only source of water for many irrigators and is used to provide a reliable source of water throughout the year.

Extensive livestock grazing occurred at the Pike Floodplain since 1860, supporting both sheep and cattle. All livestock grazing on the Pike Floodplain ceased as of June 2012 when through RRP funding the South Australian Government acquired the last livestock grazing rights. An exception is a small (<20 acres), highly elevated (well beyond the influence of managed inundation) area north of Bank C, which was part of an outcome which facilitated the permanent cessation of livestock grazing rights elsewhere on the floodplain.

Infrastructure has been constructed to improve hydraulic connectivity and fish passage throughout the Pike anabranch complex and also to improve floodplain hydraulics during natural flow events. This has been funded by the Australian Government's *Water for the Future* initiative as part of the Murray Futures RRP. Infrastructure funded under this program included the Deep Creek Regulator and Fishway (refer Figure 8 below).

Figure 8: Deep Creek Inlet Regulator and Fishway, funded under RRP (Photo courtesy of H. Pocock (2015)).

Pike irrigators, graziers, the Renmark to the Border Local Action Planning Group and state government agencies have collaborated over the last decade to formulate the Pike Implementation Plan (PIP) program (Hollis et al., 2010). Under this program, a coordinated approach has been established to improve the environmental health of the floodplain and protect it from further degradation, reduce salinity impacts and provide a secure and sustainable water supply for domestic and irrigation water use. The Pike Management Plan (Ecological Associates and AWE, 2008) was commissioned under this program.

Salinity management is a long term challenge at Pike Floodplain. The Pike irrigated area in the highlands adjacent to the Pike floodplain is considered a high impact zone with significant discharge to the Pike floodplain and anabranch complex and ultimately the river (Hollis, 2010). In 2010-11, South Australia constructed the first stage of the Pike Salt Interception Scheme (SIS). This included 2.5 km of pipeline and three production bores in the Simarloo Reach. This work is proposed to be further developed through the SMM package of SARFIIP.

Katarapko Floodplain

The majority of the Katarapko Floodplain is managed as a National Park, and as a result is less affected by historical grazing. Management activities are governed by the Murray River National Park Management Plan and the Katfish Reach Implementation Plan. The Implementation Plan is an integrated action plan to address threats to the natural assets of the area. A Memorandum of Understanding (MoU) exists between the Department for Environment and Heritage (now DEWNR) and a range of other stakeholders and local groups regarding plan implementation.

Artificial watering to improve vegetation health has been conducted since 2000 on the Katarapko floodplain. Environmental watering by gravity feed from upper Lock 4 pool level and pumping has occurred at three sites with a total area of 65 ha across the Eckert Creek section of Katfish Reach. Recent gravity flood events occurred in 2012 at Katarapko Carpark lagoons, Katarapko Island Horseshoe Lagoons and Yabby Creek (Woods et al., in prep).

New infrastructure and modifications to existing infrastructure have been identified as one of the most effective ways to achieve the ecological objectives for Katfish Reach and have commenced through the RRP works. RRP aims to replace all in-stream fish and flow barriers and remove or modify existing irrigation water supply pumps from within the Eckerts and Katarapko Creek System to enable the introduction of variable flows through the system to simulate a more natural flow regime. Figure 9 below shows the Eckert-Creek Regulator and Fishway that was constructed as part of RRP. For a summary of the infrastructure constructed as part of RRP, refer to Figure 3.

Figure 9: Eckert Creek Regulator and Fishway at Katfish Reach constructed as part of RRP at Eckert Creek *(Photo courtesy of H. Pocock, 2015).*

Recognized as being the only Demonstration Reach for native fish in South Australia and one of eight within the MDB under the Native Fish Strategy of the MDBA, approximately $850,000 has been invested into Katfish Reach investigations and planning activities (DEWNR, 2013b). The South Australian Murray-Darling Environmental Works and Measures Feasibility Program (DEWNR, 2013a) conducted a range of investigations into ecological and salinity risk assessments, as well as operating strategies, to assist in future infrastructure works proposed at Katfish Reach Floodplain, such as SARFIIP.

Salinity management first commenced in 1990 via the commissioning of the Woolpunda SIS (DEWNR, 2013b). This scheme has been operating effectively for the past 21 years and achieves a significant reduction in salt load to the river in the order of 200t/day (DEWNR, 2013b). The intercepted saline groundwater is removed to the Stockyard Plain Disposal Basin (DEWNR, 2013b).

5 Other Values

In additional to their ecological values (outlined in Section 4), the Pike and Katarapko floodplains are recognised as having significant cultural, social and economic importance.

5.1 Cultural Heritage Values

The First Peoples of the River Murray Mallee region are the Traditional Owners and Native Title holders of lands that include the SARFIIP project areas. They represent the multiple language groups that inhabited the Riverland prior to European settlement and are represented by the River Murray and Mallee Aboriginal Corporation.

The Pike and Katarapko floodplains have particular cultural significance to the First Peoples given the number of heritage sites across the floodplains.

Extensive heritage surveys have been conducted across the floodplains and has been incorporated in the planning and design of infrastructure. The heritage surveys undertaken have provided an opportunity to characterize the floodplains in terms of its Indigenous cultural heritage values while acknowledging that heritage cannot be defined simply by dots on maps and that the First Peoples appreciation of heritage is a concept that extends to its people, mythologies, histories and physical and spiritual landscapes. The River Murray is at the core of this heritage, and it is the intent of SARFIIP to deliver tangible benefits to the river and its environs as well as to the First Peoples.

The Cultural Heritage Management Plans (CHMPs) for each of the Pike and Katarapko floodplains document the processes used to manage the risk of damage to Aboriginal heritage sites and plans to manage the Cultural landscape of the floodplains into the future.

5.2 Economic, Social and Recreational Values

European settlement occurred on the Pike floodplain by 1851. Irrigation development began in 1887 at Renmark and was the first irrigation development in South Australia. The Pike irrigation area has grown to encompass 2,331 ha of irrigated crops, including wine grapes, citrus, almonds and stone fruit. The main crops grown in the region are wine grapes, citrus, almonds and stone fruit. The annual average Gross Value of Production (GVP) for the Pike irrigation area is approximately $18 million (AWE, 2008) and, as such, is an important part of the local economy.

The Pike Floodplain supports a number of recreational uses including fishing, camping, picnicking and boating. The Pike River Conservation Park and National Trust property also provide opportunities for camping, bush walking and nature appreciation in the northern part of the floodplain. Recreational fishing generally takes place in the larger water bodies.

The Katarapko floodplain is part of the Murray River National Park which attracts up to 40,000 visitors each year who use the park for recreational activities. Katarapko is a popular tourist destination that offers high social and recreational value, attracting visitors who participate in a range of activities including camping, fishing, house-boating and canoeing.

6 Ecological Objectives and Targets

6.1 Overarching Management Objectives

The proposed SARFIIP works complement local, State and Commonwealth-level policy objectives to support a healthy river, a sustained economy and build resilience to climate change impacts into the future.

The vision for the Katfish Reach Floodplain is: *'A healthier and more productive aquatic and floodplain ecosystem that everyone can enjoy'*.

The vision for the Pike Floodplain is: '*To achieve a healthy mosaic of floodplain communities which is representative of the communities which would be expected under 'natural' conditions and which ensure that indigenous plant and animal species and communities survive and flourish throughout the site'*.

The SARFIIP surface water management works and supporting measures proposed for the Katarapko and Pike floodplains aim to (Jacobs SKM, 2014a; 2014b):

- Facilitate targeted and scalable management of environmental water through the introduction of broad-scale floodplain inundation;
- Integrate management approaches that improve the environmental health of the floodplain;
- Improve the condition of existing vegetation;
- Improve key aquatic riparian and terrestrial habitats required by native flora and fauna, including water birds, fish, reptiles, mammals and frogs; and
- Achieve a sustainable balance between the needs of the various users of the floodplain.

6.2 Specific ecological objectives and targets for Pike and Katarapko Floodplains

SARFIIP ecological objectives and targets have been developed at the floodplain scale for the Pike and Katarapko Floodplains (Table 1) based on data and information collected during the SARFIIP investigations stage (Nicol et al., 2015; Bice et al., 2015; Willoughby et al., 2014). These objectives and targets align with the Basin Plan and the Long-term Watering Plan for the South Australian River Murray. These targets will be refined during the program delivery before being tested and re-refined once the proposed measures are operational.

Table 1: Ecological objectives and targets for the Pike and Katarapko Floodplains.

Ecological Objective	Ecological Target(s)
Maintain a viable River Red Gum population	In standardised transects that span the floodplain elevation gradient and existing spatial distribution, >70% of trees will have a Tree Condition Index Score (TCI) ≥10 by 2020
	A sustainable demographic that matches the modelled profile for a viable population is established within existing communities across the floodplain elevation gradient by 2020
Maintain a viable Black Box population	In standardised transects that span the floodplain elevation gradient and existing spatial distribution, >70% of trees will have a Tree Condition Index Score (TCI) ≥10 by 2020
	A sustainable demographic that matches the modelled profile for a viable population is established within existing communities across the floodplain elevation gradient by 2020
Maintain a viable River Cooba population	In standardised transects that span the floodplain elevation gradient and existing spatial distribution, >70% of trees will have a Tree Condition Index Score (TCI) ≥10 by 2020
	A sustainable demographic that matches the modelled profile for a viable population is established within existing communities across the floodplain elevation gradient by 2020
Maintain a viable lignum population	In standardised transects that span the floodplain elevation gradient and existing spatial distribution, ≥70% of lignum plants will have a Lignum Condition Score (LCI) ≥6 for colour by 2020
Establish and maintain a diverse plant community comprised of native flood dependent and amphibious species	In temporary wetlands, a minimum of 40% of cells either inundated or containing native flood dependent or amphibious taxa once every two years on average with maximum interval no greater than 4 years. Native flood dependent and amphibious species richness >20.
	In temporary wetlands, a minimum of 80% of cells either inundated or containing native flood dependent or amphibious taxa once every four years on average with maximum interval no greater than 6 years. Native flood dependent and amphibious species richness >40.

Ecological Objective	Ecological Target(s)
	In shedding floodplain zones, a minimum of 20% of cells containing native flood dependent or amphibious taxa once every three years on average with maximum interval no greater than 5 years. Native flood dependent and amphibious species richness >15.
	In shedding floodplain zones, a minimum of 40% of cells containing native flood dependent or amphibious taxa once every five years on average with maximum interval no greater than 7 years. Native flood dependent and amphibious species richness >25.
	In shedding floodplain zones, a minimum of 65% of cells containing native flood dependent or amphibious taxa once every seven years on average with maximum interval no greater than 10 years. Native flood dependent and amphibious species richness >40.
Limit the extent of invasive species including weeds (temporary wetlands)	In temporary wetlands, a maximum of 1% of cells containing *Xanthium strumarium* in any given survey.
	In temporary wetlands, a maximum of 10% of cells containing exotic taxa in any given survey.
	In shedding floodplain zones, a maximum of 1% of cells containing Xanthium strumarium in any given survey.
	In shedding floodplain zones, a maximum of 5% of cells containing exotic taxa in any given survey.
Establish groundwater and soil conditions conducive to maintaining a diverse native vegetation community	Establish and maintain freshwater lenses in near-bank recharge zones.
	Maintain soil water availability, measured as soil water potential at soil depth 20-50cm, greater than -1.5MPa in order to sustain the recruitment of long-lived vegetation.
	Reduce soil salinity (EC 1:5) to below 5,000 μS/cm to prevent shifts in understorey plant communities to salt tolerant
	Maintain soil sodicity below the exchangeable sodium present (ESP) value of 15 (highly sodic).
Restore and maintain resilient populations of large bodied native fish (i.e. Murray cod, golden perch, silver perch, and freshwater catfish)	Expected species occur in 60% of sites within each mesohabitat (channel, anabranch, wetlands).
	Abundance (CPUE[2]) of Murray Cod increases by ≥50% over a 5 year period (i.e. 2015-2020).
	Abundance (CPUE) of golden perch and silver perch increases by ≥30% over a 5-year period (i.e. 2015-2020).
	Abundance (CPUE) of freshwater catfish increases by ≥30% over a 5-year period (i.e. 2015-2020).

Ecological Objective	Ecological Target(s)
Restore and maintain resilient populations of foraging generalists (e.g. Australian smelt, bony herring, Murray rainbowfish, unspecked hardyhead, carp gudgeons, flathead gudgeons)	The length-frequency distributions for foraging generalists include size classes showing annual recruitment.
Create conditions conducive to successful, small scale breeding events for waterbirds	A habitat mosaic comprising shallow water, open water, mud flat and littoral zones is provided simultaneously at least once every three years by 2020
	Minimum inundation periods required for successful breeding by a range of water bird species are provided during 80% of floods by 2020
Provide habitat conducive to support communities of native reptiles and mammals and woodland birds	Each of the bird species known to utilise similar floodplain woodland habitats in the region will be recorded at ≥ 3 sites in any three year period by 2020.
	Each of the reptile species known to utilise similar floodplain/woodland habitats in the region will be recorded at ≥ 3 sites in any three year period by 2020.
	Each of the native mammal species known to utilise similar floodplain/woodland habitats in the region will be recorded at ≥ 3 sites in any three year period by 2020.
Provide habitat conducive to supporting communities of riparian frogs	Each of six riparian frog species will be recorded at ≥ 4 sites in any three year period.
	Record tadpoles from 3 species in later stages of metamorphosis.
Maintain sedimentation and erosion processes within normal ranges	Limit the maximum rate of drawdown (averaged over 3 consecutive days) to ≤0.1 $mday^{-1}$ whilst surface water levels are out of channel and to ≤0.05 $mday^{-1}$ when surface water levels are within channel to minimise risk of bank failure.
	Maintain velocity within creeks below critical threshold (e.g. 0.4 ms^{-1}) to minimise likelihood of excessive bank and channel erosion.

Ecological Objective	Ecological Target(s)
Provide diverse hydraulic conditions and complex habitat for flow dependent biota and processes	Increase the proportion of habitat with velocity >0.18 ms^{-1} and high structural diversity habitat by >20% by 2020 relative to that recorded in the 2009 baseline survey.
	Maintain daily exchange rate within the impounded area at or above 20%.
Maintain a diurnally-mixed water column to ensure diverse phytoplankton and avoid negative water quality outcomes.	Persistent thermal stratification (thermal gradient >0.5°C for more than 5days) is not allowed to establish within (i) the creek system, or (ii) the adjacent river channel
Implement a seasonal hydrograph that encompasses variation in discharge, velocity and water levels	Promote bacterial rather than algal dominance of biofilms
	Discharge, water level and velocity metrics of planned seasonal hydrograph(s) are implemented
Provide for the mobilisation of carbon and nutrients from the floodplain to the river to reduce the reliance of instream food-webs on autochthonous productivity	Open-water productivity shows a temporary shift from near zero or autotrophic dominance (positive Net Daily Metabolism) towards heterotrophy (negative Net Daily Metabolism) during periods when (i) QSA>30,000 ML/d, or (ii) managed inundations are occurring.
	During inundation periods, record an increase in the abundance and diversity of invertebrate food resources for higher order organisms relative to those available during base flow.
Minimise real time and long-term salinity impacts to third parties / downstream users	Maintain water quality consistent with the Murray-Darling Basin Agreement and within targets for managing water flows, water dependent ecosystems, irrigation and recreational water as outlined in the Basin Plan or any relevant Water Resource Plan (once developed).

Ecological Objective	Ecological Target(s)
Maintain concentrations of nutrients and other compounds within ranges that are (i) not problematic for users; and (ii) do not exceed statutory guidelines.	Total phosphorus (TP), Filterable Reactive Phosphorus (FRP), Total Kjeldahl Nitrogen, Nitrate and Nitrite (NOx), Total nitrogen (TN), Ammonia
	Turbidity during base flows = 40 NTU for water from Murray system, <76 for water from Darling system.
	Metals: Iron ≤ 1mg/L, Manganese 0.5 mg/L (respective values for aluminium, cobalt, zinc, copper, nickel, chromium) [Schedule 2 of the Environment Protection (Water Quality) Policy (2003)]
	Chlorophyll a < 20 ug/L
	Total algae count > 20,000 cells /mL, Cyanobacteria counts > 1,000 cells/mL Cyanobacteria – recreational guideline, 50,000 cells/mL
	<10 mm 3L-1 total bio-volume of all cyanobacteria
Maintain water quality to support aquatic biota and normal biogeochemical processes.	pH = 6.5-9
	Basin Plan Target: Maintain dissolved oxygen about 50% saturation throughout water column at all times.

The frequency, extent and duration of watering by operating the SARFIIP measures (With Measure) compared to without development (WOD), baseline (pre-2009 conditions) and Basin Plan (BP-2750 GL) are outlined in Table 2 and 3 and are based on the preliminary operating scenarios presented in Section 11.

It can be seen in Table 2 and 3 that larger areas of the floodplain have the potential to be inundated for longer periods more frequently under without development conditions compared to baseline and Basin Plan conditions. The additional flows provided by the Basin Plan scenarios provide an increase in inundation frequency, but the magnitude of these increases is much less than the overall deficit between Baseline and the Without Development scenarios. The SARFIIP infrastructure measures at the Katarapko and Pike Floodplains will provide more frequent inundation than Basin Plan conditions (Montazeri and McCullough, 2016a; 2016b). For example the Pike floodplain infrastructure can enable inundation equivalent to a flow of 60,000 ML/day compared to a flow of 40,000 ML/day for Basin Plan only.

Table 2: Pike Floodplain: Hydrological analysis of flow rates (ML/d) that meet the average frequency and duration metrics provided by Without Development (WOD), Baseline, Basin Plan-2750GL (SDL adjustment benchmark) and Pike Floodplain Measure (Montazeri and McCullough, 2106a).

Operation (Equivalent Natural flow-ML/d)	Duration at maximum extent	Frequency	Timing	WOD (ML/day)	Baseline (ML/day)	Basin Plan (ML/day)	With Measure (ML/day)	Key Vegetation Objectives
1. Managed Inundation (60 000)	**60 days**	1 in 2 2	August - January	60 000	25 000	40 000	60 000	Maintain a viable River Red Gum population; Maintain a viable Black Box population; Maintain a viable lignum population
2. Managed Inundation (80 000)	**30 days**	1 in 2.8		80000	45 000	55 000	80 000	Maintain a viable River Red Gum population; Maintain a viable Black Box population; Maintain a viable lignum population

Table 3: Katarapko Floodplain: Hydrological analysis of flow rates that meet the average frequency and duration metrics under different scenarios (Montazeri and McCullough, 2016b).

Operation (Equivalent Natural flow-ML/d)	Duration at maximum extent	Frequency	Timing	WOD (ML/day)	Baseline (ML/day)	Basin Plan (ML/day)	With Measure (ML/day)	Key Vegetation Objectives
Low Inundation (55 000)	**60 days**	1 in 2	August - January	55 000	20 000	35 000	55 000	Maintain a viable River Red Gum population; Maintain a viable Black Box population; Maintain a viable lignum population
Max Inundation (70 000)	**60 days**	1 in 3		70 000	35 000	50 000	70 000	Maintain a viable River Red Gum population; Maintain a viable Black Box population; Maintain a viable lignum population

7 Water requirements of floodplain biota

This Section provides an overview of the water requirements that support key groups of floodplain biota and processes for the Pike and Katarapko Floodplains.

Table 4 presents the current knowledge of water regime preferences, including an indication of the ideal timing, frequency, duration and depth of flooding, for floodplain biota, based primarily on the consolidated information provided in published Murray-Darling flow-ecology summaries (Bice et al., 2014; Roberts and Marston, 2011; Rogers and Ralph, 2010), with complementary data provided by other sources (as listed within the table). The information in these sources is intended to apply across the Murray-Darling Basin and focusses on the effects of inundation. In most cases, it does not take into consideration the potential modifying effects and complexity of groundwater interaction. Future work within the SARFIIP project will investigate salinity and groundwater interactions at the floodplain scale. Further details on the water preferences for key groups of floodplain biota for the Pike and Katarapko Floodplains are provided in Denny (in prep-a; in prep-b).

Table 4: Summary of preferred water regime (duration, timing, frequency of inundation) for floodplain biota.

Biotic groups	Timing	Frequency	Duration	Depth	References
River Red Gum forests and woodlands	Spring - Summer	1 in 1 – 3 years	2 months (potentially up to 7 months tolerance)	0.05 – 0.5 m, maximum of 2 m	Rogers and Ralph (2010); Roberts and Marston (2011); Doody et al. (2014)
Black Box woodlands	Spring to Summer	1 in 2 – 10 years	<1 – 8 months	N/A	Rogers and Ralph (2010); Roberts and Marston (2011),
Lignum shrublands	Spring to Summer	1 in 2 - 9 years	<1 – 7 months 2 months for reproduction	<1 metre	Rogers and Ralph (2010); Roberts and Marston (2011); Young et al. (2003); Jensen (2008); Ecological Associates (2010)
River cooba		3–7 years (max interval 7 years)	2–3 months		Roberts and Marston (2011)
Emergent aquatic and littoral zone sedges, rushes and herbs	Any	1 in 1 year for many species, up to 1 in 4 years for drought tolerant species	Range from permanent to months, drawdown often required for germination	Damp soil to shallow inundation (generally up to 0.3 – 0.5 m, 1.5 m for large species such as Typha and Phragmites). Variation in depth.	Nicol (2004); Rogers and Ralph (2010); Roberts and Marston (2011); Bice et al. (2014)
Vegetation (aquatic)		1–1 years	4 months (submergent/ temporary wetlands) to permanent (permanent water)	0.10 to <1m Variation required for submergent species in temporary wetlands	Bice et al. (2014); Wallace (in prep);Rogers and Ralph (2010)
Frogs	spring–summer	1-in-2 years	2–6 months in wetlands		Bice et al. (2014); Ecological Partners (2009); Anstis (2007).
Flow dependent specialist fish	October–end February	~2.5 years (max interval 4 years)	1 month		Bice et al. (2014); Wallace et al. (2014a, 2014b)
Circa-annual spawning nester fish	October–end February	~4 years(max interval 5 years)	1 month		Bloss et al. (2012); Bice et al. (2014), Wallace et al. (2014a, 2014b)
Foraging generalists and wetland/floodplain specialists	Late-spring–early summer	1–2 years (max interval 2 years)	1–12 months in wetlands		Lintermans (2007); Bice et al. (2014) Wallace et al. (2014a, 2014b)
Waterbirds	Variable	1–2 years	4–12 months	Ideal depths vary between species	Rogers and Ralph (2010)

8 Anticipated Ecological Benefits

The proposed works at the Pike and Katarapko Floodplains will increase the frequency of inundation events to promote recruitment, breeding and population development of flora and fauna. They will also support both fast and slow flowing water habitats. SARFIIP as a whole will also coordinate management at the reach and floodplain scales to enable the floodplains to be managed as interconnected units which better mimics a natural river system.

The ecological benefits of improved inundation from SARFIIP infrastructure at the Pike and Katarapko Floodplains, including salinity management measures are presented below along with a description of the high level potential ecological benefits that could be achieved through weir pool manipulation.

8.1 Ecological Responses of Floodplain Biota to delivery of environmental water

A synthesis of the current understanding of ecosystem response to watering in South Australian River Murray (SARM) floodplains (Bice et al., 2015) is outlined below to demonstrate the benefits of increasing the frequency of inundation.

- **Nutrients, carbon, biofilms and microbes:** Inundation of River Red Gum and black box vegetation will contribute significant amounts of carbon (natural organic matte (NOM)) and nutrients to the river. Inundation of the shedding floodplain and wetland basins will increase the surface area available for biofilm growth.
- **Microbiota:** Newly inundated temporary wetlands support quite different microfaunal communities from the main river channel, including organisms imported from upstream and hatched or germinated from the sediments. Inundation of the shedding floodplain will provide further opportunities for microfaunal growth, promoted by increased primary productivity and NOM availability. Lignum inundation provides structurally complex habitats for many microfaunal species.
- **Vegetation:** Vegetation responds indirectly via changes to inundation extent, duration, depth and water regime history. Typically, the greater the discharge, the greater the area of inundation of different vegetation communities and the more habitats available for colonisation. Some species require inundation for germination and growth, others germinate on flood recessions and some produce seed in a canopy seedbank during one flood event, but rely on flooding the following year for seed release and germination (Jensen, 2008). Regular inundation is important for maintaining the seedbank while lateral and longitudinal connectivity is important for dispersal of propagules.
- **Frogs:** Increased areas of inundation, particularly River Red Gum, Black Box and Lignum-dominated vegetation, increase the area of preferred breeding habitat for all species. Frogs and tadpoles strongly associate with vegetation in aquatic zones (DEWNR, 2012; Kilsby and Steggles, 2015). Increased areas of wetland habitat leads to successful recruitment and possibly more than once breeding event. Different species require different conditions. The nationally threatened southern bell frog is the most sensitive of the 11 frog species in the River Murray corridor to frequency, timing, extent and duration of water regime (DEWNR, 2012).
- **Fish:** Riverine fish respond to both high flows and floodplain inundation with the specific response dependent on the guild, and highly dependent on the season, particularly in relation to spawning and recruitment strength. More detail on spawning times of relevant native and non-native fish are presented in Kilsby and Steggles (2015).
- **Water birds:** Temporary inundation of aquatic zones and the shedding floodplain will increase habitat availability and provide wetland-scale breeding opportunities for water birds, providing the duration is long enough (this is species dependent). Inundation of living River Red Gum and Lignum dominated vegetation is important for colonial nesting birds (Ecological Associates, 2010; Kilsby and Steggles, 2015).

- **Other fauna:** Other fauna may not rely directly on inundated areas but on healthy woodlands, and/or the mosaic of aquatic zones within woodland areas. For example, the large-footed myotis bat preys on insects and small fish in still water bodies and shelters in woodland tree hollows. Similarly bats often forage on insects from the riparian zone. The inland carpet python hibernates in tree hollows (particularly Black Box) and preys on frogs and nestling water birds on the fringes of adjacent wetlands. Turtles will also use temporarily inundated wetlands. Feathertail gliders require healthy woodlands with tree hollows and the water rat also uses riparian woodland. Some woodland birds (such as the regent parrot) may be strongly associated with River Red Gum or Black Box.

8.2 Specific Ecological Benefits of SARFIIP at Pike and Katarapko

A number of investigations have occurred for Pike and Katarapko Floodplains to determine the ecological response as a result of managed inundation, including Wallace (2011; 2012) and Denny (in prep-a; in prep-b).

Conceptual models have also been developed for the Pike and Katarapko Floodplain ecological targets and the potential response to the delivery of environmental water (Wallace, in prep). These models will be continually refined as new knowledge becomes available over the coming years as management actions become available and are tested under a wide range of conditions. These will be used to refine the objectives and targets of management.

Based on the assumption that the environmental water requirements (duration and frequency of inundation) of River Red Gum, Black Box and Lignum communities must be met to ensure these vegetation communities are supported (Section 7), as well as an analysis of the areas inundated at different flow scenarios (as presented in Table 2 and 3), the areas of existing vegetation likely to be inundated with the proposed infrastructure on the Pike and Katarapko Floodplains can be interpolated to provide an understanding of the potential ecological benefits.

Pike Floodplain

The works and measures proposed under SARFIIP at Pike Floodplain will allow operators to maintain a more natural pattern of flooding frequency and duration over approximately 1,971 ha of the Pike Floodplain and facilitate the scalable and targeted management of surface water for environmental outcomes, reducing floodplain salinisation and managing short and long term salinity impacts to the River Murray (Ecological Associates and Tonkin Consulting, 2015).

The proposed works will ameliorate the threats that the Pike Floodplain is currently facing and bring benefit by increasing the availability of low-salinity water to the soil zone of floodplain vegetation (Ecological Associates and Tonkin Consulting, 2015). The floodplain will be managed to maintain productive and diverse floodplain vegetation, particularly River Red Gum and Black Box woodlands, Lignum shrublands and Sporobolus grasslands.

Figure 10 and Table 6 provide the inundation extents expected with the proposed SARFIIP works at Pike Floodplain for the existing dominant water dependent vegetation and temporary wetlands. The major water dependent vegetation communities to be inundated include River Red Gum, Black Box and Lignum. Appendix 4 provides the area of water dependent vegetation communities and temporary wetlands inundated at different flow bands (ML/day).

Under Basin Plan 2750 GL conditions, inundation at the desired duration and frequency to enable improved condition and recruitment of existing River Red Gum forest and woodlands, Black Box and Lignum would occur at 40 000 ML/day (Table 2). With the works in place, under managed inundation scenario 1 (Table 2), inundation at the desired duration and frequency would then reach areas equivalent to occur at flows up to 60 000 ML/day. This results in an additional 37% of existing River Red Gum forest and woodlands, 22% of Black Box and 51% of Lignum that would have improved condition and would recruit as a result of the proposed infrastructure.

Under the managed inundation scenario 2 at Pike Floodplain (Table 2), inundation at the desired duration and frequency would then reach areas equivalent to occur at flows up to 80 000 ML/day. This will improve the condition of an additional 58% of existing River Red Gum forest and woodland, 88% of Black Box and 78% of Lignum in comparison to Basin Plan 2750 GL conditions (Table 2).

Improved tree and understorey condition on the floodplain will increase the quality of habitat available to fauna including reptiles, woodland birds and native mammals. Flooding of woodland and lignum vegetation provides nesting habitat for waterbirds and promotes breeding by aquatic fauna including frogs and turtles. When flooded, the vegetation will also provide habitat for small-bodied fish species, and nesting water birds, such as platform-building water birds that nest in flooded lignum. The recession of water from the flood event will be rich in organic matter contributing to the productivity of the wetlands and the main River channel between flood events (Junk et al., 1989).

The proposed water regime enabled through SARFIIP will increase the extent and complexity of riparian vegetation by allowing water levels to be varied on a seasonal and inter-annual basis (Ecological Associates and Tonkin Consulting, 2015). A vegetated, seasonally flooded riparian zone is important to a number of fauna species, including frogs, small-bodied fish species, macroinvertebrates and a range of waterbirds. Flooding and exposure will promote the mineralisation of organic matter and the development of bacteria-dominated biofilms (Ryder, 2004).

Table 6: Area (ha) of dominant water dependent vegetation and temporary wetlands inundated under proposed SARFIIP works at Pike Floodplain.

Dominant Vegetation Type – Water dependent	**Area Inundated under Proposed SARFIIP Works at Pike Floodplain (ha)**
Black Box Woodland	189
Lignum Shrubland	354
Red Gum Forest and Woodland	206
Tea-tree	0.6
Samphire	93
Flood dependent grassland	162
Emergent sedgeland	23
Temporary Wetland	72*

*Note that some of the above vegetation types inundated at different flow thresholds will also be accounted for as temporary wetland area inundated.

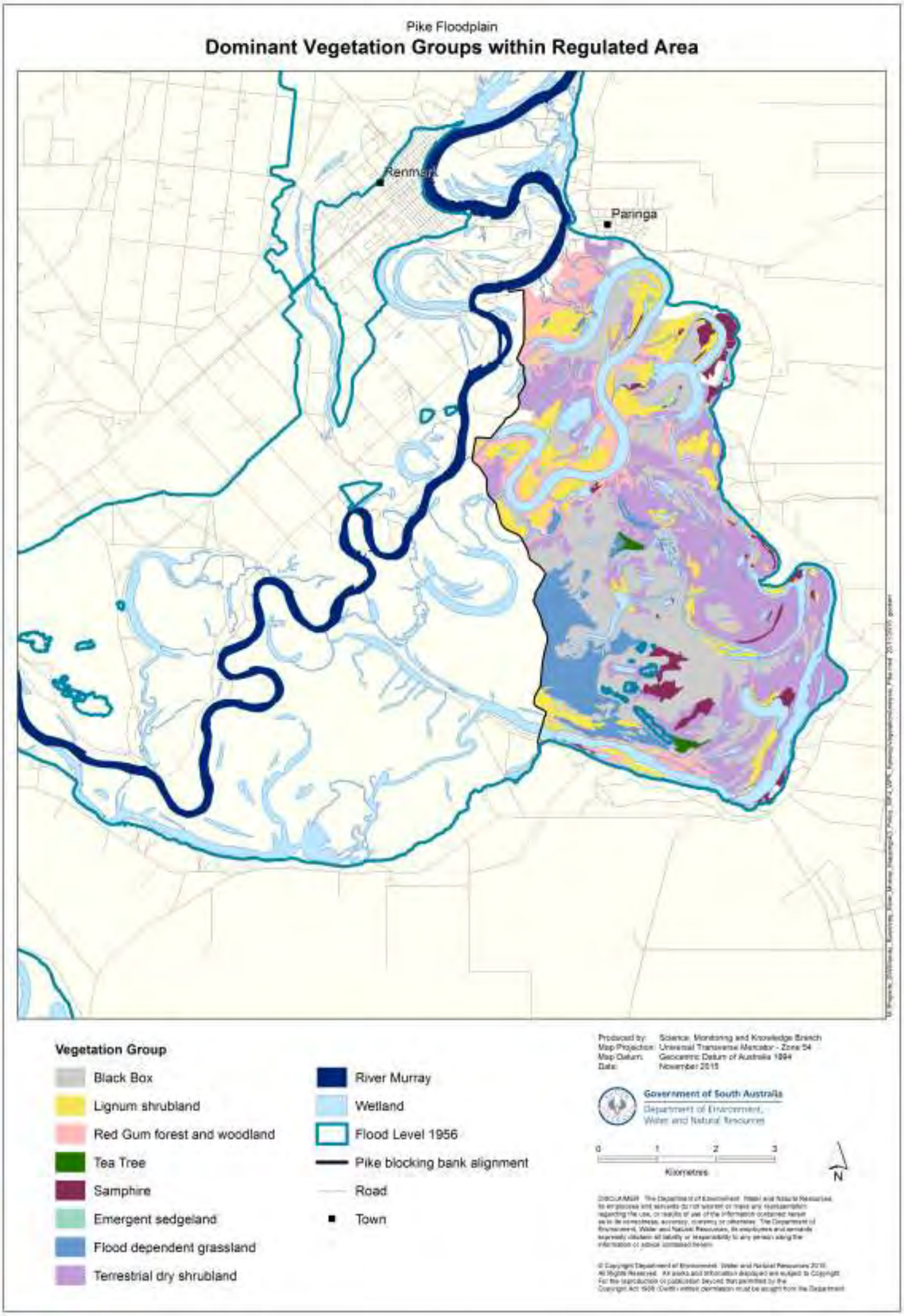


Figure 10: Dominant vegetation types inundated through SARFIIP measures at Pike Floodplain (note: not all of this are will be inundated during an event).

Katarapko Floodplain

The works and measures proposed under SARFIIP will allow a more natural pattern of inundation frequency and duration over approximately 1,300 ha of the Katarapko Floodplain. This natural flooding regime will provide a mosaic of habitats within the anabranch system, providing breeding opportunities for water birds and frogs. Inundation of the floodplain is anticipated to provide some vertical infiltration of low salinity surface water, creating and refreshing freshwater lenses, and improving soil moisture content and reducing soil salinity. An improvement in growth conditions associated with the temporary increase in soil moisture availability for long-lived and floodplain understory vegetation is anticipated.

The operation of environmental regulating structures will utilise the water head differential of up to 3 m around Lock 4 to maintain a number of different environmental habitats using variable flows and water velocities. The ability to maintain these different habitats under a range of flow conditions, particularly low flow conditions improves resilience against periods of extended low flows and droughts into the future.

Figure 11 and Table 7 provide the inundation extents for the dominant water dependent vegetation and temporary wetlands expected with the proposed SARFIIP works at Katarapko Floodplain. The major water dependent vegetation communities to be inundated include Black Box, River Red Gum and Lignum. Appendix 5 provide the area of vegetation communities inundated at different flow bands (ML/day).

Under a low managed inundation scenario at Katarapko Floodplain (Table 3), an additional 46% of existing River Red Gum forest and woodland, 37% of Black Box and 49% of Lignum would be inundated at the desired duration and frequency to enable improved condition and recruitment. This is in comparison to Basin Plan 2750 GL conditions, where only approximately 5% for each of the three dominant vegetation types would receive the desired duration and frequency to enable improved condition and recruitment.

Under the maximum managed inundation scenario (Table 3), an additional 66% of existing River Red Gum forest and woodland, 68% of Black Box and 68% of Lignum would be inundated at the desired duration and frequency to improve condition and allow recruitment (compared to Basin Plan 2750 GL conditions).

Table 7: Area (ha) of dominant water dependent vegetation (water dependent) and temporary wetlands inundated under proposed SARFIIP works at Katarapko Floodplain.

Dominant Vegetation Type – Water dependent	Area Inundated under Proposed SARFIIP Works at Katarapko Floodplain (ha)
Black Box Woodland	266
Lignum Shrubland	369
Cooba	2
Red Gum Forest and Woodland	372
Tea-tree	27
Samphire	141
Flood dependent grassland	95
Emergent sedgeland	26
Temporary Wetland	48*

*Note that some of the above vegetation types inundated at different flow thresholds will also be accounted for as temporary wetland area inundated.

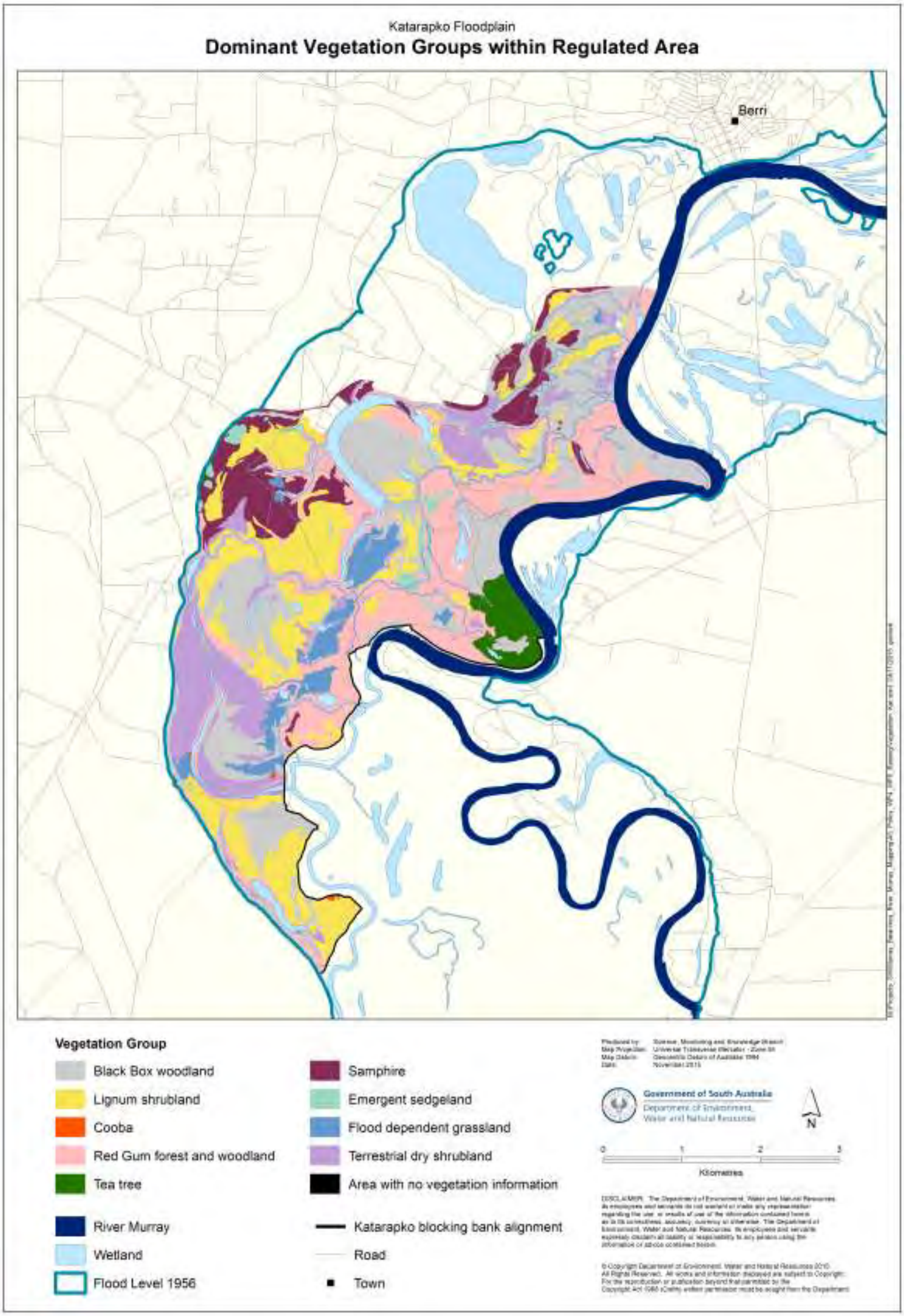


Figure 11: Dominant vegetation types inundated through SARFIIP measures at Katarapko Floodplain.

8.3 Salinity Management

The construction of groundwater management and salt interception infrastructure proposed as part of the salinity management package of SARFIIP will improve the ability to flexibly manage the proposed environmental water regulators to ensure maximum benefit to the floodplain's ecological condition and to downstream ecosystems and to manage any risks. Salinity management also increases the ecological benefit achieved through inundation measures by increasing the area of soil salinity that is within the salinity tolerances of target vegetation.

Results of previous investigations[1] show that when floodplain groundwater is actively managed there are numerous benefits to the establishment and maintenance of freshwater lenses and subsequently to environmental condition. Additionally, the use of groundwater management prepares the floodplain for inundation by creating space in the floodplain soils for freshwater to infiltrate the soils. In turn, this is expected to retard the mobilisation of salt to the river by reducing the 'mobile' load able to be affected by the first flush of inundation, thereby reducing the short term (or real time) salt loads to the river.

By increasing the frequency, duration and extent of inundation events in conjunction with salinity management measures, groundwater quality can be maintained and large freshwater lenses that are the cornerstone of floodplain vegetation survival, can be maintained.

8.4 Weir pool manipulation

Weir manipulation has been shown to benefit the river channel, ephemeral wetlands, anabranch creeks, and low-lying parts of the floodplain (DEWNR, 2012). Weir pools can be managed independent of flow. This means that a weir can be used to inundate the floodplain to a level much higher than would have naturally occurred for a particular level of flow (up to a limit). Weir pool manipulation can achieve a range of benefits (DEWNR, 2012) including:

- enhanced diversity in the riparian vegetation
- creation of small- and medium-scale flooding events in low-lying floodplain habitats
- improve habitat quality and recruitment potential for flow dependent biota, including Murray cod and golden perch
- improved riverine and wetland productivity
- improved hydrological connectivity of the anabranch channels
- promotion of cycling of carbon and nutrients within the river, anabranches, floodplain and wetlands.

The exact response of individual species or ecosystems is difficult to predict, even where significant ecological information exists (e.g. vegetation) due to the number of factors involved (e.g. soil type, bank slope, depth to groundwater etc.) and their interaction. Several different responses could be expected to occur within a given weir pool depending on how these factors interact locally.

Ongoing investigation into the benefits of Weir pool manipulation are being undertaken as part of the Environmental Pathways component of SARFIIP and builds on previous work through RRP which trialed weir pool raising at locks 1, 2 and 5.

[1] A TLM funded trial conducted as part of the Bookpurnong SIS investigations (Berens et al., 2009).

To achieve the full benefits of SARFIIP, locks 4 and 5 will need to be raised in conjunction with the Pike and Katarapko Floodplain infrastructure and will potentially inundate an additional 885 ha and 1,134 ha of floodplain as shown in Appendices 3 and 4, respectively, which show the area of vegetation communities inundated.

8.5 Monitoring and Evaluation Plans

In order to maximise ecological benefit and minimise the potential for adverse effects as assessed and quantified in Section 9, the operation of the inundation infrastructure will be undertaken in an adaptive management approach, whereby there will be the opportunity for continuous improvement in management practices. The adaptive management framework includes a robust monitoring and evaluation program, that not only determines the change of condition of the floodplain, particularly the floodplain vegetation, but also assesses the impacts and benefits of the manufactured flood to floodplain soil condition, groundwater, receiving water in the Murray River and other important biota (Brookes et. al., 2007).

Monitoring and evaluation plans developed in 2012 for the Katarapko and Pike Floodplain, are currently being updated to incorporate the changes and new information requirements associated with operation of the proposed SARFIIP infrastructure. The plans will:

- identify existing monitoring activities
- identify the hierarchical relationship between management and ecological objectives
- further develop and refine the set of ecological targets based on SMART principles
- identify priority targets likely to require monitoring
- operational strategies that outline a strategy for collection of the data required to understand the long and short term biotic and abiotic responses associated with operation of the proposed infrastructure
- responsibilities for the commissioning, reviewing and actioning of monitoring data.

Baseline monitoring data is currently being collected and key knowledge gaps are currently being investigated to inform the construction of infrastructure and development of detailed operation plans for the infrastructure.

Through the Environmental Pathways Package component of SARFIIP, a decision capture, planning and reporting tool known as a Management Action Database (MAD) will be applied. It aims to enhance the capacity for effective monitoring, evaluation and reporting. The MAD enables improved data consistency, data entry coordination and management of current and historical data, through a central data repository about the River Murray in South Australia. It is predominantly a tool for wetland managers and infrastructure operators and with SARFIIP investment will enable more sophisticated and effective adaptive management efforts for Pike and Katarapko floodplains, as well as other sites in South Australia, such as Chowilla.

A monitoring and evaluation plan will also be developed for the salinity element of the program that informs operation of the structures as well as fulfils reporting requirements in relation to Basin Plan and the Murray-Darling Basin Agreement.

9 Potential Adverse Ecological Impacts

Whilst the proposed environmental regulators at both the Pike and Katarapko Floodplains will provide environmental benefits to these floodplains, operation of the environmental regulators would not be without risks that require management.

A risk assessment, presented in Table 8, in line with AS/NZS ISO 31000:2009 standards has been undertaken to assess the risk for adverse ecological impacts to occur, for both project construction and operation at the Pike and Katarapko Floodplains. Further refinement of risk and risk treatments is continuing as part of detailed design and investigations and the development of a detailed operational plan.

Table 8: Ecological Risk Assessment for Pike and Katarapko Floodplains.

Threat	Site	Description	Likelihood	Consequence	Risk without mitigation	Mitigation	Residual risk	Source
Risks pertaining to poor water quality								
Low dissolved oxygen (DO) levels	Pike	Low DO concentrations can occur through a variety of processes, including algal and cyanobacterial blooms, high organic matter loadings (blackwater events) and stratification. Low DO can limit habitat availability or cause the death of aquatic fauna and have negative impacts on the health of wetland communities in general. Note: Risk is higher at Pike than Katarapko due to reduced water exchange capacity at Pike.	Likely	Severe	High	Planning phase: • Risk will be evaluated prior to each floodplain inundation event and be used to inform the operational regime for each event in order to find an appropriate balance between potential benefits and adverse water quality issues transpiring during operation. Risk factors will include organic matter loads, watering history at site, timing of operation and the operational scenario ensuring sufficient water exchange during operations • More frequent inundation (i.e. through managed watering events) will reduce the accumulation of organic matter on the floodplain between inundation events. Therefore, the maximum interval between inundation events should not be exceeded in order to avoid the extensive accumulation of organic matter and hence high carbon loads being mobilised during operation. • Ensure design of regulating infrastructure enables operations to distribute flows via multiple flow paths enabling extensive operational options should an adverse water quality issue be detected during operation. Operation phase: • Ensure managed inundation is undertaken when flows are adequate to manage risk • Maintain appropriate flows throughout the operational regime to provide adequate water exchange. It will be important to maximise water exchange during the operational event to minimise the likelihood of black water events • A range of operating events and variable hydraulic regimes will be used to mitigate negative events and to meet inundation targets (e.g. through-flow scenario). For example, consider commencing operational regime during August when water temperatures are unlikely to be optimal for algal bloom formation.	Moderate	Wallace, 2011
	Katarapko	As above. Note: The risk at Katarapko is considered lower than at Pike due to higher inflows and modelled water exchange percentage.	Possible	Severe	High		Moderate	Wallace, 2012

Threat	Site	Description	Likelihood	Consequence	Risk without mitigation	Mitigation	Residual risk	Source
						• Ensure comprehensive surface water monitoring is employed throughout the anabranch complex to detect the likelihood of adverse water quality issues arising. The data will also inform, in real time, the operational regime and how each of the surface water regulators are operated. • Ensure coordinated river management with other measures along the SA River Murray via the Environmental Pathways Project to ensure benefits are maximised and risks are minimised when operating different sites. Managing consequences: • Localised areas of blackwater may be tolerated. • Abort the Floodplain Inundation Event. Water levels would be lowered at the fastest allowable rate, accompanied by high through-flow to mix and flush anoxic water. • Ensure availability of a contingency flow to manage any negative water quality outcomes. This may be delivered in the form of increased flow to (i) avoid stratification and disperse any undesirable algal blooms, and (ii) decrease the relative proportion of hypoxic water from the floodplain in the river, and thereby increase dissolved oxygen concentrations (Wallace, 2012). Research: • Blackwater risk assessment currently being undertaken to understand the blackwater risk in more detail.		
Poor water quality affecting floodplain ecology	Pike	Water manipulations may lead to suspension of sediments and/or organic matter causing elevated nutrients, high turbidity and/or low dissolved	Possible	Severe	High	As above.	Moderate	Wallace, 2011

Threat	Site	Description	Likelihood	Consequence	Risk without mitigation	Mitigation	Residual risk	Source
	Katarapko	oxygen (DO) levels beyond biologically tolerable thresholds. Note: the risk assessment for low DO water is presented as a separate item above.	Possible	Severe	High		Moderate	Wallace, 2012
Inability to discharge poor quality water	Katarapko and Pike	Inability to discharge water of poor quality during a managed inundation event, due to downstream impacts being considered to be unacceptably high (e.g. increases in instream salinity). This could result in impacts on floodplain vegetation (due to extended inundation) or formation of blackwater /algal blooms and localised concentrations of salt.	Likely	Severe	High	• Continue to undertake water quality monitoring before, during and after watering events to inform adaptive management strategies and real-time operational decision making. • Operate only when flows to South Australia (QSA) are adequate in line with operating strategy (e.g. 15-30GL/day QSA). • Implementation of Environmental Pathways Program (EPP) to optimise coordination of watering at different sites.	Moderate	
Groundwater mobilization across floodplain as a result of changed hydraulic gradients from managed inundation	Pike	An increase in groundwater levels may occur in response to project inundation events. Shallow saline groundwater can impact on the health of floodplain vegetation and wetland communities, and result in an increase in salt load to the river.	Possible	Moderate	Moderate	Design and construction: • Continual investigations during the project design phase such as drilling floodplain bores, monitoring groundwater depths and salinity, and numerical groundwater flow modelling to improve understanding of groundwater system and to estimate the potential response of the groundwater system to managed inundation. • Construction of groundwater management scheme (GMS) infrastructure is proposed to lower groundwater levels locally and to reduce the flux of saline groundwater to the floodplain. • Other salt management e.g. SIS infrastructure will be constructed to reduce salt loads to river with the objective that SARFIIP is salinity neutral. Operation: • Monitor the salinity of ground and surface water salinity before, during and after watering events to inform	Low	Wallace, 2012

Threat	Site	Description	Likelihood	Consequence	Risk without mitigation	Mitigation	Residual risk	Source
						management (including ensuring sufficient volumes are available for mitigating in-river salinity if needed). • Operating to a reduced inundation extent and / or frequency if salinity risks cannot be addressed through other treatments.		
	Katarapko	As above. However, geophysical data suggest that the salinity regime of any mobilised groundwater will be moderate – that is there appear to be neither significant low salinity lenses nor any significant high salinity groundwater zones. However, larger areas of higher value vegetation are present throughout the floodplain.	Possible	Minor to moderate	Moderate	As above	Low	Wallace, 2012
Increased groundwater levels that persist long after the managed inundation event (i.e. permanent changes to groundwater, not temporary changes during and shortly after a managed inundation event).	Pike	Displacement of freshwater lenses where there is high ecological value that currently exists (also known as the fringing vegetation effect). Raised groundwater levels close to the blocking bank. Risk of this identified on the non-inundated side of the blocking banks.	Possible	Moderate	Moderate	Design and construction: • Continual investigations during the project design phase such as drilling floodplain bores, monitoring groundwater depths and salinity, and numerical groundwater flow modelling to improve understanding of freshwater lens extent, distribution and movement to estimate the potential response of any freshwater lenses potentially impacted on through managed inundation. • Construction of groundwater management scheme (GMS) infrastructure is proposed to lower groundwater levels locally and to reduce the flux of saline groundwater to areas where it may have negative impacts on freshwater lenses. • Adjustment of blocking bank alignment if risk remains moderate after investigating other mitigation options. Operation: • Monitor groundwater salinity in areas where freshwater lenses exist, before, during and after watering events to inform management and ensure no permanent degradation of freshwater lenses occurs as a result of managed inundation.	Low	

Threat	Site	Description	Likelihood	Consequence	Risk without mitigation	Mitigation	Residual risk	Source
						• Operating to a reduced inundation height and/or frequency if negative impacts on freshwater lenses are forecast or occur.		
The potential to increase pest species								
Increased pest fish populations (Carp)	Pike and Katarapko	Carp will breed in response to both natural and managed floods. Increased carp populations can threaten the health and diversity of wetland vegetation and water quality, affecting native fish and other aquatic fauna. This has potential impacts both within the project site and at the reach scale.	Certain	Moderate	High	Planning phase: • Management Plans have been developed for Chowilla Floodplain and Pike Floodplain (Stuart and Mallen-Cooper, 2011) and include .options for mitigating regional population impacts • Develop a Katarapko Carp Management Plan building on the Chowilla and Pike Plans. Operation phase: • Minimise the conditions which specifically favour carp over native biota to try and increase the population of native fish in order to manage (through predation and competition) carp populations. • Manage a rapid rate of recession to strand carp on the floodplain as they return to channel habitats from off-stream flood waters slower than many native fish (Jones and Stuart 2009) and often become trapped in these environments. Careful monitoring and management to avoid impacts on native fauna during the operation of a rapid recession rate as per Mallen-Cooper et al. (2011), along with consideration to any increase in bank slump or erosion impacts. Research: • Continue to monitor ecological tradeoffs regarding management of carp and achieving the intended ecological benefits through floodplain inundation measures and adaptive management. • Provide support to broader research initiatives in regard to elimination of carp (e.g. daughterless carp, Koi herpes virus) and continue to support studies to reduce spawning.	Moderate	Wallace, 2012; Jones and Stuart, 2009; Mallen-Cooper et al., 2011.

Threat	Site	Description	Likelihood	Consequence	Risk without mitigation	Mitigation	Residual risk	Source
Proliferation of pest plants	Pike and Katarapko	Pest plants may be promoted under certain water regimes, potentially impacting the health of wetland and floodplain communities. This in turn may impact on dependent fauna.	Likely	Moderate	Moderate	• A targeted baseline assessment of nuisance plants will be undertaken prior to initial operations. • Ongoing monitoring of pest plants. If monitoring detects that pest plant distribution is expanding, a control program specific to the species posing a threat may be implemented. Best practice weed control will be undertaken for localised or monospecific infestations. • Flood areas where pest plants have germinated and provide varying water regimes to favour native species.	Low	Wallace, 2012
Increase in pest animals	Pike and Katarapko	The reinstatement of more frequent flooding regimes is likely to provide and maintain more favorable conditions for many terrestrial animal pests, including goats and rabbits.	Likely	Minor	Low	• Ongoing monitoring of pest populations. • Control pest populations via pest management strategies and park management plans. • Work with the regional NRM Board and park management to support targeted control programs including volunteer programs.	Low	Wallace, 2012
Transport or proliferation of invasive weeds due to construction activity	Pike and Katarapko	Proliferation of weeds may have impacts on the health of wetland and floodplain vegetation communities. This, in turn, may impact on dependent fauna.	Likely	Moderate	Moderate	• Development of Environmental Management Plans for construction (building on those developed as part of RRP) that includes hygiene protocols, enforcement and contractor management responsibilities. • Undertake remediation activities post construction to provide conditions for natural regeneration for native species.	Low	Wallace, 2012
Adverse impacts on ecological function and connectivity								
Not being able to achieve benefits due to compromised existing vegetation condition, diversity and capacity to respond.	Pike and Katarapko	Benefit not achieved as a result of a lack of: • diversity of age class • lack of seedbank • conditions that are conducive to recruitment. Risk that inundation scenarios don't improve age class and demographic diversity of vegetation, therefore not meeting ecological objectives.	Unlikely	Severe	Moderate	• Ecological response associated with managed watering regimes elsewhere in the Basin provide strong evidence that if, through adaptive management, we can closely align the frequency and duration of inundation with the conditions encountered under "natural" conditions, we are likely to see extensive ecological recovery in the areas influenced through managed intervention. Small scale trials undertaken on both floodplains have indicated a positive ecological response is likely to occur once managed inundations have commenced.	Low	Wallace, 2012
Broad scale lack of vegetation response to managed	Pike and Katarapko	There is a risk that vegetation benefits associated with surface water management actions may not be fully	Possible	Severe	High	• Investigations and monitoring are currently underway to identify the most viable suite of complementary groundwater measures to further increase the benefit of improved surface water management.	Moderate	Wallace, 2012

Threat	Site	Description	Likelihood	Consequence	Risk without mitigation	Mitigation	Residual risk	Source
inundation due to soil salinization.		realized due to existing high soil salinity levels not being reduced significantly by inundation or by increased salinization as a result of raised water levels. For example, intended benefits to red gums and black box may not be achieved due to negative salinization impacts.				• Evidence from other site in South Australia has shown the effectiveness of floodplain and highland bores at manipulating the groundwater conditions under vegetation in the vicinity of the bores. Current investigations will allow an optimized borefield to be designed and built to increase the likelihood of persistent ecological response.		
Stranding and isolation of native fish on floodplains	Pike and Katarapko	Stranding can occur through sudden changes in water levels and / or new barriers preventing native fish from escaping drying areas during flood recessions and/or fishways not proposed for some regulating structures. This may result in the death of a portion of the native fish populations.	Possible	Moderate	Moderate	• When draining / drawdown, adhere to an appropriate operating regime and hydrograph to maintain fish passage for as long as possible in line with requirements for the native fish species and to provide cues suitable for these fish. • Analyse the digital elevation model for each floodplain to ascertain how much of the floodplain is likely to pond water or strand fish and adjust management. • Monitor fish movement and adapt operations as required. • Continue to build on knowledge and understanding through current studies relating to fish movement in response to watering and cues.	Low	Wallace, 2012
Barriers to fish and other aquatic fauna movement during managed inundation.	Pike	Installation and operation of regulators in waterways and wetlands create barriers to the movement of fish and other aquatic fauna. This can reduce access to feeding and breeding habitat, and limit migration or spawning opportunities.	Likely	Severe	High	• Regulators on major flow paths will incorporate fishways to facilitate the passage of target species throughout an operational regime. • Design and operation of ancillary structures will enable flood water to enter and exit the floodplain reducing the consequences and likelihood of impact on fish and other aquatic fauna passage/movement. • SARFIIP infrastructure will improve current conditions as currently there are barriers throughout Pike and Katarapko.	Moderate	
	Katarapko		Likely	Severe	High	• Install fishways, baffles and roughened sides based on fish requirements in the system to improve passage for fish through the regulators. • Design and operation of ancillary structures will enable flood water to enter and exit the floodplain reducing the consequences and likelihood of impact on fish and other aquatic fauna passage/movement.	Moderate	

Threat	Site	Description	Likelihood	Consequence	Risk without mitigation	Mitigation	Residual risk	Source
						• SARFIIP infrastructure will improve current conditions as currently there are barriers throughout Pike and Katarapko.		
Barriers to fish and other aquatic fauna during natural floods	Pike and Katarapko	Blocking banks and regulator structures may affect the way water behaves during a natural flood and may present as barriers. Installation of regulators in waterways and wetlands, and blocking bank alignments create barriers to the movement of fish and other aquatic fauna. This can reduce access to feeding and breeding habitat, and limit migration or spawning opportunities.	Likely	Moderate	Moderate	• Ancillary structures will be designed, constructed and operated (e.g. ensure structures are opened) to provide adequate connections and minimise the barriers during natural floods. • Structures will be appropriately sized to prevent high velocity or unsatisfactory turbulence conditions from occurring during natural flood events, which may otherwise have compromised fish passage.	Moderate	Wallace, 2012
Reduction in preferred habitat for large bodied native fish during operation	Pike and Katarapko	Installation of regulators within waterways will affect flows and create lentic zones in regulator pools when in operation. In particular, a managed inundation could reduce or eliminate fast-flowing habitat that is particularly important for some fish species, including the Murray Cod.	Likely	Moderate	Moderate	• Coordinated management between sites to provide a diversity of hydraulic conditions for different fish preferences. • Adaptive management of regulators based on velocity modeling and monitoring to increase habitat (hydraulic) diversity for large-bodied native fish. Fishways will also be established on areas identified as critical habitat for Murray Cod.	Moderate	Bice et al., 2015
Managed inundation regimes do not match water requirements for key species	Pike and Katarapko	The delivery of an inappropriate water regime may occur through: • inadequate knowledge of biotic requirements or conflicting requirements of particular species with broader ecological communities.	Possible	Moderate	Moderate	• Confirm the validity of modelling assumptions pre and during operations to inform future planning and future refinement of the operating arrangements. • Design structures to maximise operational flexibility and control. • Ensure gauges are installed and maintained on/near regulators to measure inflow and outflows to systems. • Operate to target different taxa at different times (e.g. target vegetation one year and fish the next).	Moderate	Wallace, in prep

Threat	Site	Description	Likelihood	Consequence	Risk without mitigation	Mitigation	Residual risk	Source
		• design and construction issues; • invalid modelling assumptions and/or flow measurement; • errors in planning and calculation of the volumes required, or • an inadequate volume allocated to the event. This may lead to adverse ecological outcomes, such as drought-stress of vegetation, loss of seed bank, loss of habitat and limited breeding opportunities for fauna e.g. failure of water bird breeding events, lack of spawning response in fish, spawning response but no recruitment.				• Operating regimes are developed to deliver watering events based on understanding of the key requirements of species/communities. • Assess ecological response during and after managed watering events and adjust operational requirements if required. • Adaptive management and response assessment post watering to constantly improve knowledge on ecological response to watering events. • Update operating strategies to capture new information on the water requirements / response of key species/communities. • Develop and maintain coordinated river management with other water managers including through the Environmental Pathways project.		
Increase in fire frequency, extent and intensity	Pike	The reinstatement of more frequent flooding regimes may increase the biomass of floodplain vegetation, increasing the fuel load for bushfires. An increase in the frequency, extent and duration of bushfire could have impacts on ecosystem form and function. Note: Risk is considered to be less than at Katarapko due to lower fuel load and recreational users (e.g. campers with campfires).	Unlikely	Severe	Moderate	• Fire management plans in place	Moderate	

Threat	Site	Description	Likelihood	Consequence	Risk without mitigation	Mitigation	Residual risk	Source
	Katarapko	As above. Note: Risk is considered to be higher than at Pike due to increased fuel load, increased number of recreational users and therefore increased likelihood of fire occurring.	Possible	Severe	High	• Visitor management (education and awareness) and fire restrictions in place. • Fire management plans in place.	High	
Geomorphology changes	Pike and Katarapko	High velocity flows can cause bank erosion and excessive bed scour and channel incision. Low velocity generates depositional zones and high rates of sedimentation on floodplains. Fast drawdown rates upon recession could lead to mass bank failure (Wallace, 2012).	Possible	Moderate	Moderate	Planning phase: • Prior to initial operations, the outputs from the hydraulic models will be used to determine maximum operating ranges for flows to ensure thresholds are not exceeded. • The geomorphological, soil and vegetation characteristics of areas that have been identified as having a moderate to high risk of erosion potential (Burnell et al., 2012) will be assessed in more detail in conjunction with closer analysis of the hydraulic modelling. This will inform detailed operating plans. • A field visit to the areas identified as at moderate to high risk will be conducted so that the stream characteristics on a site by site scale can be assessed. Operations phase: • Gauging of flows will be undertaken at a range of sites during initial operations to ensure velocity and shear stress thresholds are not exceeded. • Routine assessments of geomorphology will be undertaken using standard methods within the monitoring program. • Rates of recession will be carefully managed to avoid bank failure and maximise outcomes for birds, fish and vegetation. For example applying maximum recommended draw-down rates (Gippel et al., 2008).	Very low	Burnell et al., 2012; Gippel et al., 2008; Wallace, 2012

Qualitative measures of likelihood

Level	Descriptor	Description	Probability
1	**Rare**	The event may only occur in exceptional circumstances.	less than 2% chance of occurrence
2	**Unlikely**	The event could occur at some time.	between 3% to 10% chance of occurrence
3	**Possible**	The event might occur at some time.	between 11% to 64% chance of occurrence
4	**Likely**	The event will probably occur in most circumstances.	between 65% to 94% chance of occurrence
5	**Certain**	The event is expected to occur in most circumstances.	greater than 95% chance of occurrence

Qualitative measures of consequences (impact)

Level	Descriptor	Description
1	**Minor**	The effects are limited in extent or duration and do not significantly impact on the site values
2	**Moderate**	The effects are moderate in extent or duration and are in conflict with site values or will have minor impacts on offsite values
3	**Severe**	The event significantly undermines sites values or moderately impacts on offsite values
4	**Catastrophic**	The event is in significant conflict with the site values or servery impacts offsite values and will result in a serious deterioration of the system

ISO Risk Matrix

	Consequences			
Likelihood	**Minor**	**Moderate**	**Severe**	**Catastrophic**
Rare	1	2	3	4
Unlikely	2	4	6	8
Possible	3	6	9	12
Likely	4	8	12	16
Certain	5	10	15	20

Definitions of the levels of risk

	Scores	Risk	Definitions
Risk	1-2	Very Low	There is no reasonable prospect the project objectives will be affected by the event
	3-4	Low	The event is a low priority for management but risk management measures should be considered
	5-8	Moderate	The risk is a moderate priority for management. Risk management measures should be undertaken
	9-12	High	The risk is a high priority for management. There is a reasonable likelihood it will occur and will have harmful consequences. Risk management is essential.
	15-20	Very High	The risk is a very high priority for management. It is likely to occur and will have very harmful consequences. Risk management is essential.

10 Hydrology

Hydraulic modelling has been undertaken to understand the historical and current hydrological regime, and to assess the hydrological changes proposed under a range of managed operational scenarios within the Pike and Katarapko floodplains. The numerical hydrodynamic models were originally produced and calibrated by Water Technology using the MIKE FLOOD modelling platform that combines the dynamic coupling of the one-dimensional MIKE 11 river model and MIKE 21 two dimensional model system. Details of the original MIKE FLOOD model configuration are presented in Water Technology (2009; 2010). The MIKE FLOOD model was further refined and re-calibrated in 2013 for Pike (McCullough, 2013) and 2014 for Katarapko (McCullough, 2014) and again in 2015 (McCullough, in prep-a; in prep-b) to address the updates implemented by DEWNR. Refer to McCullough (2015) for details (including modelling assumptions, calibration and validation results) of the most recently calibrated MIKE FLOOD model which was used as a basis in this investigation.

In assessment of the hydrology at the sites, various scenarios were considered including the following which are relevant to this submission as outlined in Montazeri and McCullough (2016a; 2016b):

- **Without Development Condition / Natural**

  Floodplain conditions that are as near to natural conditions as possible and depict a flow regime based on MDBA without development model run that excludes diversions and river infrastructure such as storages.

- **Baseline Condition / Current flow regime**

  Existing floodplain condition (structures, locks and operating rules) with flow regimes representing pre Basin Plan river development (representative of 2009 conditions).

- **Basin Plan- 2750 GL Condition**

  Existing floodplain condition (structures, locks and operating rules) with a flow regime based on a water recovery of 2750 GL under the Basin Plan.

10.1 Current River Hydrology

The flow regime of the South Australian River Murray (SARM) displays strong inter-year flow variability (Walker and Thoms, 1993). This variability has shaped the life-history characteristics of many of the native biota. Peak seasonal flows occur in spring. This was true of the historic natural regime, and the peak remains, although much reduced, as part of the present regime (Kilsby and Steggles, 2015).

River regulation, including the operation of weirs and barrages and the extraction of water for irrigation, stock and domestic use, has profoundly changed the flow regime of the Murray (Kilsby and Steggles, 2015; Leblanc et al., 2012; Maheshwari et al., 1995; Walker and Thoms, 1993). One of the greatest impacts has been on the frequency and duration of mid-sized floods. For example, a discharge of 60,000 ML/day for 30 days formerly had a without development Average Return Interval (ARI) of 1 in 1.9 years, but this has reduced to 1 in 6.7 years (current condition i.e. pre-Basin Plan level) (Kilsby and Steggles, 2015). Similarly, a discharge of 80,000 ML/dayfor 30 days has reduced from an ARI of 1 in 4 years to 1 in 14.3 years. The same trend is highlighted by the average monthly flows where the magnitude of the spring pulse has more than halved. The altered flow regime has reduced the frequency and extent of watering events for biota on the floodplain, affecting the condition, recruitment and demography of many species (e.g. Walker, 2006). Table 9 further demonstrates the changes in frequency of inundation for different durations under without development and current conditions.

Table 9: Frequency of inundation for 30, 60 and 90 day flood events under current and without development condition scenarios.

Flow, ML/day	Annual exceedence probability					
	30 days		60 days		90 days	
	Without Development	Basline/ Current	Without Development	Basline/ Current	Without Development	Basline/ Current
25,000	1 in 1.1 (91%)	1 in 1.7 (58%)	1 in 1.14 (87%)	1 in 2.1 (47%)	1 in 1.17 (85%)	1 in 2.6 (38%)
40,000	1 in 1.2 (79%)	1 in 2.7 (37%)	1 in 1.36 (73%)	1 in 3.3 (30%)	1 in 1.63 (61%)	1 in 4.3 (23%)
60,000	1 in 1.8 (54%)	1 in 4.7 (21%)	1 in 2.2 (45%)	1 in 7.1 (14%)	1 in 2.9 (34%)	1 in 16.6 (6%)
80,000	1 in 2.8 (35%)	1 in 9 (11%)	1 in 5 (20%)	1 in 14.2 (7%)	1 in 12.5 (8%)	1 in 25 (4%)

10.2 Current Pike Floodplain Hydrology

The Pike River anabranch extends over 6 700 ha of River Murray floodplain between Paringa and Lyrup Village (Ecological Associates and AWE, 2008). It is a complex system of creeks, backwaters and lagoons and the system can be broadly divided into the Upper Pike River and Mundic Creek area which extends from the inlets from the River Murray to the Col Col embankment and the Lower Pike River and Rumpagunyah Creek area extending from the Col Col embankment to the downstream confluence of the River Murray and the Pike River (Figure 12).

Flow permanently enters the Pike anabranch complex upstream of Lock 5 through Margaret Dowling Creek and Deep Creek. Water then discharges into Mundic Creek where the majority of flow would have naturally entered Tanyaca Creek at a range of locations (existing locations of Banks E, D, F and F1). Other permanent flow paths result in flow leaving Mundic Creek and entering Snake Creek and Pike River. Crude earthen and rock embankments (Bank E, D, F and F1) were constructed shortly after Locks 4 and 5 which currently prevent water from flowing into Tanyaca Creek from Mundic Creek. Water is instead diverted into the Pike River via two outlets (Mundic Creek southern and northern outlets). Similar embankments also restrict flow entering Snake Creek (Banks H and G, the former has since been removed).

Snake Creek re-enters Pike River upstream of Col Col. Col Col is another earthen embankment which also features a sluiced pipe culvert and a rock spill way. Col Col and the other earthen embankment further upstream act to keep water levels artificially elevated (14.35m AHD upstream of Col Col and 14.75m AHD upstream of the Mundic Creek embankments). This retains a mid-pool water level between Locks 4 and 5 (~2m less than Lock 5 and ~1m greater than Lock 4).

Flow enters downstream of Lock 5 via a range of locations, such as Banks B, B2 and C, when flow to SA (QSA) exceeds 35,000ML/day; Swift Creek and Wood Duck Creek when QSA exceeds 15,000ML/day, Rumpagunyah Creek is permanently connected but can act as either an inlet or outlet depending on QSA and operation of Lock 4; and Letton's flood-runner which commences to flow at approximately 35,000ML/day QSA.

Banks B, B2 and C flow into Mundic Creek. Swift Creek and Wood Duck Creek flow into Tanyaca Creek. Tanyaca Creek flows into Rumpagunyah Creek. Rumpagunyah Creek typically (at flows >2,000ML/day QSA and "normal" Lock 4 pool) flows into the Lower Pike River. Letton's Floodrunner flows into Lower Pike River. Lower Pike River flows into the River Murray at Lyrup.

Due to the close proximity of Deep Creek and Margaret Dowling Creek to Lock 5, raising Lock 5 has only a marginal influence on flows into these Creeks. Conversely, raising Lock 4 has a significant influence on flows entering the Pike anabranch complex from downstream of Mundic Creek, with Swift Creek, Wood Duck Creek, Rumpagunyah Creek in particular providing significant additional flow during elevated flows to SA or elevated Lock 4 pool levels.

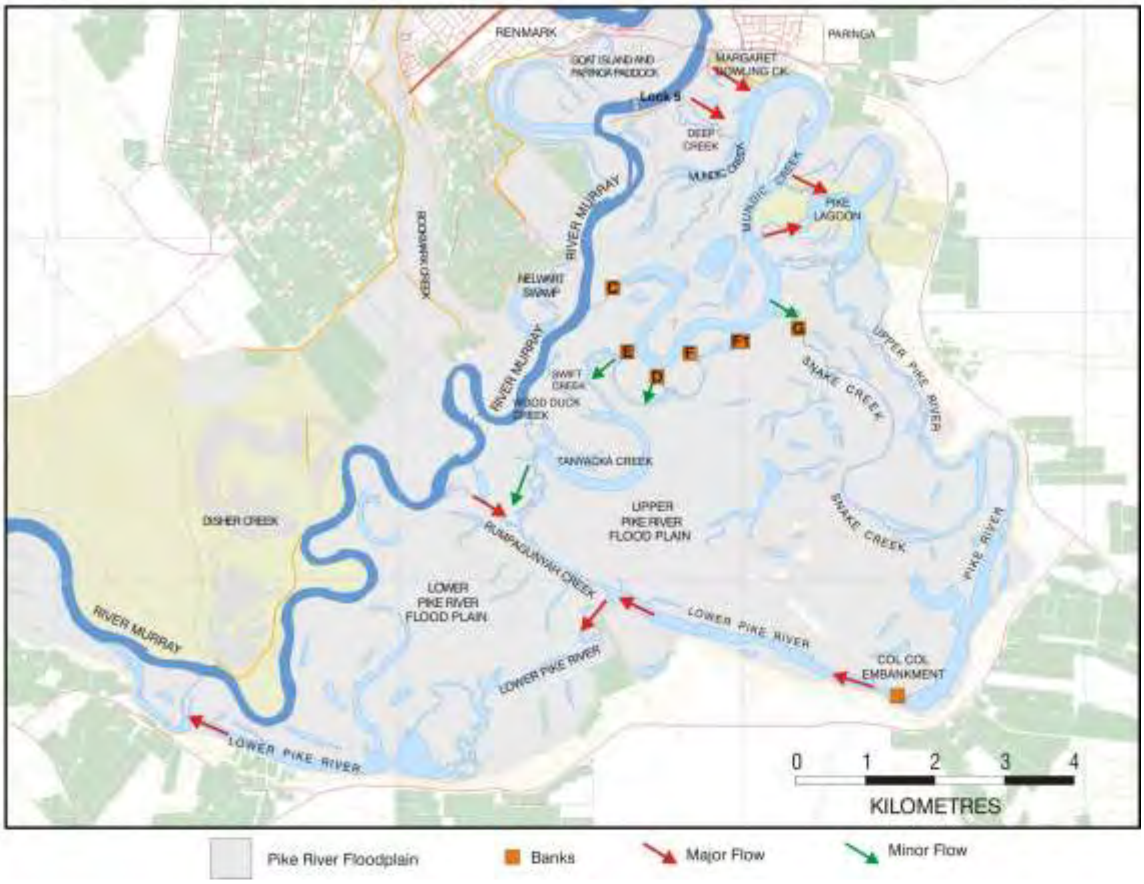


Figure 12: Pike floodplain location plan

As indicated in Table 9, under without development conditions flow was highly variable and frequently reached levels which inundate the floodplain. River flow exceeded 30,000 ML/d almost every year for durations of six months, and events of 70,000 ML/d occurred in 50% of years for durations of 3.6 months. Events of 120,000 ML/d, which would inundate most of the Pike River floodplain including Black Box woodlands, occurred on average one year in four for durations of 2.2 months (Hollis et al., 2010).

River regulation and diversions have severely reduced the frequency and duration of peaks in river flow. The frequency of flow peaks between 20,000 and 40,000 ML/d have been reduced by approximately 50% while the duration of these events has been reduced by approximately 30%. Higher flow peaks (100,000 ML/day events) have even greater reductions with the frequency of events reduced by approximately 70%. The duration of these events has been reduced by one third. The change in hydrology has resulted in extensive ecological impacts over time.

The construction of Lock 5 near the upstream end of the Pike floodplain has resulted in permanently higher water levels on the adjacent floodplain area, higher groundwater levels, and the continuous flows of water through the Pike anabranch system. A 3m head now drives flow through the anabranch. Water levels in the lower section of the Pike anabranch are also maintained by the presence of Lock 4 further downstream.

Inundation frequency mapping illustrates that larger areas of the Pike floodplain were inundated for longer periods more regularly under Without Development conditions, compared to BP 2750 GL conditions. The modelling reveals that river flows less than 10 000 ML/d are still received almost as frequently now and under proposed Basin Plan scenarios compared with the natural scenarios. Flow bands from 15 000 to 65 000 ML/d under Basin Plan scenarios have the potential to be significantly improved over the Current condition, however these scenarios still fall a long way short of the Without Development conditions. This indicates that additional flows delivered to the Murray-Darling Basin through the Basin Plan alone cannot be expected to optimise ecological benefits without additional measures being implemented, such as those being proposed under SARFIIP.

Figure 13 and 14 show inundation extents under Without Development and BP2750 GL for 30 day duration. Refer to Montazeri and McCullough (2016a) for figures for 60 and 90 day durations.

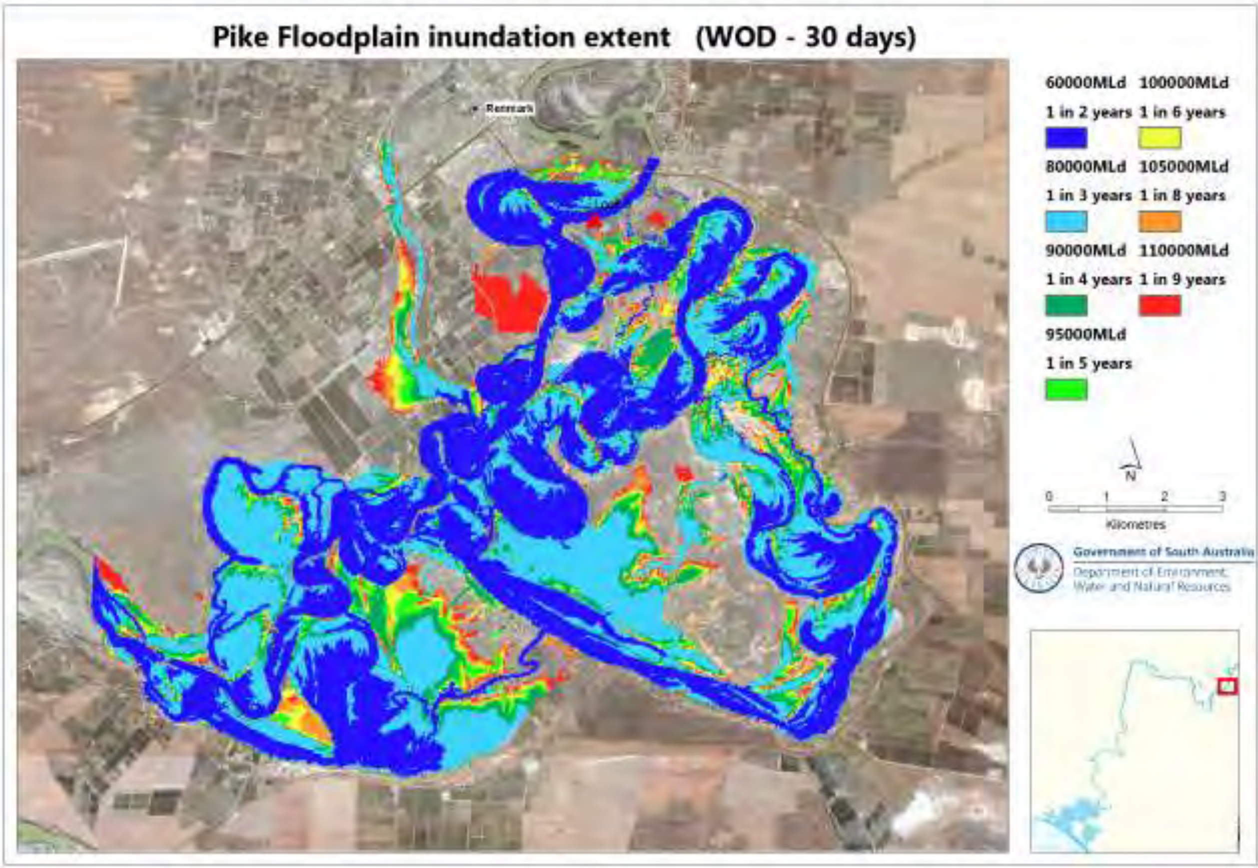


Figure 13: Pike Floodplain inundation extent under Without Development conditions for a 30 day duration (Montazeri and McCullough, 2016a).

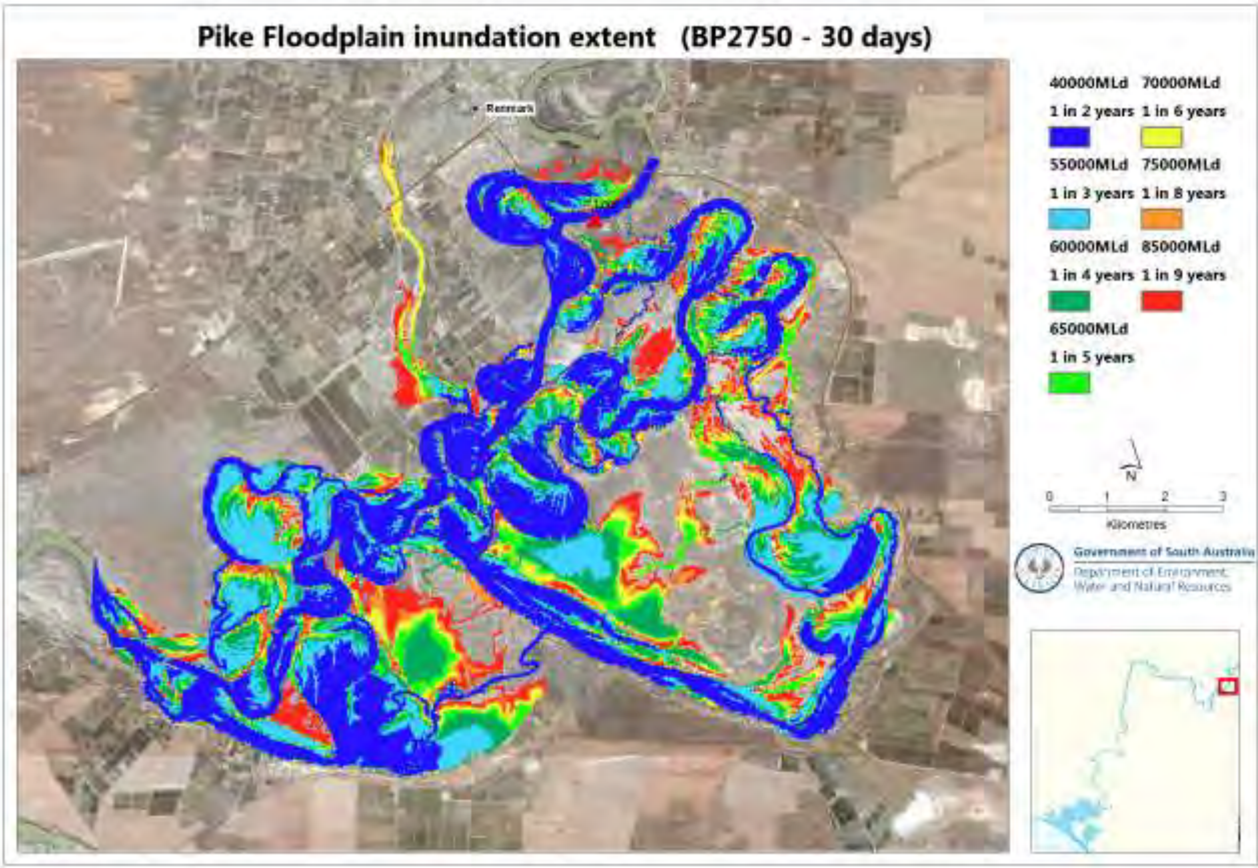


Figure 14: Pike Floodplain inundation extent under BP 2750 GL conditions for a 30 day duration (Montazeri and McCullough, in 2016a).

10.3 Proposed Changes Pike Floodplain

Infrastructure proposed under SARFIIP at Pike Floodplain aims to achieve a flooding regime that is more closely aligned with what was achieved under Without Development conditions and to greatly enhance the environmental outcomes with less water.

Through the proposed SARFIIP works at Pike Floodplain, inundation extents of approximately 1,971 ha that would have been achieved through river flows of 80,000 ML/d under Without Development conditions, will be able to be achieved with river flows of only 10,000 ML/d. Figures 15 – 17 illustrate the inundation extents possible with SARFIIP with river flows of 10,000 ML/d for durations of 30, 60 and 90 day floods respectively and under Without Development and BP 2750 GL conditions.

Further information showing the current and proposed hydrology including modelling assumptions and calibration details are provided in McCullough et al. (in prep-a).

The water balance for operation at the site is highly dependent on the operation, including the duration of filling, holding and draining periods as well as the height that the environmental regulator is operated to, the maximum inundation extent, and the time of year. As an example, for a 120 day duration event and with the Pike environmental regulators being operated to 16.4 m AHD and the raising of Lock 5 to 16.8 m AHD, the volume of water consumed through seepage and evapotranspiration during (or following) operation of the regulator has been calculated at 16.6 GL (McCullough et al., in prep-a).

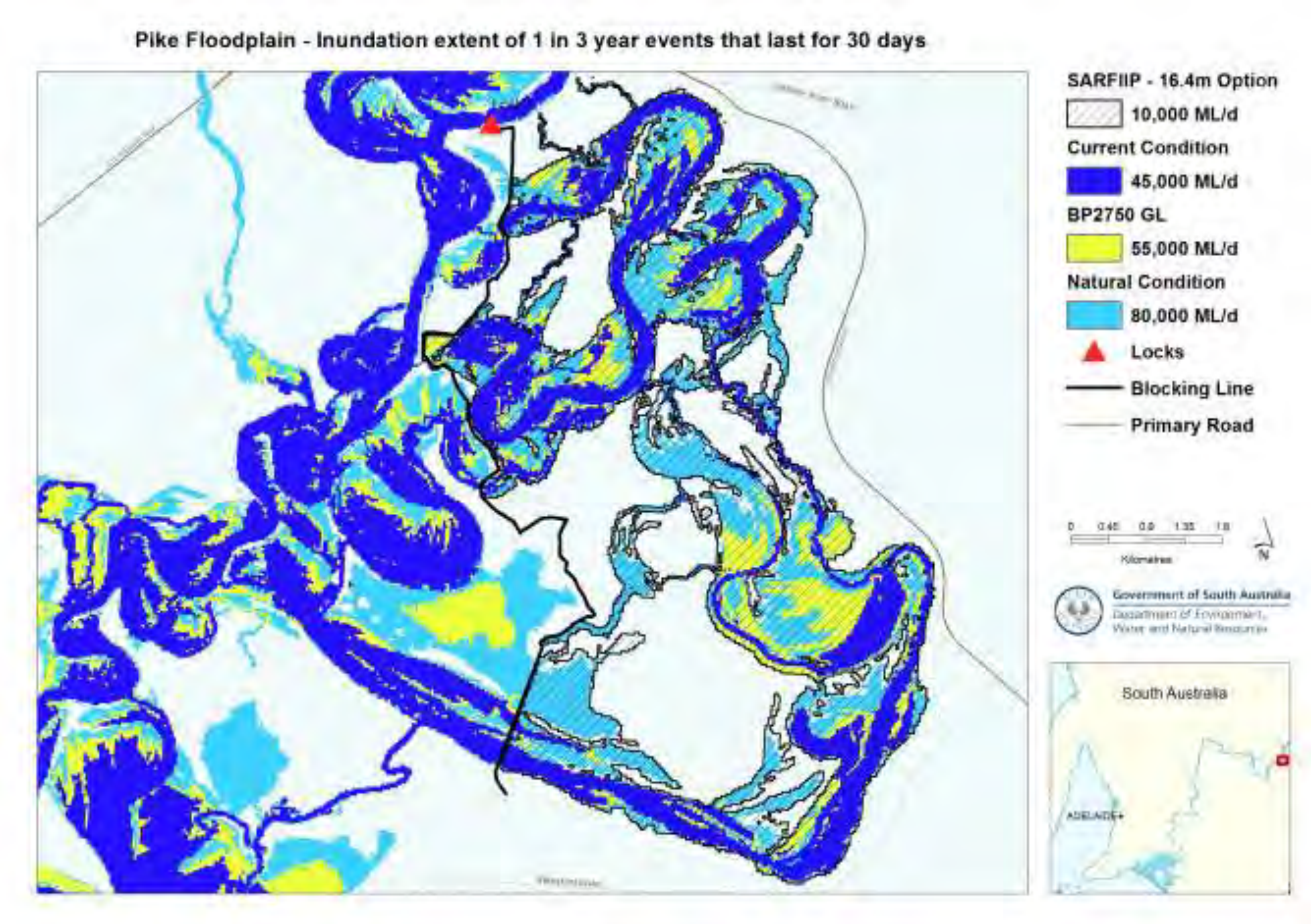


Figure 15: Pike Floodplain inundation extent of 1 in 3 year events that last for 30 days achieved under 10 000 ML/d with - managed inundation and corresponding extents achieved under Without Development, Baseline/Current and Basin Plan 2750GL conditions.

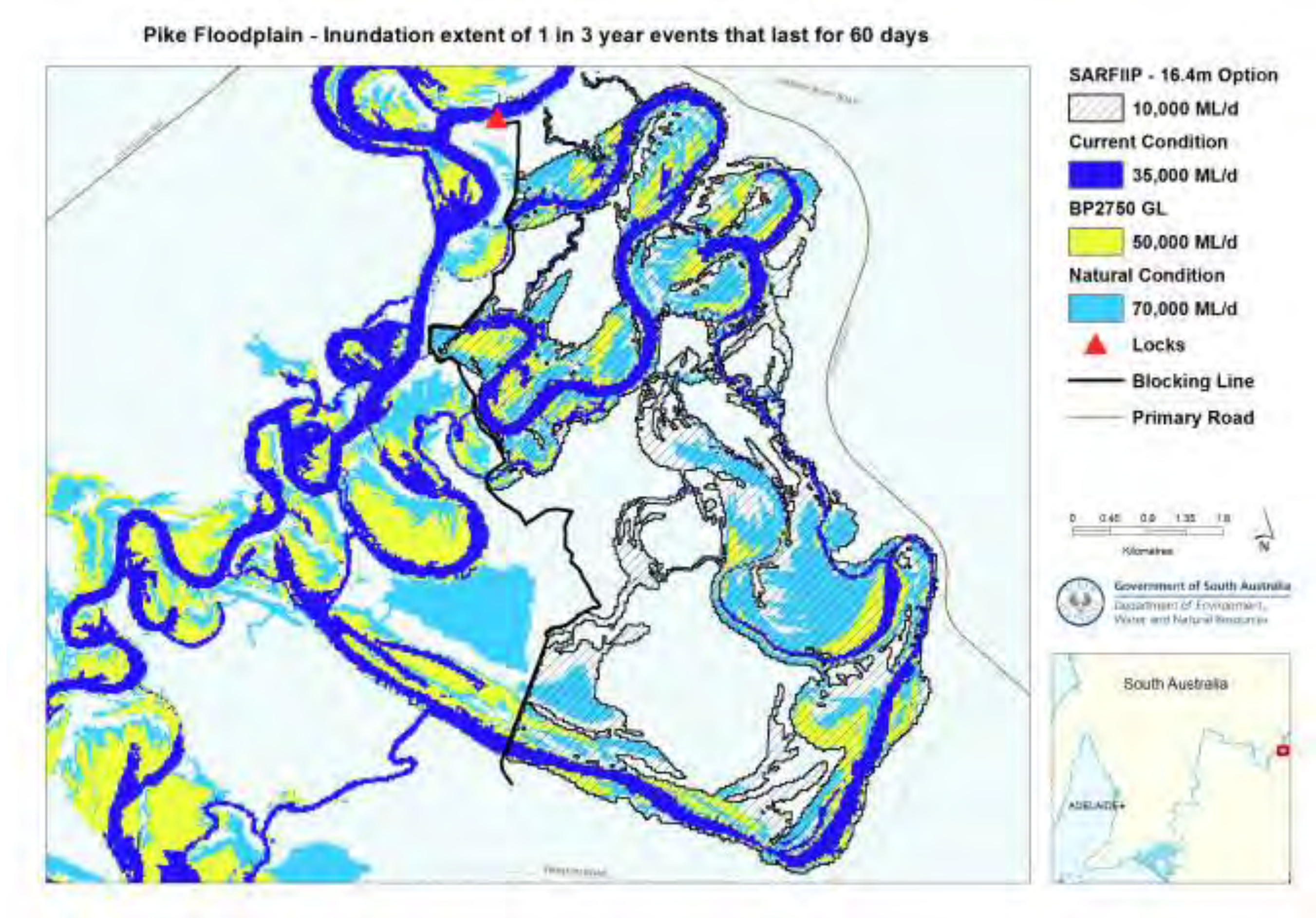


Figure 16: Pike Floodplain inundation extent of 1 in 3 year events that last for 60 days achieved under 10 000 ML/d with - managed inundation and corresponding extents achieved under Without Development, Baseline/Current and Basin Plan 2750GL conditions.

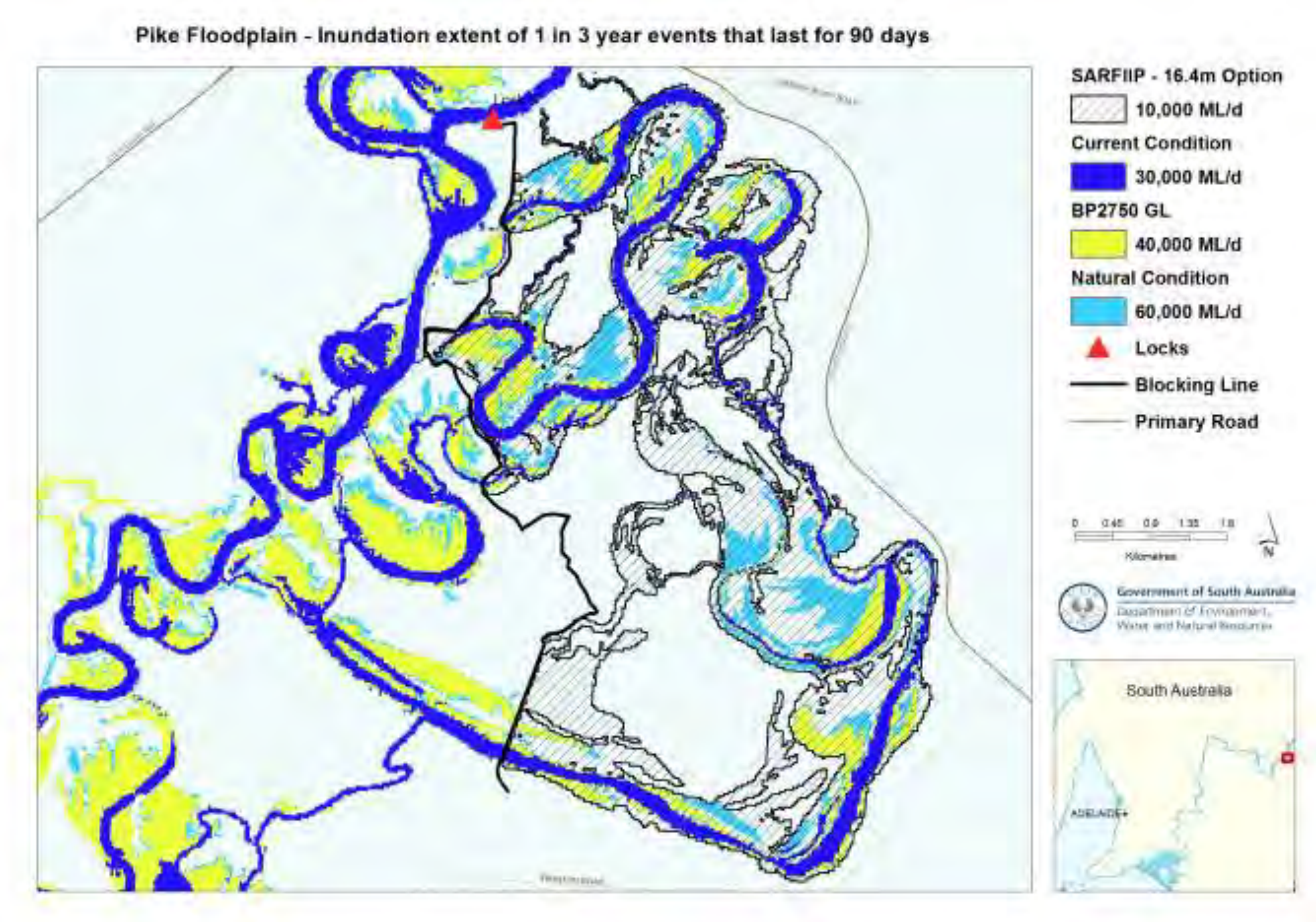


Figure 17: Pike Floodplain inundation extent of 1 in 3 year events that last for 90 days achieved under 10 000 ML/d with -managed inundation and corresponding extents achieved under Without Development and Baseline-BP 2750GL conditions.

10.4 Current Katarapko Floodplain Hydrology

The Eckert Creek system receives water directly from the River above Lock 4 at pool level through the Northern Arm and main Eckert Creeks. Katarapko Creek receives water directly from the River Murray below Lock 4 and from Sawmill Creek and The Splash. Below the mouth of Sawmill Creek there is a stone weir across Katarapko Creek to limit flows through the waterway. The hydrological structures on both Eckert and Katarapko Creeks significantly restrict flows down both Eckert and Katarapko Creeks. The main Eckert Creek inlet structure (Bank J is estimated to overtop at above 45,000 ML/d). The main Katarapko Stone Weir starts to be overtopped at flows above 8,000 ML/d and is completely inundated at approximately 13,000 ML/d river flows (Wallace, 2012).

Figure 18 illustrates the main creeks and structures on the Katarapko Floodplain.

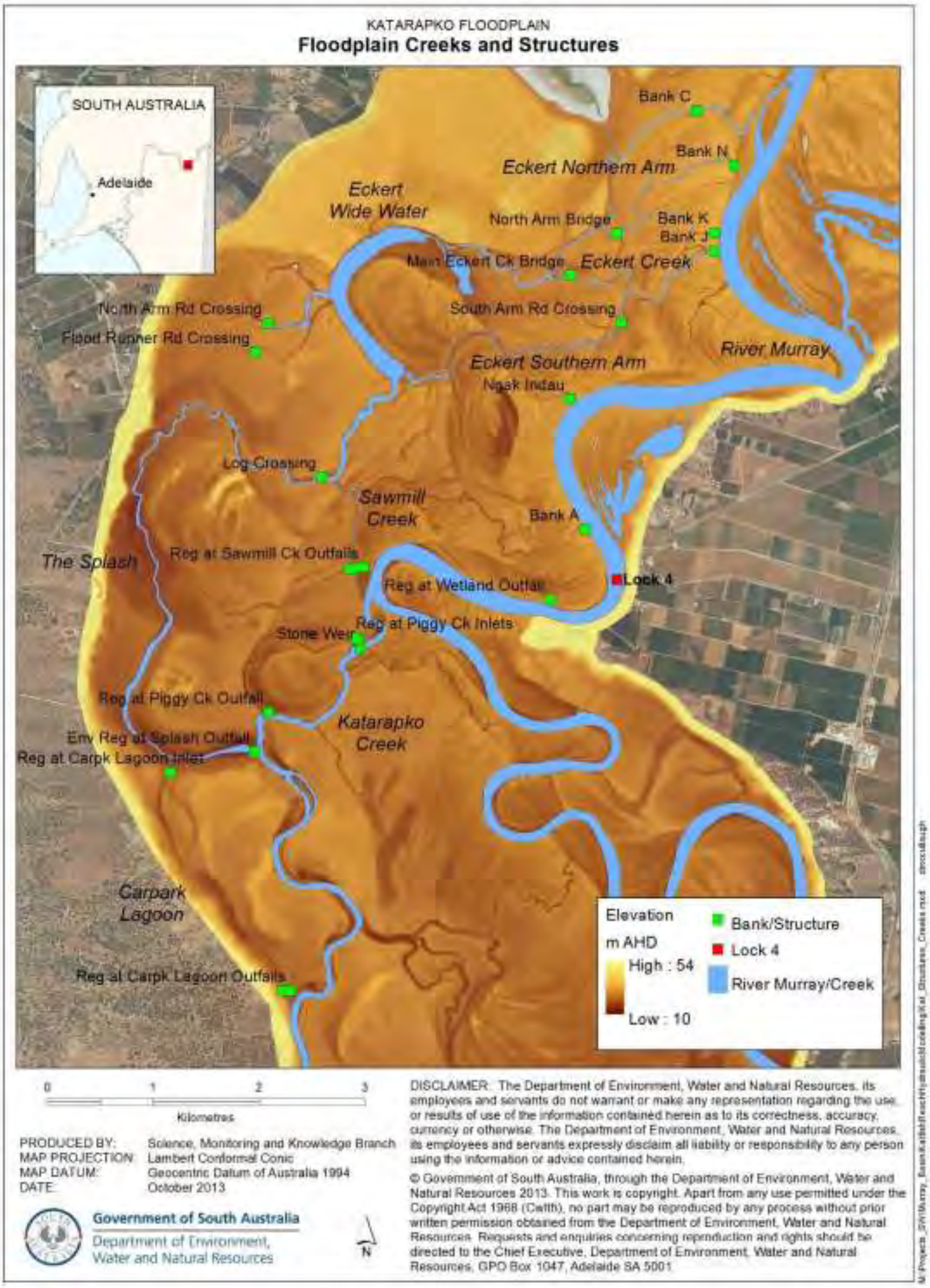


Figure 18: Katfish Floodplain location plan (McCullough et al., in prep-b).

At low River flows, the hydrology of the Katarapko Floodplain is governed by the operation of Locks 3 and 4. These maintain elevated pools in the River Murray and permanent water in the main anabranch creeks (Katarapko and Eckert) and wetlands (Eckert Creek Wide Waters). When River flows are in the range of 15,000 – 60,000 ML/d, flows from the river are directed into the main basin area through Bank C and then flow through into Eckert Creek through Bank B to attain some measure of flushing of salt from the system (Woods et al., in prep).

When River flows reach approximately 60,000 ML/d large areas of the floodplain become inundated (Woods et al., in prep) and there is large scale lateral connectivity with the floodplain. At flows of 60,000 ML/d a large percentage of temporary wetlands and large areas of floodplain shrubland and open plain become inundated.

As previously indicated in Table 9, the frequency of inundation of the floodplain for a given flow is significantly reduced under Baseline/Current condition compared to Without Development conditions. Inundation frequency mapping for the Katarapko Floodplain (Montazeri and McCullough, 2016 b), reveals that under Without Development conditions, larger areas of the floodplain were inundated for longer periods more regularly compared to Current conditions and Basin Plan-2750 GL. For example, 1,724 ha of the Katarapko floodplain was inundated once every three years for 30 days (80,000 ML/d flow) under Without Development conditions, whereas under BP-2750 GL conditions 767 ha was inundated at this frequency and duration (55,000 ML/d flow) (Montazeri and McCullough, 2016 b). This is illustrated in Figure 19 and 20 with similar outcomes for flood durations of 60 and 90 days and frequencies up to a 10 year recurrence interval. Infrastructure works will increase the area that can be inundated at the required frequency and duration compared to Basin Plan-2750 GL conditions alone.

10.5 Proposed Changes at Katarapko Floodplain

Works proposed at Katarapko Floodplain as part of SARFIIP aim to achieve a flooding regime that is more closely aligned with what was achieved under Without Development conditions (natural) with less water.

According to McCullough et al. (in prep-b) for a design blocking bank height of 13.9 m AHD:

- Operation of SARFIIP at Katarapko under the Low-floodplain Managed Inundation scenario which is designed to inundate 445 ha (equivalent to inundation achieved under Without Development river flows of between 50,000 and 60,000 ML/d) can be achieved with River flows of between 10,000 and 20,000 ML/d.
- Operation of SARFIIP at Katarapko under the Maximum-floodplain Managed Inundation scenario which is designed to inundate approximately 1,331 ha (equivalent to inundation achieved under Without Development river flows of between 60 000 and 75 000 ML/d) can be achieved with River flows of between 10 000 and 20 000 ML/d.

As one example, Figure illustrate the inundation extents possible with SARFIIP at Katarapko Floodplain with River flows of 10,000 ML/d for durations of 30, 60 and 90 day floods respectively and under Without Development, Current (Baseline 2009) and BP-2750 GL conditions.

The water balance for operation at the site is highly dependent on the operation, including the duration of filling, holding and draining periods, the maximum inundation extent, and the time of year. The approximate volume of water consumed for operation under Low-floodplain and Mid-floodplain Managed Inundation scenarios (refer Section 11 Operating regime) is 1.8 and 3.6 GL respectively.

Further information showing the current and proposed hydrology including modelling assumptions and calibration details are provided in McCullough et al. (in prep-b).

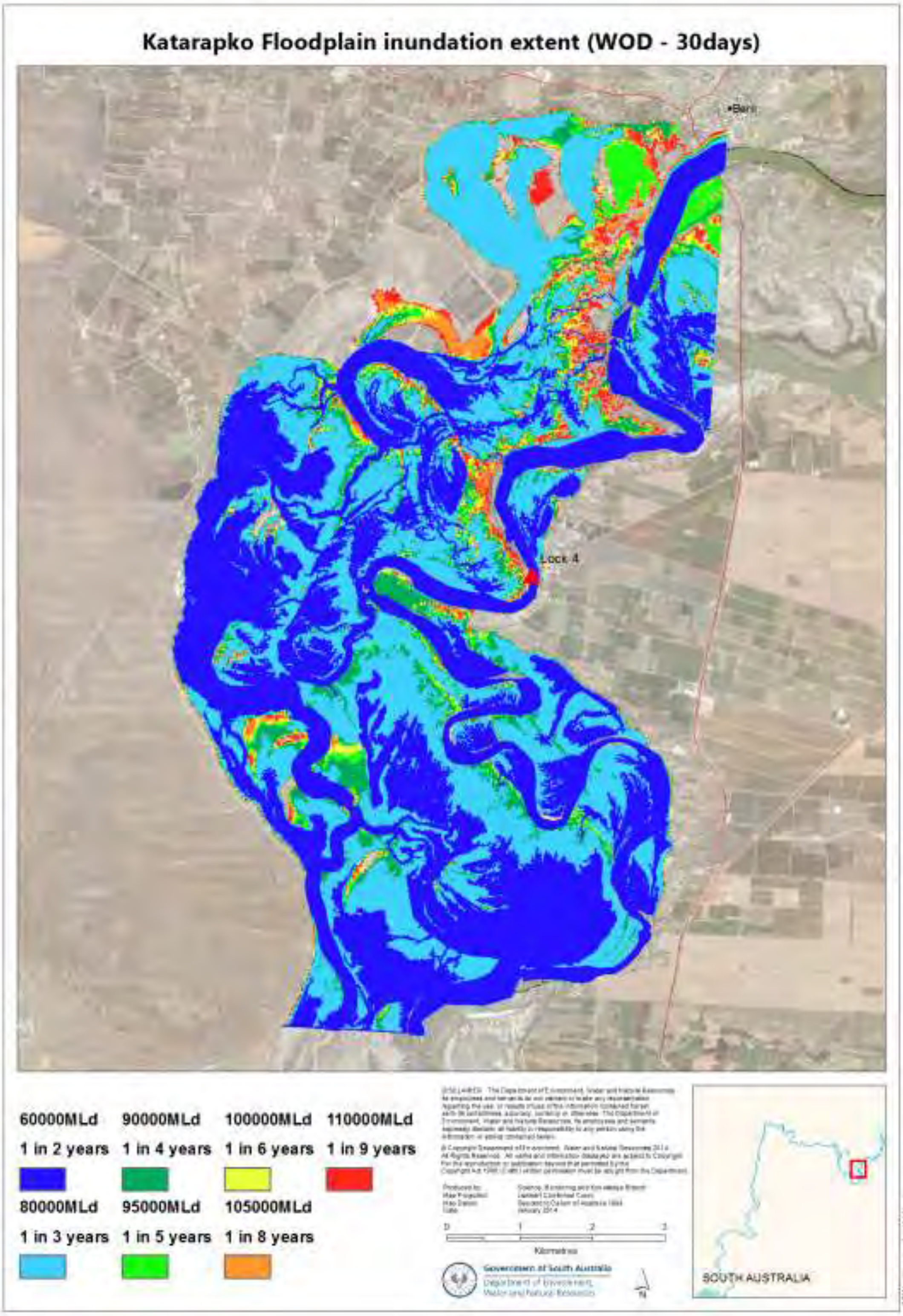


Figure 19: Katarapko Floodplain inundation extent under Without Development conditions for a 30 day duration (Montazeri and McCullough, 2016b).

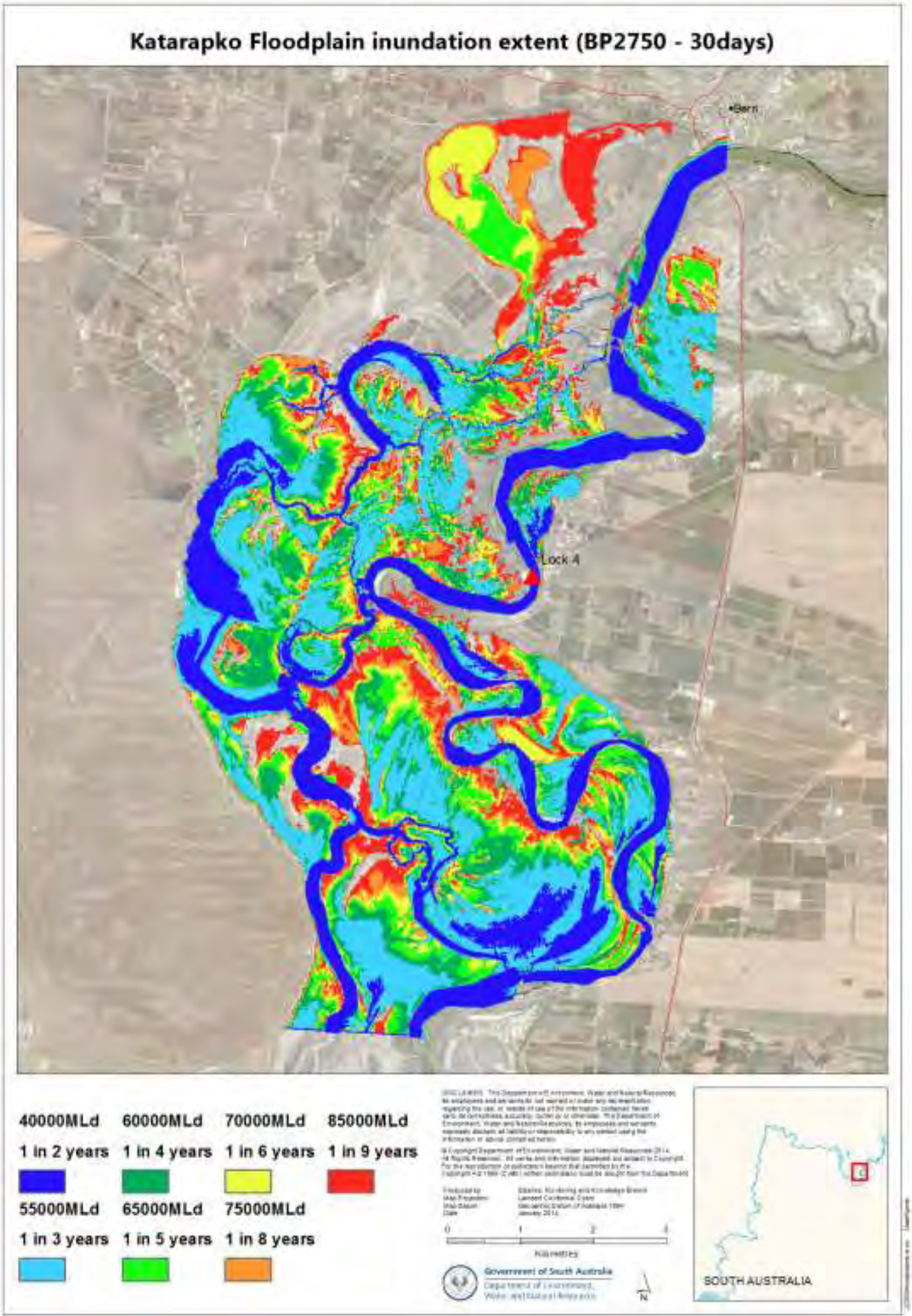


Figure 20: Katarapko Floodplain inundation extent under Baseline-2750GL conditions for a 30 day duration (Montazeri and McCullough, 2016 b).

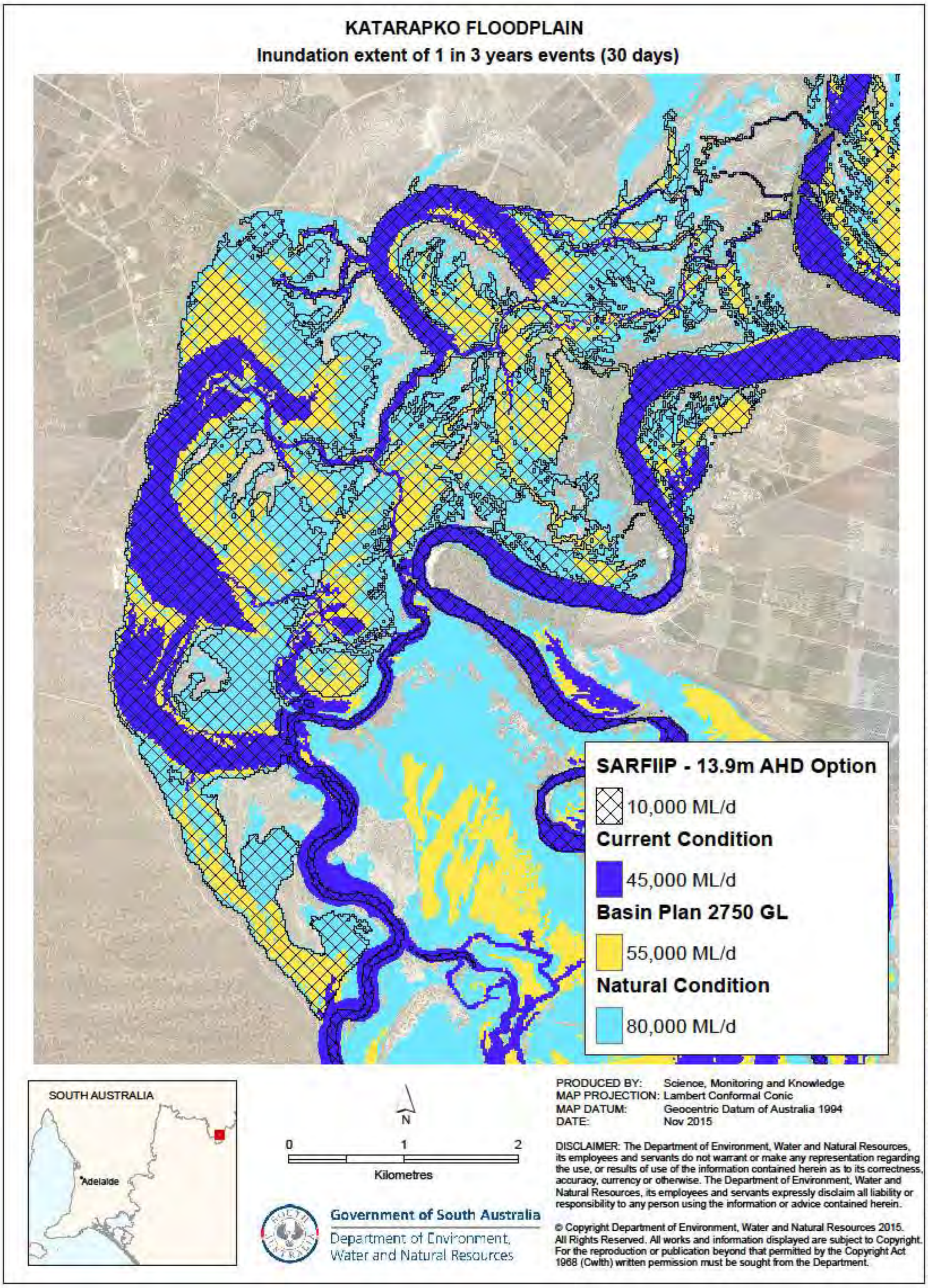


Figure 21: Katarapko Floodplain inundation extent of 1 in 3 year events that last for 30 days achieved under 10 000 ML/d with -managed inundation and corresponding extents achieved under Natural (WOD), Baseline and Basin Plan 2750GL conditions.

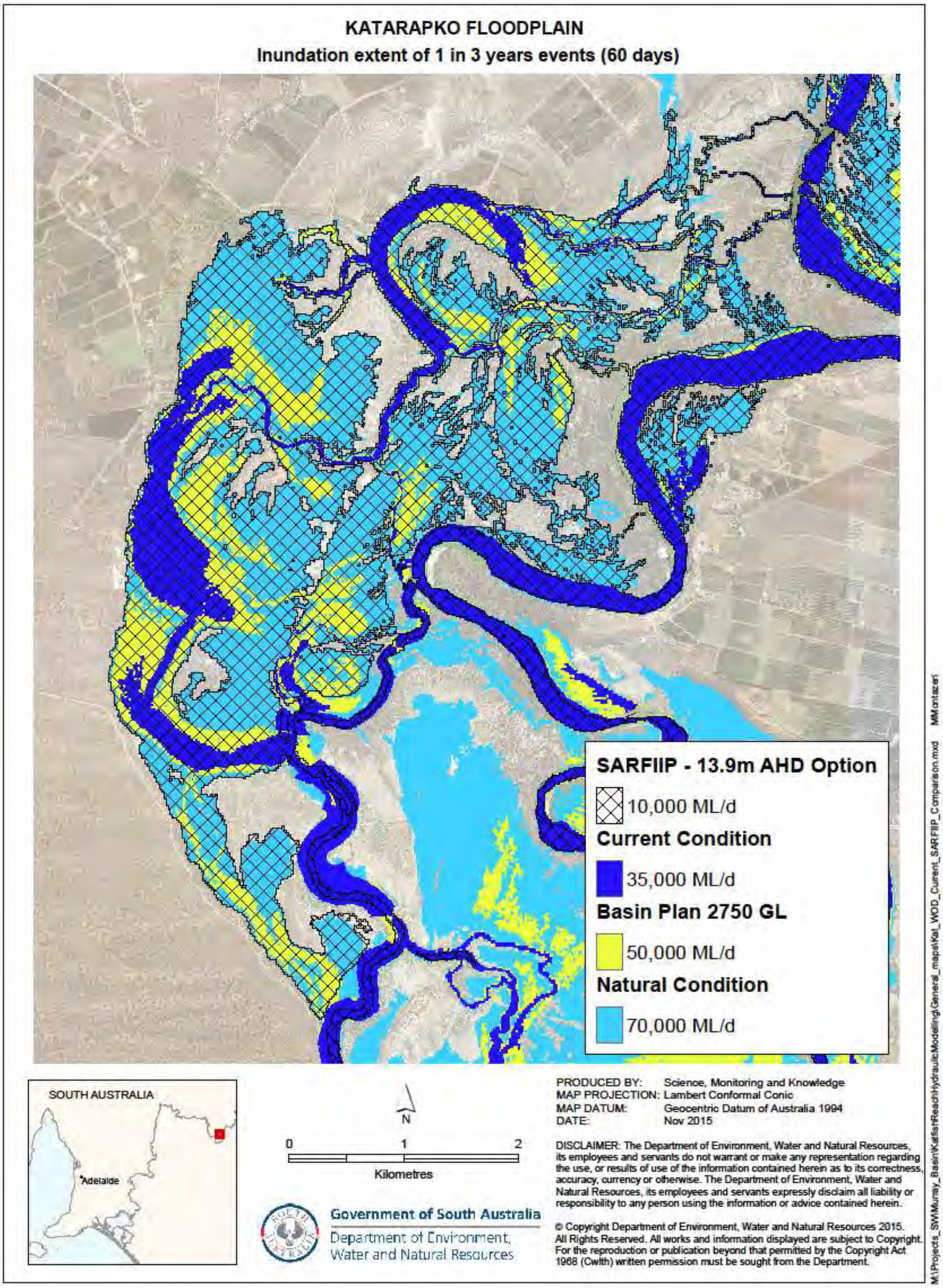


Figure 22: Katarapko Floodplain inundation extent of 1 in 3 year events that last for 60 days achieved under 10 000 ML/d with -managed inundation and corresponding extents achieved under Natural (WOD), Current (Baseline) and Basin Plan 2750GL conditions.

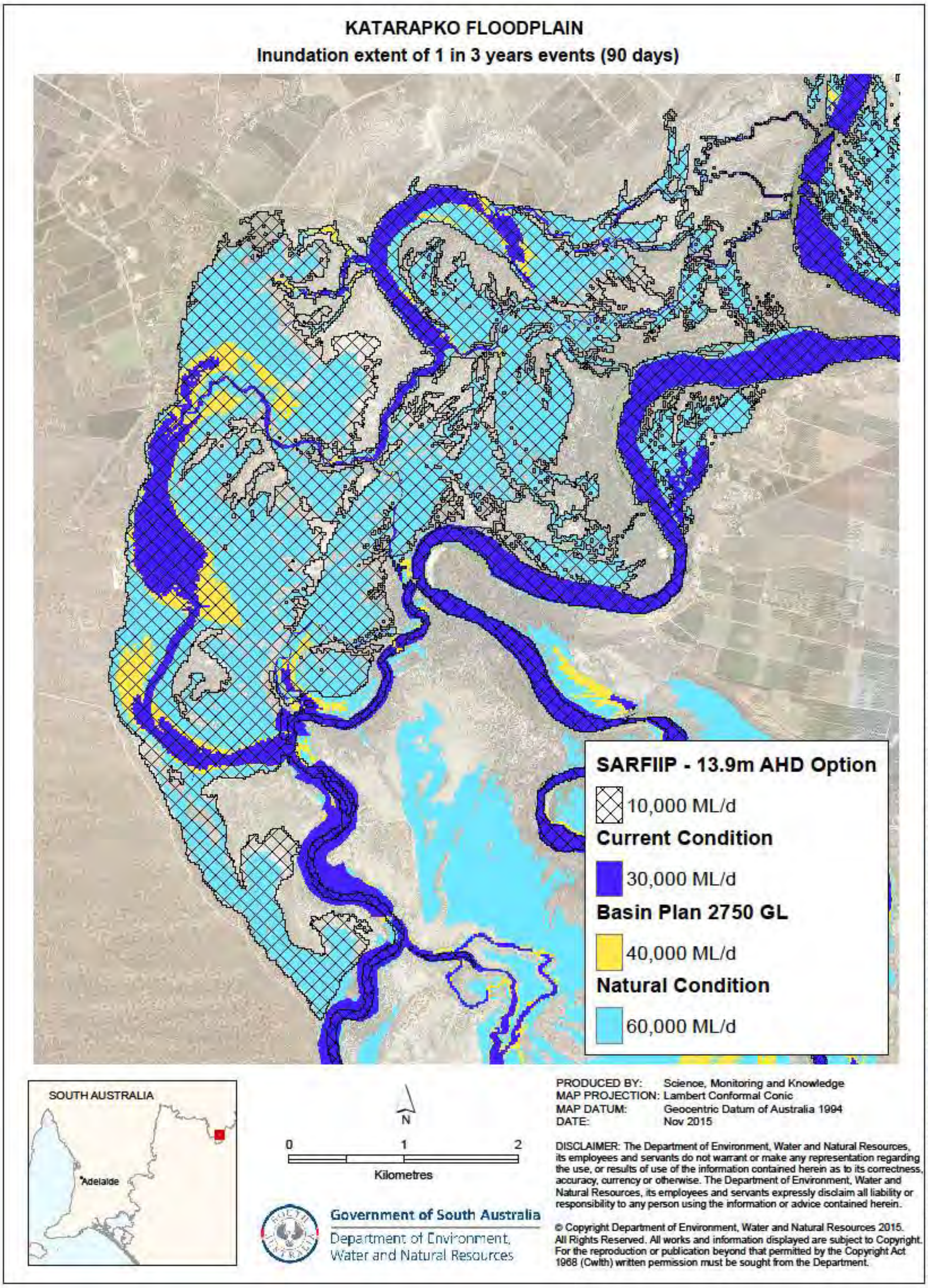


Figure 23: Katarapko Floodplain inundation extent of 1 in 3 year events that last for 90 days achieved under 10 000 ML/d with -managed inundation and corresponding extents achieved under Natural (WOD), Current (Baseline) and Basin Plan 2750GL conditions.

11 Operating Regime

An overview of the proposed operating scenarios for Pike and Katarapko are provided below. In order to maximise ecological benefit and minimise the potential for adverse effects, the operation of the regulators will be undertaken in an adaptive management framework, which includes a robust monitoring program, that not just determines the change of condition of the floodplain, particularly the floodplain vegetation, but also assesses the impacts and benefits of the manufactured flood to floodplain soil condition, groundwater, receiving water in the Murray River and other important biota (Brookes et. al., 2007).

All operating scenarios for Pike and Katarapko are presented, as outcomes beyond those resulting from increased inundation alone, are objectives of the project (for example, improving in-channel hydraulic diversity). However, for the purposes of the SDL adjustment Ecological Elements scoring method, the Managed Floodplain Inundation scenarios are most relevant.

The flow settings presented here have been determined through preliminary hydraulic modelling. They are indicative of the flows required to achieve habitat outcomes but are not necessarily optimal. Further hydraulic modelling and field trials are required to determine the optimum system settings in each scenario.

The supply of water to users is maintained for both managed inundation scenarios presented at Pike and Katarakpo.

Pike Floodplain

Six operating scenarios have been developed to guide how the Pike Floodplain infrastructure will be operated to meet the targeted habitat outcomes as outlined in this section. The scenarios describe operations under all river flow conditions including regulated flows and flood flows and have been developed taking into account the need to manage ecological risks identified for algae, blackwater, fish and pest species.

For all scenarios, a minimum level is maintained in Mundic Creek of 14.75 m AHD upstream of the Tanyaca Creek environmental regulator and 14.35mAHD upstream of the Pike River environmental regulator. For all operational scenarios, at least 400ML/day is required to flow into the upper Pike River from Mundic Creek in order to meet the needs of existing water users.

Additional work remains to be done in further developing the operating regime for the Pike environmental regulators. Operation will be determined by the antecedent conditions, prevailing inflows, the ecological requirements of the floodplain and the level of risk. Above entitlement flows (>10,000 ML/d QSA) will provide optimal conditions for regulator operation, making it possible to gain maximum ecological benefit whilst minimising ecological risk.

The proposed operating scenarios at Pike are summarised below.

1. **Baseflow Scenario:**

   The overall objective is to maintain water supply, permanent aquatic habitat and perennial fast-flowing habitat. Fast-flowing habitat will be provided in Deep Creek, Margaret Dowling Creek, Tanyaca Creek and Mundic Creek Primary Outlet. The existing extent of the Pike-Mundic waterbody will be maintained and structures will be operated to distribute water throughout the system to maintain water quality and habitat connectivity.

Operational Objective	Base Flow
Description	Default when other regimes aren't operating
Suggested flow band for operation	Entitlement - 35,000ML/d
Timing	Late summer, autumn and early winter
Frequency	Most years depending on seasonal requirements
Action required	400ML/day flowing into Deep Creek and Margaret Dowling Creek 400ML/day flowing via the Mundic outlets into Pike River 400ML/day flowing into Tanyaca Creek
Operating Range of structures	Pike River Regulator to 14.35 mAHD Tanyaca Creek Regulator to 14.75 mAHD

2. **Spring Fresh:**

   The overall objective of the Spring Fresh Scenario is to meet the seasonal growth and breeding requirements of aquatic biota by achieving inundation of the Mundic floodplain up to 15.3mAHD. This scenario involves raising water levels in Mundic Creek to inundate littoral habitat and connected wetlands. Discharge will be increased in Tanyaca Creek, Margaret Dowling Creek and Deep Creek to increase the extent and depth of flowing habitat and to increase the inundation of riparian vegetation and woody debris. This scenario will achieve some additional inundation and therefore is relevant for the purposes of SDL Adjustment purposes at Pike.

Operational Objective	Spring Fresh
Description	Meet seasonal growth and breeding requirements of aquatic biota
Suggested flow band for operation	Entitlement - 35,000ML/d
Timing	Between August and January for between two and five months (minimum duration of one month)
Frequency	Annually
Action required	600ML/day flowing into Deep Creek and Margaret Dowling Creek 700ML/day flowing via the Mundic outlets into Pike River 400ML/day flowing into Tanyaca Creek 100ML/day being impounded on the Mundic floodplain
Operating Range of structures	Up to 15.30mAHD upstream of Mundic outlets 14.85mAHD upstream of Pike River regulator Up to 15.30mAHD upstream of Tanyaca Creek regulator

3. **Managed Inundation:**

The overall objective of the Floodplain Managed Inundation scenario (two potential scenarios as presented below) is to improve the productivity and habitat value of floodplain vegetation and to support major breeding events for aquatic fauna and water birds. This regime involves inundation of 30% of the Pike floodplain up to 16.4 m AHD whenever ecologically required and is the regime most relevant for the purposes of SDL Adjustment purposes at Pike.

Operational Objective	Managed Inundation
Description	Improve the productivity and habitat value of floodplain vegetation. Support major breeding events for aquatic fauna water birds.
Suggested flow band for operation	15,000 – 35,000 ML/d
Timing	Between August and January for two to five months (minimum one month duration)
Frequency	One in three years
Action required	600ML/day flowing into Deep Creek and Margaret Dowling Creek 400ML/day flowing via the Mundic outlets into Pike River 800ML/day flowing into Tanyaca Creek
Operating Range of structures	Up to 16.4 mAHD upstream of Pike River Regulator Up to 16.4 mAHD upstream of Tanyaca Creek Regulator Up to 16.8 mAHD at weir pool 5

4. **River Through-flow**:

The overall objective of the River Through-flow scenario is to replicate the conditions of a fresh in the River Murray where elevated flows inundate riparian habitat, channel velocities increase and aquatic habitats become connected to allow for the dispersal of aquatic biota and the redistribution of organic matter. When river levels permit, regulators will be opened to allow the exchange of water between Mundic Creek and the river and the free movement of aquatic fauna. It is expected that the flow of water in floodplain watercourses and possibly chemical signals in river water may promote the dispersal and migration of aquatic fauna, particularly fish, turtles and large macro invertebrates such as shrimp and so these events will provide an opportunity for floodplain fauna to disperse to the river.

Operational Objective	River Through-flow
Description	Replicate the conditions of a fresh in the River Murray
Suggested flow band for operation	35,000-90,000ML/d OR QSA>35,000ML/d
Timing	When River levels permit
Frequency	When River levels permit
Action required	Banks B, B2 and C fully open 600ML/day flowing into Deep Creek and Margaret Dowling Creek 400ML/day flowing via the Mundic outlets into Pike River Remaining flow entering Tanyaca Creek Remaining flow entering Tanyaca Creek
Operating Range of structures	>14.35mAHD upstream of Pike River regulator >14.75mAHD upstream of Tanyaca Creek regulator

5. **Natural Flood:**

The overall objective of the Natural Flood scenario is to inundate the Pike Floodplain by allowing the unimpeded passage of water and biota during large natural floods, such as when QSA exceeds 90 000 ML/d and involves having all regulating structures fully open.

Operational Objective	Natural Flood scenario
Description	Allowing the unimpeded passage of water and biota during large natural flood events
Suggested flow band for operation	>90,000 ML/d
Timing	During flood event
Frequency	As dictated by natural events
Action required	Leave all structures fully open

6. **Flood Capture:**

The overall objective of the Flood Capture scenario is to extend the duration of a natural flood to meet ecological requirements whenever it is assessed as being of insufficient duration. This scenario is progression from the River Through-flow scenario as levels downstream of regulating structures equilibrate with upstream levels and structures are opened or removed.

Flood Capture on the draining limb of a natural flood when QSA returns to 30,000ML/day. For this scenario regulating structures are re-engaged as the transition from Natural Flood to Floodplain Inundation scenario occurs.

Katarapko Floodplain

The Operating Strategy describes eight hydrological scenarios each of which is design to contribute to the ecological objectives for the hydrological management of Katfish Reach. Further details are provided in DEWNR (2015b).

1. Katarapko Creek Base Flows

The crest of the Katarapko Creek Stone Weir will be modified to allow river flows of 5,000ML/d to over top the structure and a rock fish-way will be built.

The primary operational objective is to enhance longitudinal connectively along the Katarapko Creek during low flow periods by the enhancement of high value flowing habitats and by providing fish passage during low flow periods.

Component	Description
Operational Objective	Enhancement of high value flowing habitats
	Provide fish passage during low flow periods
Flow band	> 5,000ML/day
Action required	AHD set no operation required
Operating range of structures	5,000ML/day

2. Eckert Creek Anabranch – Base Flows

The structures at Banks J, K & N, Eckert Creek South Arm road crossing and Log Crossing will all be replaced to enable greater flow capacity through the anabranch system at all times during periods of no other hydrological management.

The primary operational objective is to enhance longitudinal connectively along the anabranch system during low flow periods by;

- The enhancement of high value flowing habitats
- Providing fish passage during low flow periods.

Component	Description
Operational Objective	Enhancement of high value flowing habitats
	Provide fish passage during low flow periods
Flow band	< 35,000ML/day
Action required	AHD set no operation required
Operating range of structures	Bank J 11.6 to 13.6mAHD , Banks K & N 12.6 to 13.8mAHD

3. Eckert Creek Anabranch – Pulse Flows

The structures at Banks J, K & N, Eckert Creek South Arm road crossing and Log Crossing will all be replaced to enable greater flow capacity through the anabranch system. This could occur every year to some extent.

The primary operational objective is to:

- Enhance longitudinal connectively along the anabranch system during low flow periods;
- Maximise high value flowing habitats
- Provide fish passage during low flow periods
- Reduce the disconnect between the hydrology of the river and the anabranch;
- Deliver seasonal variability in the flow pattern (i.e. provide a spring-summer flow pulse)
- Increase flows in the creek proportional to QSA when flow exceeds entitlement, and;
- Temporarily reverse the hydraulic gradient between surface water and groundwater at the edge of the creek line.

Component	Description
Operational Objective	Maintain longitudinal connectivity within anabranch system during very low flow periods • Maximize high value fast flowing habitats
	Reduce the disconnect between the hydrology of the river and the anabranch • Deliver seasonal variability in the flow pattern (i.e. provide a spring-summer flow pulse) • Increase flows in the creek proportional to QSA when flow exceeds entitlement
	Temporarily reverse the hydraulic gradient between surface water and groundwater at the edge of the creek line
Flow band	< 35,000ML/day
Action required	Manipulation of Banks J & K and Log Crossing
Operating range of structures	Bank J 11.6 to 13.6mAHD , Banks K & N 12.6 to 13.8mAHD

4. Eckert Creek Wide-waters – Pool Level Variation (up or down)

Instate a temporary rise and fall in water level within the Eckert Creek Wide-waters, independent of prevailing flows. It is anticipated that the rise in water level would be in the range of 2 -2.9 m at The Splash, Piggy Creek and Sawmill Creek Regulators. This scenario could occur every year to some extent.

The primary operational objectives are to:

- Deliver seasonal variability in in-channel water levels;
- Create wetting and drying regime of the littoral and riparian edge, and;
- Temporarily reverse the hydraulic gradient between surface water and groundwater at the edge of the creek line.

Component	Description
Operational Objective	Deliver seasonal variability in in-channel water levels
	Create wetting and drying regime of the littoral and riparian edge
Flow band	< 35,000ML/day
Timing	Spring/Summer (raising) Summer/Autumn (lowering)
Action required	Manipulation of Bank J and Log Crossing
Operating range of structures	Bank J 200ML/d -633ML/d Log Crossing full Open -150ML/d

5. Eckert Creek Anabranch – Temporary Partial Drying (Southern and Northern Arms & The Splash)

Instate a temporary dry of the North and South Arms, Bank K Creek and The Splash independent of prevailing flows. It is anticipated that 20.5 km of waterway will be temporary dried covering an area of 17 ha.

The primary operational objective is to:

- Reintroduce a drying phase to these permanent flooded waterways, and;
- Consolidate sediment.

Component	Description
Operational Objective	Deliver seasonal variability in in-channel water levels
	Create wetting and drying regime of the littoral and riparian edge
Flow band	< 10,000ML/day
Timing	Summer/Autumn
Action required	Manipulation of Bank J and Log Crossing
Operating range of structures	Bank J 100-200ML/d Banks k &N, South Arm & Log Crossings Closed

6. Eckert Creek Managed Floodplain Inundation: Low Floodplain Managed Inundation

Instate a temporary rise in water level within the Eckert Creek Anabranch, independent of prevailing flows. It is anticipated that the rise in water level would be in the range of 2 -2.9 m at The Splash, Piggy Creek and Sawmill Creek Regulators. Operational details are provided in Table 10.

The primary operational objectives are to:

- Reverse the hydraulic gradient between surface water and groundwater at the edge of the creek line;
- Fill early commence to flow wetlands, and;
- Inundate shallow elevation sections of the floodplain.

7. Eckert Creek Managed Floodplain Inundation: Maximum Extent Managed Inundation

Instate a temporary rise in water level within the Eckert Creek Anabranch, independent of prevailing flows. It is anticipated that the rise in water level would be in the range of 3-3.7 m at The Splash, Piggy Creek and Sawmill Creek Regulators. Operational details are provided in Table 10.

The primary operational objectives are to:

- Reverse the hydraulic gradient between surface water and groundwater at the edge of the creek line;
- Create lateral connectivity between river and floodplain;
- Fill all wetlands, and;
- Inundate significant proportion of the floodplain and provide opportunity for vertical infiltration to create/freshen freshwater lenses, increase floodplain soil moisture content.

Table 10: Summary of proposed managed inundation operating regimes at Katarapko Floodplain

Hydrological Type	Delivery Mechanism	Operating Regime	Flow Band	Timing	Action Required	Operating range of structure	Operational Limits
Eckert Creek floodplain - managed floodplain inundation (low floodplain)	Bank C, J , K, N and Carpark Lagoons inlet regulators , The Splash, Piggy Creek, Sawmill Creek outfall regulators, Sawmill Creek ancillary, Carpark Lagoons and Lock 4 outlet regulators and Piggy Creek North & South Arm inlet regulators	4 to 6 years in 10	8,000-20,000 ML/ day QSA (suggested for operation to occur)	Spring / Summer	Full open of Banks C, J, K & N, and manipulation of The Splash, Piggy Creek, Sawmill Creek Regulators + Car Park Lagoons ancillary structures	Lock 4 13 2m AHD; Regulators 11.8-12.7mAHD (2-2.9m @ Structures); ≤ 600ML/ d inflow at Bank J; ≤ 15ML/ d and 24ML/d inflows at Bank K & Bank N respectively	TBD during detailed design
Eckert Creek floodplain - managed floodplain inundation (maximum extent)			>12,000 - 20,000 MLday -1 QSA (suggested for operation to occur)	Spring / Summer	Full open of Banks A, C, J, K & N, and Manipulation of Lock 4, The Splash, Piggy Creek, Sawmill Creek Regulators + all ancillary structures	Lock 4: ≤ 14.2m AHD; Regulators ≤ 13.9m AHD; ≤ 1,000ML/d inflow at Bank J; ≤ 210ML/d and 155ML/d inflows at Bank K & Bank N respectively (all structures drowned); Outfall Regulators set @ 13.5mAHD	Lock 4 weir pool raising is restricted to 20,000ML/d or less. Others TBD during detailed design

12 Assessment of Risks and Impacts of the Operation of the Measure

A comprehensive risk assessment of the potential risks and impacts of the operation of the measure at the Pike and Katarapko Floodplains has been undertaken during the development of this SDL adjustment business case (Table 11). The risk assessment process was based on expert opinion and informed by experience with operating the Chowilla Floodplain TLM works. Table 11 presents the summary of the assessment, including mitigation measures developed and an assessment of residual risks after these are applied. This risk assessment should be considered preliminary, as a more robust risk assessment process will be undertaken during implementation of SARFIIP.

The risk assessment was completed in line with the requirements of AS/NZS ISO 31000;2009 and assesses both the likelihood of an event occurring and the severity of the outcome if that event occurred. The assessment generated a risk matrix in line with the ISO standards. Section 9 provides the risk matrix and definitions used in this risk assessment.

Section 12.1 provides a preliminary salinity assessment of the inundation measures at the Pike and Katarapko Floodplains. Ecological risk is addressed in Section 9.

Table 11: Overview of risk assessment and mitigation for operation of the measures at the Pike and Katarapko Floodplains.

Threat	Site	Description	Likelihood	Consequence	Risk without mitigation	Mitigation	Residual risk
Increased mosquito populations during inundation events	Pike and Katarapko	Ponding water on the floodplain has the potential to cause localized increase in mosquito populations or perception of increased mosquito populations. This could lead to human discomfort, disease exposure and eventually to negative perceptions about the project.	Possible	Moderate	Moderate	Continued community engagement and awareness raising to encourage people to take precautions. Monitoring of ecological response to inundation events and assessment of ecological functionality to inform adaptive management. If ecosystem benefits are achieved as intended, then mosquito populations should not increase as there will be improved ecosystem functionality. Therefore management of the community perception aspect will largely be around communication and education.	Low
Restricted floodplain access during inundation (third party risk)	Katarapko	There is an existing expectation that the site is freely accessible and hence during inundation events when existing access is restricted there might be negative perceptions about the project. There will be however, alternative recreational uses presented during site inundation events such as boating opportunities.	Certain	Minor	Moderate	A recreational master plan is being developed to provide alternative opportunities during inundation (new boat ramps, new camp sites) and opportunities for different recreational uses (boating, canoeing, bird watching). These benefits will be communicated via effective channels (i.e. the Community Working Group).	Low
Changed navigation pathways and introduction of obstacles presented	Pike and Katarapko	There is a risk that recreational users could hit submerged objects during inundation events, causing injury or damage to equipment. Water level raising will also reduce bridge and power line clearance heights.	Likely	Severe	High	Effective notification and awareness. – DPTI 'notice to mariners' and 'On Deck" website Buoys out on submerged objects. Increasing signage on inlets and near bridges with reduced clearance.	Low
Significant rise in river salinity longer term	River Murray d/s of Pike and Katarapko	Managed inundation actions or potential disposal of saline groundwater to river result in more salinity debits on the Murray-Darling Basin Authority (MBDA) Salinity Registers than can be offset by credits from the groundwater management scheme.	Likely	Severe	High	Based on conservative (i.e. high) estimates of salt loads to river and the current concept design option for SMM SARFIIP will at minimum generate sufficient credits to offset debits associated with managed inundations.	Low

Real time salinity impacts	Lower Pike	Irrigators in lower pike may be affected during, but especially shortly after a managed inundation event, due to the release of groundwater from bank storage and raised groundwater levels while surface water inflows may be tapering off.	Likely	Severe	High	Real time, in-stream salinity changes can be managed through appropriate operational strategy development including consideration of baseline conditions, available dilution flows, real-time monitoring and agreed triggers for changes to operations. It is also possible that some real-time salinity impacts may be reduced due to long-term removal of salt entering the Pike River and the resulting reduction in baseline in-stream salinity.	Low
Increase rate of decay of artefacts	Pike and Katarapko	Increase in the rate of soil salinization could also potentially increase the rate of decay of artefacts.	Possible	Severe	High	SMM doing extensive works to mitigate and manage salinity impacts. Ensure artefacts are not exposed. Acceptance that some areas of the floodplain will have elevated risk if any of these areas correlate with sites of cultural heritage vale, appropriate and effective protection measures will be developed.	Low
Poor design of structures	Pike and Katarapko	This could occur through inadequate technical rigour during design or maintenance, causing maintenance issues or reduced effectiveness in operations.	Possible	Severe	High	Engage qualified and experienced engineers to ensure robust design. Extensive peer review of structures. Engage a qualified and experienced construction company and implement an appropriate infrastructure maintenance schedule.	Low
Structural failure of new works during operation	Pike and Katarakpo	Structures can be vulnerable to natural flooding flows via processes and attributes such as insufficient protection from scour; insufficient rock armouring; as well as insufficient flood preparation including strip boards and handrails.	Remote	Catastrophic	Low	Engage qualified and experienced engineers to ensure robust structural design based on geotechnical investigation of specific conditions. Conduct regular inspections and ongoing maintenance of structures for early identification of potential problems, particularly during operation and natural flood events. Provide adequate protection from scour and erosion during and after operation and natural flood events. Flood preparation actions incorporated into O&M documents including removing structural parts likely to be barriers to flow or large debris.	Low
Unsafe operation of	Pike and Katarapko	Threat to human safety due to unsafe operation of structures.	Unlikely	Catastrophic	Moderate	Ensure appropriate design that incorporates best-practice OH&S provisions.	Low

built infrastructure						Implement suitable Standard Operating Procedures (SOP) and ensure operators have had appropriate training and experience with equipment operation. Ensure operating regimes and OH&S requirements are adhered to.	
Uncertainty of Lock 4 and 5 weir pool raising limits	Pike and Katarapko	Inundation at both floodplains can only occur by raising Weir 4 (Katarapko) and 5 (Pike). There is currently a lack of clarity on the height Weir 4 can be raised.	Certain	Severe	Very High	SA Water currently undertaking investigations to determine the height allowance at Weir 4 and this will guide operation of inundation.	Moderate
Impact on existing water users at Gurra Gurra	Pike and Katarakpo	There are existing users that extract water directly from Gurra Gurra Wetland which is located above Weir 4. During water level recessions, there may be potential for salinity increases in water supply that renders it unsuitable for use on occasion. For SARFIIP to be effective, Weir 4 will be raised more frequently, potentially affecting the quality of water used by these existing users at Gurra Gurra Wetland.	Certain	Severe	Very high	Options to mitigate the potential impact to the existing users at Gurra Gurra Wetlands are currently being explored through the SARFIIP Inundation Working Group. Commitment to resolving this potential impact will be ongoing.	Very Low
Increase in river salinity during and shortly after managed inundation		Managed inundation actions or potential disposal of saline groundwater to river result in increases in salinity levels at locations where return flows from inundation or increased groundwater discharge occurs. This increase in salinity is anticipated to occur during and shortly after a managed inundation event.	Likely	Moderate	Moderate	Operational strategy to include inundation at higher river flows, providing sufficient dilution capacity to mitigate any unacceptable increases in salinity at downstream locations. It is also possible that some real-time salinity impacts may be reduced due to long-term removal of salt entering the river and floodplain and the resulting reduction in baseline in-stream salinity,	Low
Lack of clear understandin g of roles and responsibilitie s of ownership and operation	Pike and Katarapko	Lack of clear understanding of roles and responsibilities of ownership and operation could prevent the effective operation of infrastructure and ongoing maintenance.	Possible	Moderate	Moderate	Develop and agree on ongoing management strategies prior to completion of project. Facilitate shared knowledge of project objectives among asset owners and operators. Develop all documentation with relevant agencies prior to construction, including production of Operation and Maintenance manuals.	Very low

						Ensure ongoing maintenance of structures and insurance arrangements. Maintain clear lines of communication and robust reporting during operation.	
Insufficient funding for ongoing operation, maintenance and management	Pike and Katarakpo	Insufficient funding for operations and maintenance, including MERI activities result in deterioration of structures, increasing the risk of failure. Inability to coordinate / direct operations due to insufficient resources.	Possible	Moderate	Moderate	Quantify ongoing costs and resources needed (i.e. develop operations manuals and asset management plans, and map management process to identify resource dependencies (EPP)). Develop handover strategy plan and ensure funding requirements and risks are clearly articulated. Maintain strong relationships with funding body and internal departments to secure long term operational funding. Multi-jurisdictional discussions on asset management through SDL adjustment process.	Very low
Operational outcomes do not reflect hydrological modelling outputs	Pike and Katarapko	On-ground outcomes during operation do not meet expectations due to incorrect assumptions, input data, interpretation or inaccurate models. This could lead to reputation and ecological benefits not being fully realised	Likely	Moderate	Moderate	Sophisticated 1D-2D coupled hydraulic models, built from comprehensive survey data (topographical and bathymetric), and calibrated against historical gauged flow and water level data are employed to predict likely hydraulic behaviour under a range of managed and natural operational scenarios. The hydraulic models are subject to significant sensitivity testing as well as calibration, validation and re-schematisation (where necessary) assessments to minimise the likelihood of consequential discrepancies between the modelled outputs and the actual operational hydraulic conditions. Models independently peer-reviewed and determined to be fit-for purpose. Environmental Pathways will investigate the cumulative impacts of Weir Pool Manipulation and managed inundations and through adaptive management will ensure there is a feedback loop to verify models and ensure ongoing learning.	Low

Community / stakeholder resistance or poor perception	Pike and Katarakpo	Poor communication with project stakeholders and the community can result in misunderstanding of the projects' works and ongoing operations. This may limit the capacity to operate the site as required.	Possible	Moderate	Moderate	Ongoing stakeholder liaison (early and often) guided by the Community Engagement Strategy for Pike and Katarapko. Ensure a commitment to clear and honest messaging. Targeted engagement to address identified concerns of key stakeholders.	Low
Inundation of private land without prior agreement	Pike	Private land will be inundated as a result of SARFIIP infrastructure operation on the Pike Floodplain as well as from Weir Pool Raising (outside of the Pike Floodplain). If ownership changes and agreements aren't registered on title, it is possible that the new owners may not permit inundation.	Certain	Moderate	High	Early and ongoing engagement with landholders regarding planned watering events and outcomes. This will follow the process established under the weir pool manipulation trials. Exploring acquisition of private property from willing sellers. For private owners not willing to sell, furthering the development of Land Management Agreements on Title which provides DEWNR with unencumbered rights to operate infrastructure. The River Murray Act provides legislative protection to operate RM infrastructure to further the objects of the River Murray.	Low
	Katarapko	Private land will be inundated as a result Weir Pool Raising only. If ownership changes and agreements aren't registered on title, it is possible that the new owners will not permit flooding.	Certain	Low	Moderate	Early and ongoing engagement with landholders regarding planned watering events and outcomes. This will follow the process established under the weir pool manipulation trials. The River Murray Act provides legislative protection to operate RM infrastructure to further the objects of the River Murray.	Low

12.1 Salinity Impact Assessment and Mitigation Strategies

A preliminary salinity impact assessment of the SARFIIP inundation Measures Projects for Pike and Katarapko Floodplains has been completed, which includes analysis of both Basin Salinity Management considerations (as measured in EC units at Morgan) and real-time salinity impacts. The parameters applied in this assessment are based on historically observed surface and groundwater responses. Further assessment will be undertaken during the concept and detailed design phases. While the salt mobilisation responses can be identified and estimated, the actual operating regime of the River Murray under the Basin Plan will be fine-tuned in coming years, especially in relation to environmental watering and this may affect the observed salinity response. The preliminary salinity impact assessment must be considered in this context.

Preliminary Salinity Assessment Approach

The salt mobilisation processes likely to be activated by the operation of environmental regulators on both floodplains are floodplain inundation and changes in backwater/anabranch/river water levels. The differences in location and site characteristics of each floodplain result in these processes manifesting in different locations and water bodies along the River Murray, which is summarised for each floodplain in Table 12 and 13 (from AWE, in prep).

Table 12: Risks and timing of salt mobilisation from managed inundation of Pike Floodplain Source: AWE (in prep)

Salt Mobilisation Process	Salt Storage Location and Transport Pathways	Timing of mobilisation
Floodplain Inundation	Groundwater mobilised by floodplain inundation and infiltration through the Coonambidgal Formation, discharging to: • the River Murray immediately downstream of Lock 5 • To Lower Pike immediately downstream of the regulator location	Commences during the inundation phase, peaks near end of hold phase, and persists once surface water levels have returned to 'normal'
	Surface salt wash-off and mobilisation of salt from unsaturated zone via surface water flows	On the filling phase of the inundation event, assuming that passing flows are utilised through the filling phase to avoid black-water events.
Changes in Backwater/ Anabranch/ River Level	Backwater salt mobilised from the Upper Pike Lagoon and upstream of Lock 5 by raising the locks	On weir pool drawdown, for backwaters upstream of Lock 5 some salt may be mobilised although no significant salinity increase has been measured during a recent Lock 5 raising trial.

Table 13: Risks and timing of salt mobilisation from managed inundation of Katarapko Floodplain Source: AWE (in prep)

Salt Mobilisation Process	Salt Storage Location and Transport Pathways	Timing of mobilisation
Floodplain Inundation	Surface salt wash-off and mobilisation of salt from the unsaturated zone via surface water flows	On the filling phase of the inundation event, assuming that passing flows are utilised through the filling phase to avoid black-water events.
	Groundwater salt mobilised by floodplain inundation and infiltration through the Coonambidgal Formation, discharging to: • the River Murray immediately downstream of Lock 4 • To Katarapko Creek immediately downstream of the regulator location	Commences during the inundation phase, peaks near end of hold phase, and persists once levels have returned to 'normal'.
Changes in Backwater/ Anabranch/ River Level	Backwater salt mobilised from the Splash/Eckert Wide Water	In the draining phase, from the Splash/Eckert Wide Water.
	Salt mobilised from Gurra Gurra Wetland Complex as a result of weirpool manipulation	On lowering Lock 4 weir after completing the Katfish inundation phase, for backwaters upstream of Lock 4 (i.e. Gurra Gurra). Alternatively, prior to watering if the locks were briefly lowered before being raised.

The key driver of the salinity response on the Pike floodplain is the mobilisation of salt stored on the soil surface and, potentially, salt mobilised from the top 10 cm of floodplain soils via surface water. This is likely to occur during the initial filling stage of the watering event. The contribution of salt wash-off to in-stream salinity is a key area of uncertainty in the estimation of salinity impacts. For this reason, a conservative (i.e. high value) estimate of the salt load resulting from wash off is assumed until further refinement of this estimate is possible. The salt wash-off as a result of a 90-day filling period at Pike Floodplain and an operational frequency of 1 in 3 years is estimated to be up to 143 t/d over three months for the maximum inundation extent currently proposed in the concept design phase of SARFIIP. This is mostly generated in the Lower Pike section of the floodplain. The increase in discharge of saline groundwater to the River Murray as a result of a three-month managed inundation event is estimated to be 7 t/d over 90 days and the increase of groundwater discharge to the Pike River is 20 t/d over 90 days. The salt load contribution from Pike backwaters is estimated to be minimal (1 t/d for 90 days). Investigations are ongoing into the potential impact from Lock 5 backwaters as a result of weir pool raising.

For Katarapko Floodplain, in-river resistivity data indicate largely losing stream conditions along Katarapko Creek which suggests that Katarapko Creek should be contributing (although perhaps at very slow rates) to the development of low salinity lenses in the floodplain during low flow periods. Land-based geophysics data suggest that the soil and groundwater salinity regime are of moderate salinity adjacent Katarapko Creek, and there may be some small or remnant low salinity lenses in places. These two datasets suggest that the salinity regime of any mobilised groundwater will be moderate – that is there appear to be neither significant low salinity lenses nor any significant high salinity groundwater zones. An air-borne geophysical survey has recently been flown and this data will provide more information on the distribution of saline and less saline groundwater across the Katarapko Floodplain.

Limited groundwater salinity data is available for the Katarapko Floodplain, so the salt loads resulting from increased groundwater discharge during a three-month managed inundation event are estimated for a range of groundwater salinity values of 2,500 mg/L, 15,000 mg/L and 25,000 mg/L to be 12.5 t/d, 75 t/d and 125 t/d, respectively. As for the Pike floodplain, no empirical data is available to characterise the rates and quantum of salt wash-off from surface water for Katarapko floodplain. However, recently collected geophysics data suggest that the floodplain soils are not as saline as the Pike Floodplain. The salt wash-off as a result of a 90-day filling period at Katarapko Floodplain and an operational frequency of 1 in 3 years is estimated to be between 11–55 t/d over three months for the proposed inundation extent of approximately 1000 ha. The Gurra Gurra Wetland Complex is the main backwater to be activated as a result of weirpool manipulation of Lock 4. A relatively simple salt mass and water balance was used to provide a first estimate of the salt loads resulting from the Gurra Gurra Complex as a result of weirpool manipulation. It should be noted that significant uncertainties are related to this estimate, as assumptions in regards to the connectivity of certain reaches of the wetland complex were made using limited hydro-dynamic data. The salt loads estimated to be mobilised from the Gurra Gurra Complex are between 12–69 t/d during a 30-day recession period following the weirpool raising event.

Preliminary salt estimate for long-term and real-time EC impact at Morgan

The preliminary long-term salinity impact at Morgan is estimated for each floodplain for the assumed managed inundation event duration of three months and a frequency of 1 in 3 years. For Pike Floodplain the estimated salt impact at Morgan is approximately 16 t/d, which corresponds to an EC impact of 1.7 EC. For Katarapko Floodplain, the impact at Morgan is estimated as a range due to the uncertainty in groundwater salinity, salt wash-off rates and the salt load from the Gurra Gurra Complex. The salt load range at Morgan as a result of environmental watering at Katarapko Floodplain is estimated to range between 0.3–2.2 EC. These initial salt load impact estimates do not account for implementation of mitigation strategies.

Figure 24 shows an example of the relationship between flow and salinity at Morgan in a benchmark model run for the Basin Plan 2750 water recovery scenario. The model scenario including the salt loads from SARFIIP managed inundation events will provide an indication of which years in the benchmark period the operation of the proposed SARFIIP environmental regulators would impact on the Basin Plan salinity target at Morgan. This provides an indication of the mitigation measures required to minimize any impact the SARFIIP managed inundation events could have on meeting this Basin Plan requirement.

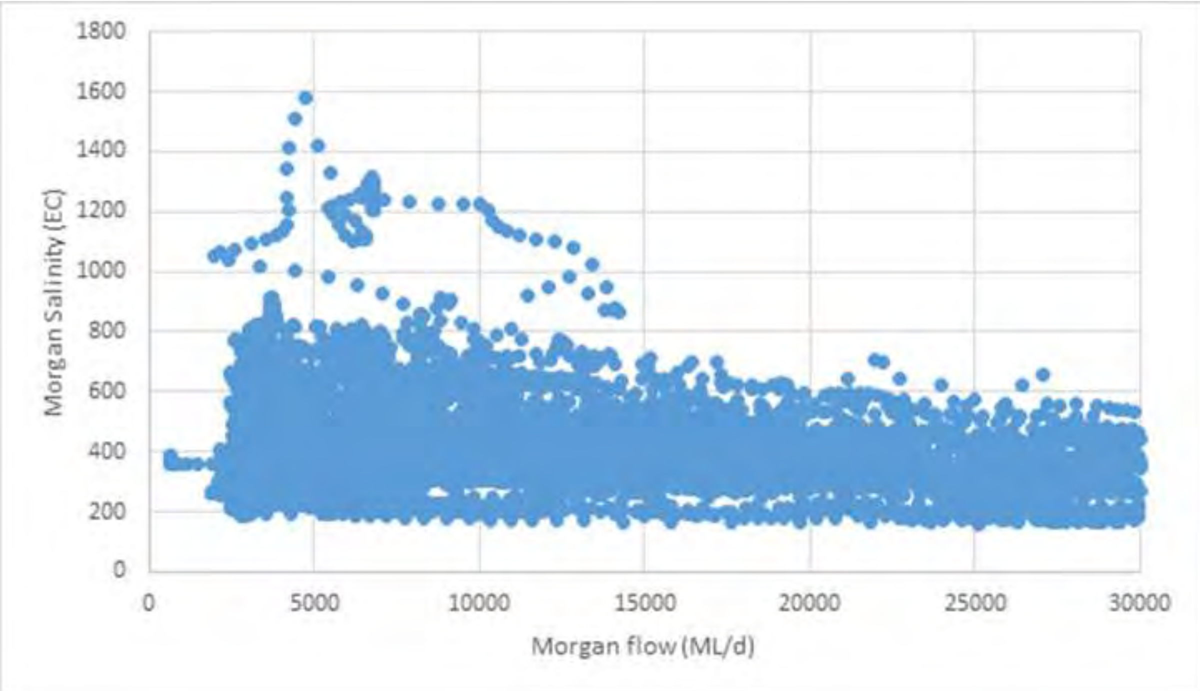


Figure 24: Relationship between flow and salinity at Morgan in a benchmark model run for the Basin Plan 2750 water recovery scenario.

Currently, the AWE (in prep) assessment does provide estimates of the real-time salinity impacts for the locations on the River Murray where the return flows from managed inundation would enter the River Murray. This was estimated using a salt and water balance spreadsheet that calculates the real-time salinity increases given a stream flow rate for the receiving water body and a salt load input (in t/d). This method assumes that salt mixes instantaneously, salt is fully mixed across the cross-sectional area of the stream at the input location and conservative transport of salt down the river.

AWE (in prep) estimate the real-time salinity impact in the River Murray downstream of Lyrup (assuming a flow of 10,000 ML/d) of a three-month managed inundation event on Pike Floodplain to be 36 EC over 90 days. For a "Possible Likely Scenario" (AWE, in prep), the real-time salt load could cause a 69 EC increase in Katarapko Creek, assuming a 10,000 ML/d flow in the River Murray and 12.5% of this river flow diverted down the Katarapko Creek. The Gurra salt inputs are estimated to cause a 1.5 EC increase upstream of the Katarapko Creek mouth. The combined salt inputs could cause a 9.85 EC increase in the River Murray, downstream of the Katarapko Creek outlet.

Mitigation strategies

A balanced approach is required to maximise environmental benefits while at the same time minimising salinity impacts. The level of impact is highly dependent on the magnitude of river flow and the baseline salt load in the river system, which in turn is dependent on whole-of-river operations and priority order for individual watering projects. Salinity impacts will be managed through construction and operation of salinity management infrastructure and floodplain infrastructure operating regimes and will include:

- Construction of groundwater management schemes to intercept regional groundwater inflow to the floodplain and river with disposal to the Noora salt disposal basin. The objectives are to help manage any salinity impacts over the long term and short term and to enhance groundwater and soil conditions conducive to maintaining a diverse native vegetation community.
- Creation of an operations protocol that explicitly connects projected salinity impacts, salinity thresholds for operation and contingency planning.
- Implementing a monitoring regime that informs both the operation of the structures within nominated thresholds as well as fulfils the reporting requirements in relation to Basin Plan salinity targets and the Murray-Darling Basin Agreement (Basin Salinity Management strategy).
- The salinity management infrastructure includes extraction bores, pipelines to existing disposal basins.

The concept design of the proposed infrastructure is currently being developed.

Future work on salinity impact quantification

Further work is underway to address uncertainties and substantiate the current estimates of salinity impacts. This will inform the detailed design phase of SARFIIP. A summary of currently proposed additional work is provided below, though additional works will be commissioned as the need arises:

- Field investigations and monitoring: drilling of more wells on the floodplains and pump tests to determine aquifer properties and monitoring of groundwater levels and salinities. This will provide an improved understanding of groundwater flow and salinity and its distribution on the floodplain.
- Numerical groundwater modelling to refine the estimates of groundwater discharge to river for both floodplains to support the quantification of the salt impact of groundwater management schemes. This work is currently being undertaken and will continue during the detailed design phase.

- Modelling and development of tools to better understand real time and longer term salinity impacts during the concept design phase with further refinement during detailed design, construction and operational phases.

13 Technical Feasibility and Fitness for Purpose

13.1 Design Development

Pike Floodplain

Surface water inundation options for Pike Floodplain have been in development since 2007. In May 2009, URS Australia Pty Ltd (URS) were engaged by the South Australian Murray-Darling Basin Natural Resources Management Board (NRM Board) to develop conceptual designs for surface water management infrastructure (URS, 2010). URS (2010) presents the final results of this study, undertaken between May 2009 and June 2010 and includes preliminary geotechnical and hydraulic evaluations of the Pike Floodplain project area, and the preparation of conceptual designs and construction cost estimates for several proposed surface water and fish passage structure measures.

In 2014, the pre-concept design options were reviewed and defined and then qualitatively assessed against a weighted Multi-Criteria Analyses (MCA) framework (Jacobs, 2014). On the basis of the Jacobs (2014) assessment, DEWNR identified three alternative infrastructure alignment scenarios for more detailed investigation. As a result of the more detailed investigation, the infrastructure option presented in this business case was settled as the option to be taken to concept design based on achieving the best outcomes with respect to floodplain vegetation condition, riparian and wetland habitat, minimizing vegetation clearance, habitat disturbance and cultural heritage impacts.

Katarapko Floodplain

Surface water management options were first developed in 2008 when URS Australia Pty Ltd (URS) were engaged by the Department for Environment and Heritage (DEH) to undertake the development of concept designs for the hydrological and fish passage structures at Katarapko floodplain (URS, 2009), with the aim to reinstate ecological health within the Katfish Reach anabranch. Design criteria included vegetation health, improving native fish populations, optimisaton of environmental watering and reducing impacts of pest species.

The initial management options were reviewed in 2014 and subject to a cost-benefit analysis (CBA) to select options for concept design. The analysis considered inundation area, target vegetation inundated, cost of infrastructure and blocking bank footprint. The analysis tool reflected the simpler nature of the selection process for Katarapko. The option selected reflected the concept design completed by URS with further investigations subsequently undertaken to refine the blocking bank alignment and height. The option presented in this business case is the option now being taken through to concept design.

13.2 Concept Design

Concept design process

The floodplain inundation options outlined in this business case are currently the subject of concept design development. The concept design work and underpinning hydraulic modelling will be subject to external peer review.

Conceptual Designs for Surface Water Management Infrastructure

An overview of the Pike Floodplain infrastructure design is described below noting that concept design is currently underway (Table 14).

Table 14: Overview of Pike Infrastructure for Surface Water Management Infrastructure (URS 2010)

Structure	Description
Blocking Banks	Compacted clay core embankment. A bank crest width of 6 metres, a 1V:3H upstream slope batter and a 1V: 4H downstream slope batter. The 6 meter crest width selected to enable a vehicle to drive along the bank crest.
Col Col Environmental Regulator and Fishway / Fish Lock	Located at one of two of the main outlets of the Upper Pike floodplain at Col Col on the Pike River. Overshot concrete structure with buttressed, reinforced concrete walls and one-metre thick reinforced concrete raft footings over a group of piles drive3n into the sand foundation. The structure has nine regulator bays, each two metres wide, separated by 640 mm or 1280 mm wide reinforced concrete piers. Other features include a bridge deck over the regulator to allow light vehicle crossing, a lightweight aluminium walkway over the line of the stop logs to provide security, and rockwork provided on the embankments and within the riverbed downstream of the structure to provide scour protection. Regulator would include a combined vertical-slot fishway and manually operated fish lock.
Tanyaca Creek Environmental Regulator and Fish Lock	Located at the second main outlet of the Upper Pike floodplain, at Tanyaca Creek downstream of Mundic Lagoon. Details as per Col Col Environmental Regulator and Fishway / Fish Lock (as above).

An overview of the Katarapko Floodplain infrastructure design is described below noting that concept design is currently underway (Table 15).

Table 15: Overview of Katarapko Infrastructure for Surface Water Management Infrastructure

Structure	Description
Bank J Inlet Regulator and Vertical Slot Fish-way	Overshot concrete structure with three two-metre wide regulator bays with aluminium stop logs and a 1 in 20 gradient reinforced concrete vertical slot fish way with seven, 3.0m long by 2.0m wide bays with grid mesh cover incorporating eight 300mm wide vertical slot baffles
The Splash Outfall Regulator	Overshot concrete structure with twelve two-metre wide regulator bays with aluminium stop logs
Piggy Creek Outfall Regulator	Overshot structure features single line of three 1800mm x 900mm x 2.44m reinforced box culverts regulator with aluminium stop logs
Piggy Creek North & South Arm Inlet Regulators	Overshot structure features single line of three 1800mm x 900mm x 2.44m reinforced box culverts regulator with aluminium stop logs
Sawmill Creek Outfall Regulator	- Overshot concrete structure with two-metre wide regulator bays - Two-metre length lightweight aluminium stop logs with lightweight aluminium walkway over the line of stop logs - 300mm deep fish plunge pool fitted to downstream side of structure - Road width 4.8m fitted with safety barrier and hand rails
Sawmill Creek Two Ancillary Regulators	Two overshot structures feature single parallel lines of three 1800mm x 1200mm x 2.44m reinforced box culverts regulator with aluminium stop logs
Lock 4 Ancillary Regulator	Two overshot structures feature single parallel lines of three 1800mm x 1200mm x 2.44m reinforced box culverts regulator with aluminium stop logs

13.3 Geotechnical Investigations

Pike Floodplain

Geotechnical investigation has been undertaken by Tonkin Consulting (2015) as part of the Pike Floodplain Management Options Assessment to inform future options assessment and design works. Key geotechnical conditions which may be the main drivers for determining the preferred locations were tested for at Tanyaca Creek and Pike River, including stability, depth to intersection of groundwater, availability and suitability of materials for reuse, bearing capacity, permeability and settlement. The report presents the results of the geotechnical investigations including:

- boreholes on land and mid-stream and test pits at Tanyaca, Pike River East and Pike River West;
- summary of the subsurface conditions encountered;
- results from laboratory testing from site investigations; and
- results from salinity testing.

Further works were recommended and are being undertaken as part of Concept Design:

- Additional investigation to confirm the soil profile after variable results were generated from the boreholes and test pits investigated on the bank and over the water at Pike River East and West.
- Additional investigations targeting the depth and extent of the sediments that would greatly impact on the embankment design based on the softness of the underlying clay materials observed in the investigations in the mid-stream locations.
- Additional testing is also recommended on the strength of the sediments to support the expected design loads.
- Further investigations to confirm the extent of suitable embankment materials within proposed borrow areas once embankment material volumes are known.

A full geotechnical investigation will be undertaken at the site of the proposed new and modified infrastructure as part of detailed design in order to develop strategies and plans for groundwater control during construction, control of under-seepage post construction and to understand the strength of the foundations.

Katarapko Floodplain

URS Australia Pty Ltd was engaged by DEWNR to undertake a targeted geotechnical investigation in July and August 2015 at the proposed SARFIIP structure sites to inform the management option assessment and the concept designs for the Katfish Reach floodplain inundation measures project. The objectives of this preliminary investigation were to:

- identify subsurface conditions at the site of each new structure to inform the concept structural design of each structure; and
- identify potential borrow pit areas for use in the construction of blocking banks and structure abutments/embankment.

The findings and recommendations for further investigations are presented in URS (2015). Further geotechnical investigations will be undertaken during the detailed design phase.

13.4 Ongoing Operational Monitoring and Record Keeping Arrangements

Operational monitoring will form a key component of the operating plans and monitoring and evaluation plans developed for the program. Roles and responsibilities for agencies tasked with undertaking this monitoring and record keeping will be clearly assigned.

Record of Event

The Site Manager will be responsible for coordinating record keeping including the following data and information during an event to support adaptive management include:

- decision record from Operational Group meetings
- monitoring results
    - compliance and hazard management
    - knowledge generation/hypotheses testing
    - critical or near-critical incidents (hazard management/monitoring)
    - incidental observations
- Operational records
    - flow (inflow and outflow) and settings (number of boards etc) through individual structures
    - depth at structures and gauge boards in wetlands/flow paths
    - satellite imagery of inundation extent (ha)
    - duration of inundation of key wetlands
    - repairs/modifications to infrastructure
- Log of all Communications activities
    - Community - correspondence in/out
    - Media - requests/published
- Water accounting.

Post-event recording

The Site Manager will be responsible for ensuring that key information from the two preceding tiers of record keeping (record of pre-event planning and record of event) is compiled along with the following information:

- Monitoring summaries
    - Compliance and hazard management
    - Knowledge generation/hypotheses testing
    - Evaluation of progress towards/achievement of event specific objectives
- Recommendations for future events from:

  - Operations staff
  - Monitoring teams – identification of ecological benefits to inform adaptive management cycle.
- Resources utilised (personnel and equipment)
- Feedback from stakeholders, landowners and community.

14 Complementary Actions and Interdependencies

SARFIIP will be implemented in conjunction with Chowilla Floodplain The Living Murray (TLM) works and RRP as a package of interconnected works. This will optimise environmental outcomes at the local site, reach and regional scales though the establishment of a mosaic of manageable wetlands and floodplains from the South Australian Border to Wellington. The environmental pathways sub-program will explore and establish processes for coordination of environmental watering, weir pool manipulation and infrastructure and other options to connect the floodplains of these sites.

The RRP, which is a component project of the Murray Futures Program, aims to restore wetting and drying cycles to key wetlands and improve floodplain inundation through infrastructure and adaptive river management. The SARFIIP works are designed to build upon this work to improve the connectivity between managed and unmanaged sites from the South Australian border to Lock 1 (Figure 25).

Complementary actions beyond water management will include pest plant and animal control programs, salinity management and other NRM activities funded by state and federal programs.

The affected resource unit from the SARFIIP is the SS11 South Australian Murray within the South Australian River Murray Water Resource Plan area.

Figure 25: Key environmental infrastructure sites.

15 Costs, benefits and funding arrangements

15.1 Cost Estimates

Total cost estimated for SARFIIP is [redacted] over seven years. The funding is provided by the Commonwealth Government and will be delivered under a series of funding agreements, to be negotiated throughout the life of SARFIIP.

15.2 Operating and Maintenance costs

Initial estimates of ongoing operations, maintenance and monitoring costs are provided below, noting that infrastructure assets to be constructed by the SARFIIP are subject to ongoing detailed investigations, planning and design processes which will refine these cost estimates. The estimates are based on the available information, industry benchmarks for capital maintenance cost and operating costs, indicative costs from other SDL projects (for ecological, salinity and compliance monitoring) and assessment of ongoing resources required for project management based on RRP weir pool manipulation operations (Table 16).

Table 16: Estimated Operating and Maintenance costs.

Cost estimate information	Ongoing operational $/year	Notes
Capital maintenance and Operating	[redacted]	Physical operation and maintenance of structures based on industry standards - [redacted] of capital expenditure with contingency.
Ecological, Salinity and Compliance monitoring (condition and intervention)	[redacted]	Planning and delivery of Ecological, Salinity and Compliance monitoring.
Critical hazard (incl. Salinity) Monitoring	[redacted]	Telemetered, transect and spot assessment of critical hazards, e.g. salinity, dissolved oxygen.
Compliance	[redacted]	Monitoring to ensure management actions have been carried out as planned (e.g. volume of water used matches volume planned, duration and extent of inundation matches that predicted).
Project Management	[redacted]	Operational planning and delivery, including direct project management, planning, communications and engagement, approvals, on ground visitor management, and interpretation and communication of management outcomes.
Total	[redacted]	

15.3 Ownership of Assets

Subject to the exception below, SARFIIP assets will be owned by the State and added to the Agency asset register or where these assets are or become River Murray Operations assets under the MDB Agreement, then they will be subject to the ownership and cost sharing rules consistent with decisions under the MDB Agreement.

There will be two assets (one road bridge and one foot bridge) constructed at the top of the Pike Floodplain which, once completed, will be handed over to Renmark Paringa Council (value <$1,000,000). This arrangement has been agreed in writing by the Council.

16 References

Anstis, M. 2007. Frogs and tadpoles of Australia, New Holland Publishers

Arthington, A. H., R. J. Naiman, M. E. McClain and C. Nilsson. 2010. Preserving the biodiversity and ecological services of rivers: new challenges and research opportunities. Freshwater Biology, 55:1-16 pp.

Australian Water Environments (AWE). 2008. Pike River Water Supply and Floodplain Management Stage 2- Sustainable Water Supply, prepared for DWLBC.

Australian Water Environments (AWE). In prep. Pike and Katfish Salinity Impact Assessments 2015. Prepared for Department of Environment, Water and Natural Resources. AWE Ref 14190.

Berens, V., White, M., and Souter, N. 2009. Bookpurnong Living Murray Pilot Project: A trial of three floodplain water management techniques to improve vegetation condition, DWLBC Report 2009/21, Government of South Australia, Department of Water, Land and Biodiversity Conservation, Adelaide.

Beyer, K., Marsland, K. B., Sharpe, C., Wallace, T., Zampatti, B. P and Nicol, J. M. 2010. Fish and Fish Habitats of the Pike River Anabranch and Floodplain Complex., SARDI Report. SARDI Publication Number F2009/000000-1.

Bice, C.M., Zampatti, B.P., Aldridge, K.A., Furst. D., Kilsby, N., Maxwell, S., Nicol, J., Oliver, R., Rogers, D., Turner, R. and Wallace, T. 2014. An assessment of the knowledge requirements to support effective provisions of environmental water in the South Australian Murray-Darling Basin: Part 2 – Development of hydro-ecological conceptual models and identification of knowledge gaps in current understanding of flow–biota relationship Prepared by the South Australian Research and Development Institute (Aquatic Sciences) for the Goyder Institute for Water Research. Goyder Institute for Water Research Technical Report Series No. 14/18, Adelaide, South Australia. ISSN: 1839-2725

Bice, C.M., Zampatti, B.P. and Suitor, L.R.K. 2015. Fish assemblage condition monitoring in the Katarapko Anabranch 2015. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2015/000634-1. SARDI Research Report Series No. 866.

Bloss, C.M., Steggles, T., Bald, M and Heneker, T.M. 2012. Hydro-ecological Analysis of the Proposed Basin Plan – South Australian Floodplain DFW Technical Report 2012/11, Government of South Australia, Department for Water, Adelaide

Brookes, J.D., Baldwin, D., Wallace, T and Burch, M. 2007. *Ecological evaluation of proposed flow control structure at Chowilla significant ecological asset*. Report prepared for the Department of Water, Land and Biodiversity Conservation.

Burnell, R., Fisher, G and Peters, B. 2012. Stream Stability Assessment and Assumptions Eckerts Creek Risk Assessment of Management Options. A report produced by Australian Water Environments for the Adelaide University.

Denny, M. in prep-a. SARFIIP – Pike Floodplain Hydraulic Modelling; Pre-Development, Current and Basin Plan Flow Scenarios for Pike Floodplain Inundation Ecological Comparison Draft. Report for Department of Environment, Water and Natural Resources (DEWNR).

Denny, M. in prep-b. SARFIIP – Katarapko Floodplain Hydraulic Modelling; Pre-Development, Current and Basin Plan Flow Scenarios for Pike Floodplain Inundation Ecological Comparison Draft. Report for Department of Environment, Water and Natural Resources (DEWNR).

Department of Environment and Natural Resources (DENR). 2012a. Katfish Reach Monitoring Plan Working Draft.

Department of Environment, Water and Natural Resources (DEWNR). 2015. Figure prepared by Salinity Management Measures team, SARFIIP.

Department of Environment, Water and Natural Resources (DEWNR). 2012 Riverine Recovery: Monitoring and Evaluation Program - Conceptual understanding of the ecological response to water level manipulation, DEWNR, Adelaide, South Australia.

Department of Environment, Water and Natural Resources (DEWNR) 2013a. South Australian Murray-Darling Basin Environmental Works and Measures Feasibility Program Volume 3: Katarakpo Floodplain Sustainable Diversion Limit Feasibility Investigation, DEWNR, Adelaide, South Australia.

Department of Environment, Water and Natural Resources (DEWNR). 2013b. Katfish Reach (Katarapko-Eckert Creek Floodplain) Infrastructure Enhancement Business Case Section 3: A component of the SA Riverland Floodplains Integrated Infrastructure Program (Cabinet in confidence, not for circulation).

Doody, T.M., Colloff, M.J,, Davies. M., Koul, V., Benyon, R.G., and Nagler, P.L. 2014. Quantifying water requirements of riparian river red gum (Eucalyptus camaldulensis) in the Murray-Darling Basin, Australia - implications for the management of environmental flows Ecohydrology doi: 10.1002/eco.1598

Ecological Associates and Australian Water Environments (AWE). 2008. Pike River Floodplain Management Plan, South Australian Murray-Darling Basin Natural Resources Management Board

Ecological Associates and Tonkin Consulting. 2015a. Pike Floodplain Inundation Measures: Management Options Development.

Ecological Associates and Tonkin Consulting. 2015b. Pike Floodplain Inundation Measures Management Options Development: Operational Plan and Engineering Feasibility Review.

Ecological Associates. 2010. The Environmental Water Requirements of the South Australian River Murray Ecological Associates report AQ010-2-D prepared for South Australian Murray-Darling Basin Natural Resources Management Board, Adelaide.

Ecology Partners. 2009. An evaluation of the proposed Chowilla Creek environmental regulator on frog populations, Chowilla Floodplain, South Australia and New South Wales Ecology Partners Pty. Ltd., Brunswick.

Fuller, A. D and Telfer, A. L. 2007. The Living Murray: Environmental Works and Measures Risk Assessment at Icon Sites. Murray-Darling Basin Commission.

Gippel, C., Anderson, B. G and Andersen, S. 2008. Evaluation of the impacts of operating proposed infrastructure on geomorphology of the Chowilla Floodplain. In: A report produced by Fluvial Systems Pty Ltd, Stockton for the South Australian Department of Water, Land and Biodiversity Conservation.

Hollis, B. A., 2010. Pike Investment Proposal. Report prepared for Department of Water, Land and Biodiversity Conservation.

Hollis, B.A., Fordham, A.E. and R.A., Thompson. 2010. Pike Implementation Plan. Berri: Department for Water, 2010.

Ireland, L., Suitor, L. and M, Harper. 2012. Katfish Reach Monitoring Plan. DEWNR Report.

Jacobs. 2014. SARFIIP Project Definition and Options Assessment Pike Floodplain. Task 3.1.5 Management Options High Level Assessment. Report for DEWNR VE23879.

Jacobs SKM. 2014a. SARFIIP Project Implementation Plan: Pike Floodplain Inundation Measures Final Rev 3.0. Report for DEWNR.

Jacobs SKM. 2014b. SARFIIP Project Implementation Plan: Salinity Management Measures Final Rev 3.0. Report for DEWNR.

Jacobs SKM. 2014c. SARFIIP Project Implementation Plan: Katfish Reach Floodplain Inundation Measures Final Rev 0. Report for DEWNR.

Jensen, A.E. 2008. The roles of seed banks and soil moisture in recruitment of semi-arid floodplain plants: The River Murray, Australia PhD Thesis, University of Adelaide, Australia

Jones, M. J and Stuart, I. G. 2009. Lateral movement of common carp (Cyprinus carpio L.) in a large lowland river and floodplain. Ecology of Freshwater Fish, 18(1), 72-82.

Junk, W. J., Bayley, P. B and Sparks, R. E. 1989. The flood pulse concept in river-floodplain systems. Canadian Special Publication of Fisheries and Aquatic Sciences 106, 110-127.

Katfish Reach Steering Group. 2008. Katfish Reach Implementation Plan.

Kilsby, N. and Steggles, T. 2015. Ecological Objectives, Targets and Environmental Water Requirements for the South Australian River Murray Floodplain Priority Environmental Asset. Report for Department of Environment, Water and Natural Resources (DEWNR).

Leblanc, M., Tweed, S., Van Dijk, A and Timbal, B. 2012. A review of historic and future hydrological changes in the Murray-Darling Basin Global and Planetary Change 80-81, 226-246.

Lintermans, M .2007. Fishes of the Murray-Darling Basin: An introductory guide MDBC Publication No. 10/07 ISBN 1 921257 20 2.

Maheshwari, B.L., Walker, K.F and McMahon, T.A. 1995. Effect of regulation on the flow regime of the River Murray, Australia Regulated Rivers: Research & Management 10: 15–38.

Mallen-Cooper, M., Koehn, J., King, A., Stuart, I. and Zampatti, B. 2008. Risk Assessment of the Proposed Chowilla Regulator and Managed Floodplain Inundations on Fish. Report produced by Fishway Consulting Services & Arthur Rylah Institute for Environmental Research for Department of Water, Land and Biodiversity Conservation, Government of South Australia.

Mallen-Cooper, M., Zampatti, B., Hillman, T., King, A., Koehn, J., Saddlier, S., Sharpe, S. and Stuart, I. 2011. Managing the Chowilla Creek Environmental Regulator for Fish Species at Risk. Report prepared by the Department of Sustainability and Environment, Fishway Consulting Services, South Australian Research and Development Institute, and Arthur Rylah Institute for Environmental Research for the South Australian Murray-Darling Basin Natural Resources Management Board, Berri, South Australia.

McCullough, D.P. 2013. Riverine Recovery Pike Floodplain Hydraulic Modelling 2012–13, DEWNR Technical Note, Government of South Australia, DEWNR, Berri.

McCullough, D. P. 2014. Riverine Recovery Katfish Reach Hydraulic Modelling 2012–13, Riverine Recovery Project Technical Note, Government of South Australia, DEWNR, Berri.

McCullough, D.P. in prep-a. Pike Floodplain Hydraulic Modelling Review and Model Optimisation, DEWNR Technical Note 2016/XX (Draft), Government of South Australia, DEWNR, Berri.

McCullough, D.P. in prep-b. Katarapko Floodplain Hydraulic Modelling Review and Model Optimisation, DEWNR Technical Note 2016/XX (Draft), Government of South Australia, DEWNR, Berri.

McCullough, D., et al. in prep-a. SARFIIP – Katarapko Floodplain Hydraulic Modelling, Managed Inundation Options Assessment Scenarios, (Draft). Report for DEWNR.

McCullough, D., et al. in prep-b. SARFIIP – Pike Floodplain Hydraulic Modelling, Managed Inundation Options Assessment Scenarios, (Draft). Report for DEWNR.

Montazeri, M and McCullough, D. 2016a. Pike Floodplain Hydraulic Modelling – Natural, Current and Basin Plan Flow Scenarios. A report prepared for DEWNR).

Montazeri, M and McCullough, D. 2016b Katarapko Floodplain Hydraulic Modelling – Natural, Current and Basin Plan Flow Scenarios. A report prepared for DEWNR.

Nicol, J. 2004. Vegetation dynamics of the Menindee Lakes with reference to the seed bank PhD Thesis, University of Adelaide, Adelaide, Australia

Roberts, J and Marston, F. 2011. Water regime for wetland and floodplain plants: a source book for the Murray–Darling Basin. National Water Commission, Canberra.

Rogers, K and Ralph, T.J. 2010. Floodplain wetland biota in the Murray-Darling basin: water and habitat requirements, CSIRO publishing, Collingwood, Victoria, Australia.

Ryder, D. 2004. Response of epixylic biofilm metabolism to water level variability in a regulated floodplain river. Journal of North American Benthological Society, 23, 214-223.; Wallace T.A. (2013) An assessment of the capacity for variation in flows to influence biofilms in the lower Darling River. July 2013. Report prepared by The University of Adelaide for the Murray Darling Basin Authority.

Smith, F.M and Kenny, S.K. 2005. Floristic Vegetation and Tree Health Mapping, River Murray Floodplain, South Australia, Department of Environment and Heritage, Adelaide. Internal Report.

Tonkin Consulting. 2015. Geotechnical Investigation Report, Pike Floodplain. Ref No. 20141227RA1. A report for the Department of Environment and Natural Resources (DENR). Pg 96

URS. 2009. Final Report: Concept Designs for the Katfish Reach Hydrological and Fish Passage Structures. A report for the Department for Environment and Heritage.

URS. 2010. Final Report: Conceptual Designs for Surface Water Management Infrastructure for the Pike Floodplain. A report for the South Australian Murray-Darling Basin Natural Resources Management Board.

URS. 2015. Geotechnical Investigation Factual Report. Report prepared for the DEWNR. November 2015.

Wallace, T. in prep. SARFIIP Conceptual Models, Pike and Eckerts-Katarapko Floodplains.

Wallace, T.A. 2011. An ecological assessment of benefits and risks associated with the proposed management actions for the Pike River and its floodplain. Report prepared for the DEWNR. South Australian Government. November 2011. 190 pp.

Wallace, T.A. 2012. An ecological assessment of benefits and risks associated with the proposed management actions for the Eckerts Creek-Katarapko Creek Floodplain Complex. Report prepared for DEWNR, South Australian Government. June 2012.

Wallace, T.A. 2009. An assessment of Tree Condition at the Pike Floodplain (South Australia). A report prepared by the Murray-Darling Freshwater Research Centre for the South Australian Murray-Darling Basin Natural Resources Management Board.

Wallace, T.A., Daly, R., Aldridge, K.T., Cox, J., Gibbs, M.S., Nicol, J.M., Oliver, R.L., Walker, K.F., Ye, Q and Zampatti, B.P. 2014a. River Murray Channel: Environmental Water Requirements: Ecological Objectives and Targets Goyder Institute for Water Research Technical Report Series No. 14/4, Adelaide, South Australia. ISSN: 1839-2725.

Wallace, T.A., Daly, R., Aldridge, K.T., Cox, J., Gibbs, M.S., Nicol, J.M., Oliver, R.L., Walker, K.F., Ye, Q and Zampatti, B.P. 2014b. River Murray Channel Environmental Water Requirements: Hydrodynamic Modelling Results and Conceptual Models Goyder Institute for Water Research Technical Report Series No. 14/5, Adelaide, South Australia. ISSN: 1839-2725.

Walker, K.F and Thoms, M.C. 1993. Environmental effects of flow regulation on the lower river Murray, Australia Regulated Rivers: Research & Management, 8: 103-119

Walker, K.F. 2006. Serial weirs, cumulative effects: the Lower River Murray, Australia In R. Kingsford (ed.). The Ecology of Desert Rivers . CUP. pp. 248- 279.

Water Technology. 2009. Pike River Project Hydraulic Model Development, Water Technology, September 2009, Reference No. J1149_D01, report for South Australian Murray-Darling Basin Natural Resources Management Board.

Water Technology. 2010. Katfish Reach Modelling – Calibration and Scenarios, Water Technology, Reference No. J874/R03, report for Department for Environment and Heritage.

Willoughby, N., Suitor, L and Wallace, T. 2015. SARFIIP Preliminary Investigations: Ecological Knowledge Review for the Katfish Reach and Pike Floodplains. Report for DEWNR.

Woods, J, Li, C., Bushaway, K., Laattoe, T., Riches, V., Green, G and Peat, V. in prep. SARFIIP Salinity Management Measures – Simple Groundwater Modelling (Task E), DEWNR Technical report 2014/XX, Government of South Australia, DEWNR, Adelaide.

Young, W.J., Scott, A.C., Cuddy, S.M and Rennie, B.A. 2003. Murray Flow Assessment Tool: a technical description CSIRO Land and Water: Canberra.

17 Appendices

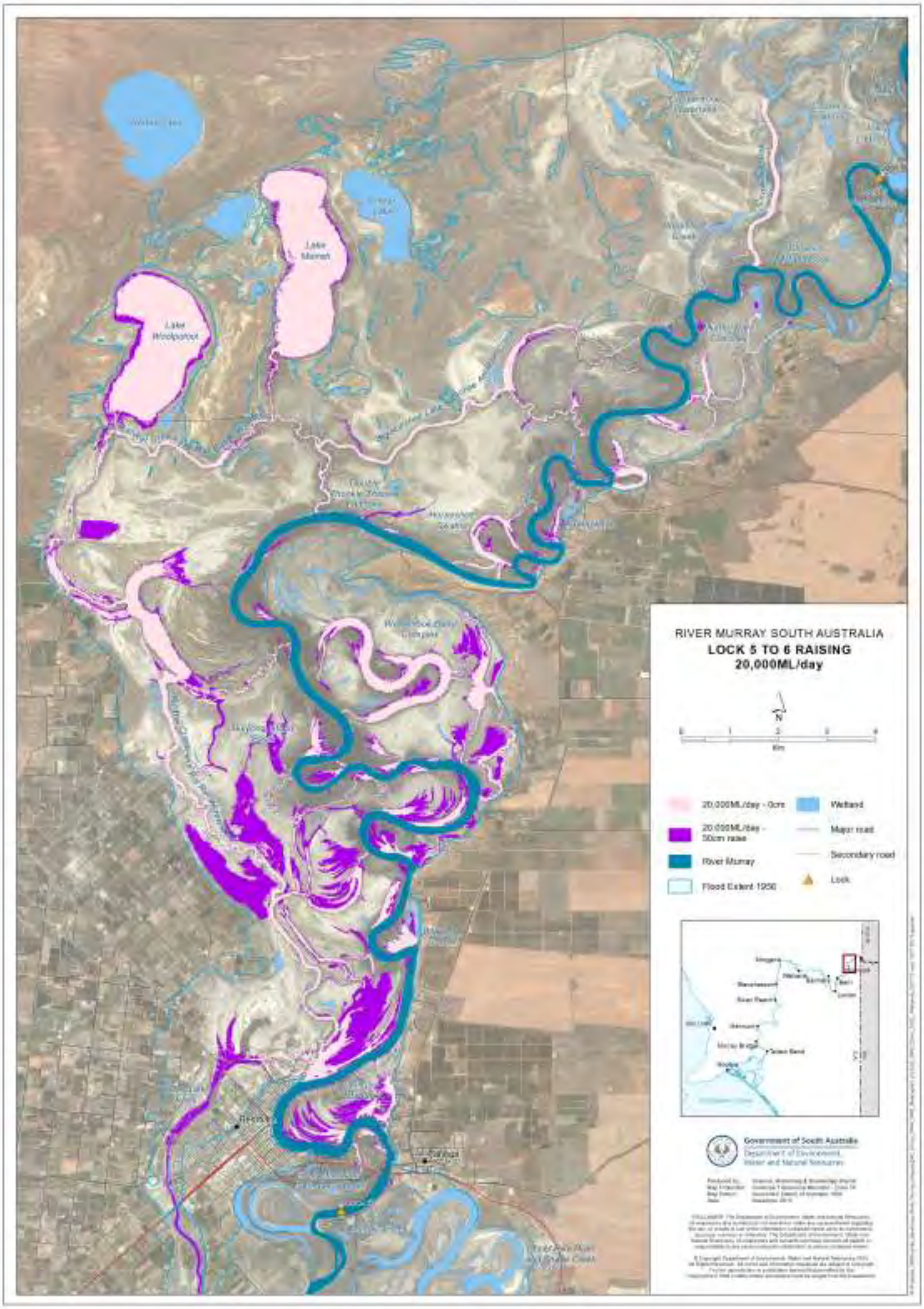
Appendix 1: Relevant document sections that address the evaluation criteria.

Note that as an existing project not seeking Commonwealth funds through the SDL adjustment process, there are a number of evaluation criteria not addressed in this proposal as specified by the Phase 2 Assessment Guidelines.

Key evaluation criteria	Guidelines Reference	Relevant Document and section of Document
Eligibility	Section 3	Section 3
Project details	Section 4.1	Section 2
Ecological values of the site	Section 4 2	Section 4
Ecological objectives and targets	Section 4.3	Section 6
Anticipated ecological benefits	Section 4.4.1	Section 8
Potential adverse ecological impacts	Section 4.4.2	• Potential adverse ecological impacts – Section 9 • Monitoring and evaluation – Section 8
Current hydrology and proposed changes to the hydrology	Section 4.5.1	Section 10
Environmental water requirements	Section 4.5.2	Section 7
Operating regime	Section 4.6	Section 11
Assessment of risks and impacts of the operation of the measure	Section 4.7	Section 12
Technical feasibility and fitness for purpose	Section 4.8	Section 13
Complementary actions and interdependencies	Section 4 9	Section 14
Costs, Benefits and Funding Arrangements for Projects not seeking Commonwealth Supply or Constraint Measure Funding	Section 4.10.2	Section 15

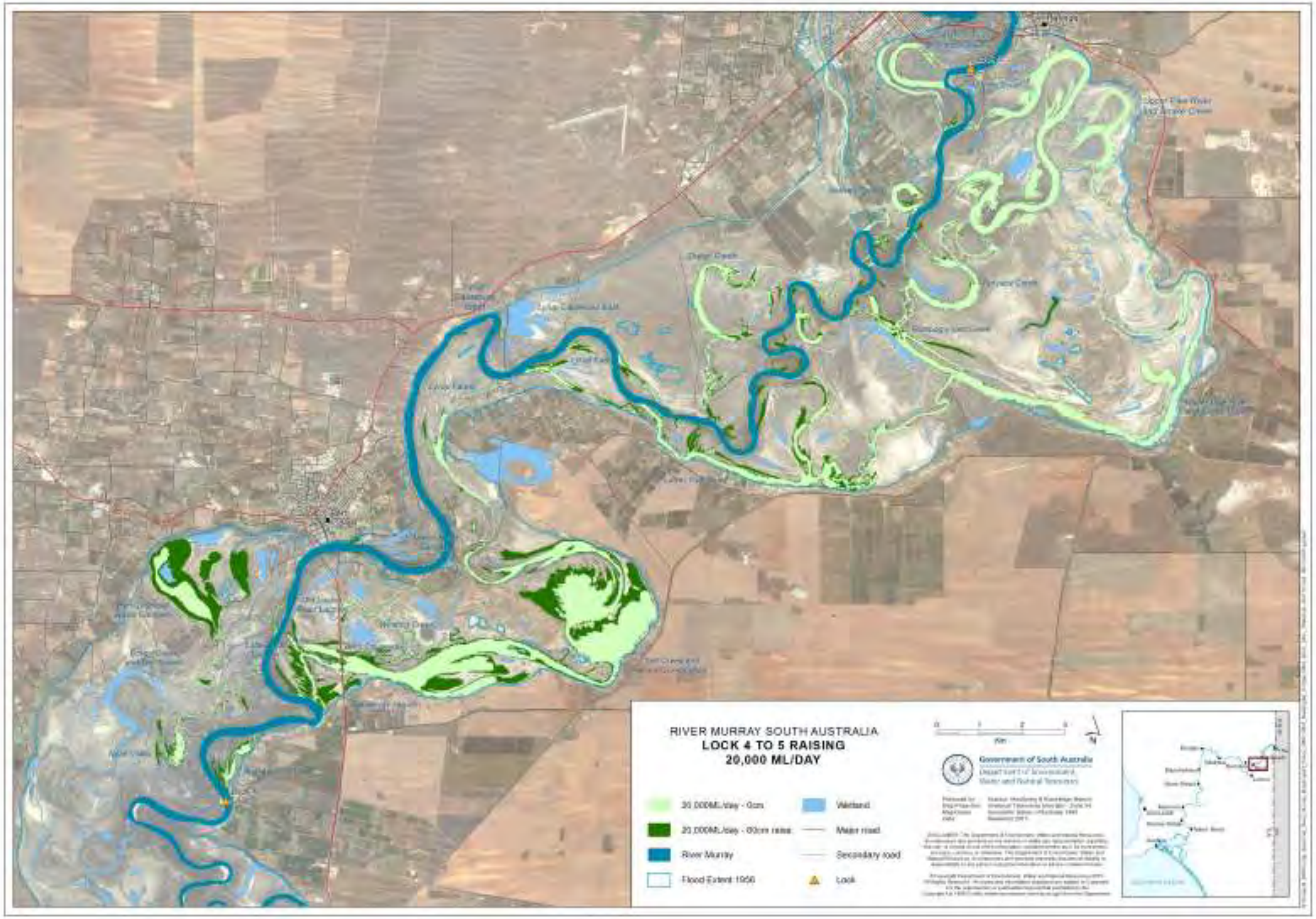
Appendix 2: Weir pool 5 raising inundation extent maps

Additional Floodplain area inundated through raising Weir 5 by 500 mm.



Appendix 3: Weir pool 4 raising inundation extent maps

Additional Floodplain area inundated through raising Weir 4 by 600 mm.



Appendix 4: Pike Floodplain – inundation extents of dominant water dependent vegetation

Area (ha) of dominant water dependent vegetation types and temporary wetlands inundated by the measure at Pike Floodplain at different flow bands (ML/d).

Flow band ML/day	Black Box woodland	Lignum shrubland	Red Gum forest and woodland	Tea Tree	Samphire	Flood dependent grassland	Emergent sedgeland	Temporary wetlands
10 000	9	11	36	0	3	0.3	12	5
20 000	9	11	36	0	3	0.3	12	4
30 000	9	11	36	0	3	0.3	12	4
40 000	13	19	56	0	5	2	14	5
50 000	23	77	87	0	14	3	17	13
60 000	55	199	132	0	46	10	23	33
70 000	118	291	172	0.4	69	13	23	54
80 000	189	354	206	0.6	93	162	23	72

Appendix 5: Katarapko Floodplain – inundation extents of dominant water dependent vegetation

Area (ha) of dominant water dependent vegetation types and temporary wetlands inundated by the measure at Katarapko Floodplain at different flow bands (ML/d).

Flow band ML/day	Black Box woodland	Lignum shrubland	Cooba	Red Gum forest and woodland	Tea Tree	Samphire	Flood dependent grassland	Emergent sedgeland	Temporary wetlands
25 000	3	3	0.0	7	0	2	2	0.4	2
35 000	6	14	0.3	20	0	10	4	1.1	4
50 000	56	98	0.6	100	0	29	19	11	24
55 000	104	182	0.7	180	6	63	36	17	39
65 000	202	311	0.8	305	16	109	76	22	46
70 000	235	348	1	345	22	124	88	24	47
75 000	266	369	2	372	27	141	95	26	48

Attachment 2: Level-volume-area relationships for Pike and Katarapko Floodplains and Weir Pool 4 and 5

Pike Floodplain

Level	LOWER PIKE		MUNDIC		TOTAL_PIKE	
m AHD	Area (ha)	Volume (ML)	Area, ha	Volume (ML)	Area, ha	Volume (ML)
10.65	0.00	0.00	0.00	0.00	0.00	0.00
10.70	0.01	0.01	0.00	0.00	0.01	0.01
10.75	0.01	0.01	0.00	0.00	0.01	0.01
10.80	0.01	0.01	0.00	0.00	0.01	0.02
10.85	0.02	0.02	0.00	0.00	0.02	0.02
10.90	0.03	0.03	0.00	0.00	0.03	0.03
10.95	0.03	0.05	0.00	0.00	0.03	0.05
11.00	0.04	0.07	0.00	0.00	0.04	0.07
11.05	0.05	0.09	0.00	0.00	0.05	0.09
11.10	0.06	0.12	0.00	0.00	0.06	0.12
11.15	0.06	0.15	0.00	0.00	0.06	0.15
11.20	0.07	0.18	0.00	0.00	0.07	0.18
11.25	0.08	0.22	0.00	0.00	0.08	0.22
11.30	0.09	0.26	0.00	0.00	0.09	0.26
11.35	0.09	0.30	0.00	0.00	0.10	0.30
11.40	0.10	0.35	0.00	0.00	0.10	0.35
11.45	0.11	0.41	0.00	0.00	0.11	0.41
11.50	0.13	0.47	0.00	0.00	0.13	0.47
11.55	0.15	0.54	0.00	0.00	0.15	0.54
11.60	0.17	0.62	0.00	0.00	0.17	0.62
11.65	0.19	0.71	0.01	0.01	0.20	0.71
11.70	0.21	0.81	0.02	0.01	0.23	0.82
11.75	0.23	0.91	0.04	0.03	0.27	0.94
11.80	0.26	1.03	0.09	0.06	0.36	1.09
11.85	0.31	1.17	0.16	0.12	0.47	1.29
11.90	0.35	1.33	0.29	0.23	0.64	1.56
11.95	0.39	1.51	0.47	0.42	0.86	1.93
12.00	0.44	1.72	0.73	0.71	1.18	2.43
12.05	0.52	1.96	1.08	1.15	1.60	3.11
12.10	0.63	2.24	1.71	1.84	2.34	4.08
12.15	0.77	2.59	2.49	2.87	3.26	5.46
12.20	0.92	3.00	3.59	4.37	4.51	7.38
12.25	1.09	3.50	5.20	6.53	6.29	10.03
12.30	1.33	4.10	7.59	9.69	8.92	13.79
12.35	1.64	4.83	10.73	14.22	12.36	19.05
12.40	2.08	5.74	14.22	20.46	16.29	26.20
12.45	2.73	6.92	18.10	28.47	20.83	35.39
12.50	3.67	8.49	23.81	39.02	27.48	47.51
12.55	4.94	10.61	27.93	51.97	32.86	62.58
12.60	6.63	13.46	31.73	66.88	38.36	80.34
12.65	9.28	17.33	35.54	83.68	44.82	101.01
12.70	14.87	23.27	39.04	102.32	53.91	125.59
12.75	21.59	32.29	42.32	122.64	63.91	154.93
12.80	28.49	44.84	45.49	144.57	73.99	189.42

12.85	34.66	60.63	48.40	168.04	83.06	228.67
12.90	41.72	79.77	51.19	192.91	92.91	272.68
12.95	47.60	102.11	53.93	219.15	101.53	321.27
13.00	52.95	127.19	57.38	246.87	110.33	374.06
13.05	57.72	154.87	61.42	276.54	119.14	431.40
13.10	61.69	184.62	64.63	308.04	126.32	492.66
13.15	66.11	216.42	67.59	341.02	133.70	557.44
13.20	72.66	250.83	71.06	375.58	143.72	626.41
13.25	77.68	288.48	74.63	411.88	152.32	700.35
13.30	82.46	328.40	78.10	449.95	160.56	778.35
13.35	88.32	371.03	81.91	489.80	170.24	860.84
13.40	95.66	416.96	86.21	531.73	181.87	948.69
13.45	106.08	467.12	90.50	575.85	196.57	1042.97
13.50	120.36	523.83	94.31	621.95	214.67	1145.78
13.55	131.42	586.73	98.00	669.93	229.42	1256.66
13.60	142.90	655.03	101.06	719.56	243.96	1374.59
13.65	153.65	729.21	103.75	770.64	257.40	1499.86
13.70	161.87	808.02	106.15	823.00	268.02	1631.01
13.75	168.50	890.46	108.39	876.49	276.89	1766.95
13.80	174.53	976.06	110.58	931.06	285.11	1907.12
13.85	179.84	1064.49	112.65	986.72	292.49	2051.21
13.90	184.32	1155.28	114.88	1043.44	299.20	2198.72
13.95	188.00	1248.09	118.99	1101.57	306.99	2349.66
14.00	191.35	1342.57	124.40	1162.18	315.74	2504.75
14.05	194.50	1438.70	127.67	1225.05	322.17	2663.76
14.10	197.80	1536.42	130.40	1289.39	328.20	2825.81
14.15	201.02	1635.81	133.22	1355.09	334.24	2990.90
14.20	203.95	1736.79	136.16	1422.21	340.10	3159.00
14.25	206.66	1839.16	138.72	1490.74	345.38	3329.90
14.30	209.39	1942.88	140.97	1560.49	350.36	3503.36
14.35	213.27	2048.25	143.05	1631.33	356.32	3679.58
14.40	219.45	2156.19	145.05	1703.22	364.50	3859.41
14.45	230.40	2268.38	147.12	1776.13	377.53	4044.51
14.50	245.93	2387.61	149.45	1850.16	395.37	4237.77
14.55	259.70	2514.19	152.48	1925.55	412.18	4439.74
14.60	273.14	2647.55	155.98	2002.57	429.12	4650.13
14.65	288.60	2788.17	159.97	2081.48	448.57	4869.65
14.70	306.38	2937.09	164.76	2162.59	471.14	5099.68
14.75	325.41	3095.30	175.90	2247.66	501.31	5342.96
14.80	346.30	3263.40	191.26	2339.56	537.56	5602.95
14.85	367.59	3441.97	207.18	2439.25	574.77	5881.22
14.90	389.69	3631.35	223.23	2547.02	612.91	6178.37
14.95	412.46	3832.00	238.71	2662.63	651.17	6494.63
15.00	434.69	4043.78	254.08	2785.94	688.77	6829.72
15.05	458.27	4266.98	269.47	2916.85	727.74	7183.83
15.10	483.80	4502.45	284.54	3055.39	768.33	7557.85
15.15	510.66	4751.02	299.38	3201.38	810.04	7952.39
15.20	538.86	5013.30	314.13	3354.79	852.99	8368.09
15.25	568.21	5290.05	328.61	3515.51	896.82	8805.56

15.30	597.96	5581.55	342.31	3683.32	940.27	9264.87
15.35	627.79	5887.99	355.84	3857.94	983.63	9745.93
15.40	658.10	6209.44	369.42	4039.29	1027.52	10248.72
15.45	690.45	6546.47	383.14	4227.50	1073.58	10773.97
15.50	727.26	6900.59	397.20	4422.65	1124.46	11323.23
15.55	770.11	7274.83	411.56	4624.91	1181.67	11899.74
15.60	814.34	7671.09	425.94	4834.36	1240.28	12505.45
15.65	855.80	8088.84	439.94	5050.92	1295.74	13139.76
15.70	896.54	8526.91	453.74	5274.45	1350.28	13801.35
15.75	938.92	8985.86	467.27	5504.82	1406.20	14490.68
15.80	980.23	9465.78	480.35	5741.89	1460.58	15207.67
15.85	1021.35	9966.29	492.81	5985.34	1514.16	15951.63
15.90	1062.94	10487.46	504.60	6234.87	1567.54	16722.33
15.95	1104.64	11029.48	516.06	6490.19	1620.69	17519.67
16.00	1147.46	11592.53	527.26	6751.19	1674.72	18343.72
16.05	1190.93	12177.31	537.76	7017.59	1728.69	19194.90
16.10	1233.68	12783.63	548.03	7289.18	1781.71	20072.81
16.15	1275.12	13411.03	558.02	7565.85	1833.14	20976.88
16.20	1315.75	14058.91	567.74	7847.39	1883.49	21906.31
16.25	1354.92	14726.77	576.77	8133.69	1931.69	22860.46
16.30	1393.04	15413.98	584.92	8424.30	1977.96	23838.28
16.35	1426.46	16119.27	591.77	8718.65	2018.23	24837.92
16.40	1449.03	16838.91	596.99	9016.02	2046.02	25854.93
16.45	1461.06	17566.95	600.73	9315.62	2061.80	26882.58
16.50	1468.10	18299.51	603.34	9616.77	2071.44	27916.28

Katarapko Floodplain

Elevation (m AHD)	Area (Ha)	Volume (ML)
9.8	0	0
9.85	0.049484	0.005138
9.9	0.205694	0.052421
9.95	0.396665	0.203422
10	0.597962	0.433796
10.05	0.82977	0.729982
10.1	1.088781	1.066382
10.15	1.407901	1.65462
10.2	1.741181	2.285883
10.25	2.087083	3.021352
10.3	2.43986	3.844607
10.35	2.795607	4.403674
10.4	4.345414	5.772262
10.45	5.486143	7.786675
10.5	6.893001	10.20489
10.55	8.740529	13.77367
10.6	24.2866	23.89525
10.65	26.82549	35.56073
10.7	29.5025	49.00049
10.75	33.39536	64.49386

10.8	39.44507	84.17218
10.85	42.42103	104.7155
10.9	45.62862	126.9753
10.95	50.67905	151.1558
11	56.39217	177.4198
11.05	61.03189	206.2414
11.1	65.46622	237.3882
11.15	69.18494	269.9521
11.2	72.45202	303.9787
11.25	75.73307	339.9132
11.3	79.3796	377.3503
11.35	83.1608	417.0239
11.4	87.13588	458.4201
11.45	94.18831	502.188
11.5	101.4051	549.1922
11.55	107.6213	601.0228
11.6	113.8453	655.3112
11.65	120.4101	713.1083
11.7	126.653	773.8945
11.75	133.1167	837.4562
11.8	139.6482	904.4509
11.85	146.8594	974.0867
11.9	153.9263	1047.918
11.95	161.6029	1125.258
12	169.5679	1207.145
12.05	177.9901	1293.694
12.1	186.2913	1383.586
12.15	195.1974	1477.482
12.2	204.6317	1575.803
12.25	214.6434	1678.883
12.3	224.3535	1786.642
12.35	234.2998	1899.738
12.4	245.276	2017.423
12.45	256.9235	2140.415
12.5	270.3565	2269.209
12.55	285.8087	2405.07
12.6	303.1128	2548.679
12.65	321.87	2701.979
12.7	342.5467	2864.492
12.75	364.6526	3038.129
12.8	387.7854	3223.583
12.85	412.4546	3420.83
12.9	438.8424	3630.323
12.95	466.8174	3853.872
13	496.6839	4091.963
13.05	530.747	4347.212
13.1	567.4403	4619.138
13.15	606.1964	4910.18
13.2	647.8304	5221.808

13.25	692.5093	5556.356
13.3	741.1214	5913.902
13.35	792.7355	6298.627
13.4	841.8825	6708.261
13.45	889.5543	7143.697
13.5	937.3544	7602.491
13.55	981.074	8088.142
13.6	1020.861	8592.904
13.65	1058.197	9119.144
13.7	1092.875	9664.916
13.75	1122.381	10227.7
13.8	1145.469	10805.52
13.85	1158.776	11396.66
13.9	1162.463	11989.27
13.95	1163.881	12572.42
14	1164.818	13155.38
14.05	1165.563	13738.5
14.1	1166.178	14321.84
14.15	1166.677	14905.49
14.2	1167.124	15489.28
14.25	1167.484	16072.95
14.3	1167.804	16657.32
14.35	1168.057	17241.61
14.4	1168.22	17826.08
14.45	1168.337	18410.61
14.5	1168.412	18995.02

Weir pool 4

Level (m AHD)	Volume (ML)	Surface Area (Ha)
0	0	0
10	0.001	1.00
10.15	16000	500
13.2	51000	2472.57
13.8	63000	3275.2
14.34	81000	4331.1
15	90000	5000

Weir pool 5

Level (m AHD)	Volume (ML)	Surface Area (Ha)
0	0	0
13.2	0.001	1.00
13.25	0.01	0.01
16.3	43000	2433.6
16.8	56700	3350.5

Attachment 3: Proposed operating rules for SARFIIP works and measures

Table 1. Summary of Proposed Operational Regimes at Pike Floodplain

Scenario			**Operations**				**Duration**			**Timing**		**Action Required**
Name	**Lower flow**	**Upper flow**	**Lock 5 Level**	**Tanayaca Ck Reg**	**Pike River Reg**	**Frequency**	**Time to raise**	**Minimum Duration**	**Draw-down time**	**Earliest Start**	**Return Normal**	
	ML/d	**ML/d**	**m AHD**	**m AHD**	**m AHD**	**1 in … yrs**	**days**	**days**	**days**			
Baseflow	-	35,000	16.3	14.75	14.35	1	-	-	-	-	-	400ML/day flowing into Deep Creek and Margaret Dowling Creek 400ML/day flowing via the Mundic outlets into Pike River 400ML/day flowing into Tanyaca Creek
Spring Fresh	-	35,000	16.3	15.3	14.85	1	7	30	14	August	January	600ML/day flowing into Deep Creek and Margaret Dowling Creek 700ML/day flowing via the Mundic outlets into Pike River 400ML/day flowing into Tanyaca Creek 100ML/day being impounded on the Mundic floodplain
Floodplain Inundation	15,000	30,000	16.8	16.4	16.4	2.85	30	30	40	August	January	600ML/day flowing into Deep Creek and Margaret Dowling Creek 400ML/day flowing via the Mundic outlets into Pike River 800ML/day flowing into Tanyaca Creek
River Through flow	35,000	90,000	16.3	14.75	14.35	-	-	-	-	-	-	Banks B, B2 and C fully open 600ML/day flowing into Deep Creek and Margaret Dowling Creek 400ML/day flowing via the Mundic outlets into Pike River Remaining flow entering Tanyaca Creek

Table 2. Summary of Operational Regimes for Katarapko Floodplain

Name	Flow band	Timing	Action required	Operating Regime
Katarapko Creek Base Flows	> 5,000ML/day	Possible all year	-	When river flows > 5,000ML/day
Eckert Creek Anabranch – Base Flows	< 35,000ML/day	Possible all year	Bank J 11.6 to 13.6mAHD , Banks K & N 12.6 to 13.8mAHD	
Eckert Creek Anabranch – Pulse Flows	< 35,000ML/day	Possible all year	Bank J 11.6 to 13.6mAHD , Banks K & N 12.6 to 13.8mAHD	Annual
Eckert Creek Wide-waters – Pool Level Variation	< 35,000ML/day	Spring/Summer (raising) Summer/Autumn (lowering)	Bank J 200ML/d -633ML/d Log Crossing full Open -150ML/d	Annual
Eckert Creek Anabranch – Temporary Partial Drying (Southern and Northern Arms & The Splash)	< 10,000ML/day	Summer/Autumn	Bank J 100-200ML/d Banks k &N, South Arm & Log Crossings Closed	3 years in every 5 years
Eckert Creek floodplain - managed floodplain inundation (low floodplain)	8,000- 20,000 ML/day	Spring / Summer	Lock 4 13.2m AHD; Regulators 11.8-12.7mAHD (2-2.9m @ Structures); ≤ 600ML/ d inflow at Bank J; ≤ 15ML/ d and 24ML/d inflows at Bank K & Bank N respectively	4 to 6 years in every 10
Eckert Creek floodplain - managed floodplain inundation (maximum extent)	>12,000 - 20,000 ML/day	Spring / Summer	Lock 4: ≤ 14.2m AHD; Regulators ≤ 13.9m AHD; ≤ 1,000ML/d inflow at Bank J; ≤ 210ML/d and 155ML/d inflows at Bank K & Bank N respectively (all structures drowned); Outfall Regulators set @ 13.5mAHD	4 to 6 years in every 10

Attachment 4 - Level-volume-area relationships

Pike Regulator Sill = 14.3 mAHD		
Level (mAHD)	Volume (ML)	Area (ha)
12	0	0
12.05	3.1	1.6
12.3	13.8	8.9
12.6	80.3	38.4
12.9	272.7	92.9
13.2	626.4	143.7
13.5	1145.8	214.7
13.8	1907.1	285.1
14.1	2825.8	328.2
14.4	3859.4	364.5
14.7	5099.7	471.1
15	6829.7	688.8
15.3	9264.9	940.3
15.5	11323.2	1124.5
15.6	12505.5	1240.3
15.9	16722.3	1567.5
16	18343.7	1674.7
16.2	21906.3	1883.5
16.4	25854.9	2046
16.5	27916.3	2071.4
17.0	34000	2400

Katarapko Sill = 9.9 mAHD		
Level (mAHD)	Volume (ML)	Area (ha)
10.40	5.8	4.3
10.55	13.8	8.7
10.60	23.9	24.3
11.00	177.4	56.4
11.40	458.4	87.1
11.60	655.3	113.8
11.90	1047.9	153.9
12.20	1575.8	204.6
12.50	2269.2	270.4
12.80	3223.6	387.8
12.95	3853.9	466.8
13.15	4910.2	606.2
13.35	6298.6	792.7
13.50	7602.5	937.4
13.65	9119.1	1058.2
13.85	11396.7	1158.8
14.15	14905.5	1166.7
14.50	18995.0	1168.4

In addition to the Level-Volume –Area relationships for the weir pools provided above, the storage and area in the reaches are affected by flow routing and travel time, based on the tables below. An explanation of the calculation of combined reach and weir storage and area is provided in MDBA Technical Report 2015/15.

Pike Regulator		
Flow (ML)	**Travel Time (days)**	**Area (ha)**
0	1.5	0
600	1.5	200
1200	0.8	200
3000	0.4	300
3700	0.4	300
4200	0.4	300
4600	0.4	300
4900	0.4	300
5100	0.4	300
30000	0.4	300

Katarapko Regulator		
Flow (ML)	**Travel Time (days)**	**Area (ha)**
0	0	0
230	0.05	130
700	1.7	150
800	4	150
900	4	150
1093	3	150
1741	3	370
4077	2	1000
5760	2	1500
30000	2	2000