ecological associates pty ltd

Pike River Floodplain Management Plan

South Australian Murray-Darling Basin Natural Resources Management Board

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BERRI SA 5343

December 2008

ECOLOGICAL ASSOCIATES AND
AUSTRALIAN WATER ENVIRONMENTS REPORT AQ006-1-B

Australian WATER Environments

Pike River Floodplain Management Plan
for South Australian Murray-Darling Basin Natural Resources Management Board
Ecological Associates Pty Ltd

Please cite as follows:

Ecological Associates and Australian Water Environments (2008). Pike River Floodplain Management Plan. Report AQ006-1-B prepared for the South Australian Murray-Darling Basin Natural Resources Management Board, Berri.

Document history and status

Revision	Date Issued	Revision Type
A	23 September 2008	Working Draft for Comment
B	22 December 2008	Draft Final Report
C	3 February 2009	Revised Final Draft

Distribution of copies

Revision	Copy No.	Quantity	Issued to
A	electronic		Rob Burnell
B	electronic		Rob Burnell
C	electronic		Rob Burnell

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Introduction

1.1 Introduction

Objectives of This Plan

The health of the River Murray and its floodplains, wetlands and other riverine environments is under threat from a range of processes including flow regulation, salinisation, over-extraction of water and land management practices. Recent dry climatic conditions have exacerbated floodplain degradation.

The Pike River floodplains is an important community asset and is used for nature appreciation, recreation and as a source of water for stock, domestic uses and irrigation. The community is becoming increasingly aware of its degradation and are seeking to take action to protect and restore it. Successful rehabilitation requires careful and thorough planning. This plan has been prepared to guide management of the Pike River floodplain.

This plan identifies assets and values, the extent to which processes threaten these values and develops strategies for management. The plan proposes coordinated management activities at local and regional scales relevant to the floodplain complex, integrates multi-disciplinary actions and prioritises actions so that the greatest benefits are obtained with the resources available. In addition, this plan provides:

- a business case for investment from funding bodies; and
- supporting evidence for the allocation of environmental flows to the Pike River floodplain.

1.2 Long Term, Aspirational Objectives

Central to this plan are the objectives which are set for the floodplain. These provide the main reference point for all future work and programs and are used to measure the success of the plan.

The following vision is proposed for the Pike River floodplain

"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."

From this vision, the following overall objectives have been identified:

- *to improve the condition of existing vegetation;*
- *to improve key aquatic riparian and terrestrial habitats required by native flora and fauna, including waterbirds, fish, reptiles, mammals and frogs;*
- *to achieve a sustainable balance between the needs of the various users of the floodplain; and*

- *to recognise and, where possible, respond to the needs of the existing productive users of the floodplain.*

2.1 Location and Extent of Floodplain

The Pike floodplain is a major floodplain and anabranch system of the River Murray located on the left bank downstream of Lock 5. It is located immediately downstream of Lock 5 and is within the weir pool of Lock 4.

The floodplain is defined as the area between the River Murray and the 1956 flood level between Lock 5, at Paringa, upstream and the Lower Pike River confluence, near Lyrup, downstream. These locations correspond to 564 river km upstream and 542 river km downstream. The area can be located on the 1:50,000 topographic maps:

- 7029-1 Paringa;
- 7029-1 Yamba;
- 7029-1 Loxton; and
- 7029-1 Renmark.

The total area is 7071 ha.

The floodplain features several watercourses and wetlands, many of which are permanently inundated. Water enters the system continuously from Lock 5 via two modified channels, first filling Mundic Creek and then flowing to the Upper Pike River. The Upper Pike River diverges to join the River Murray and the Lower Pike River. At elevated river levels, water spreads into low-lying wetlands and woodland areas adjacent to Mundic Creek, Tanyaca Creek and the River Murray, providing significant feeding and breeding habitat for waterbirds, fish, frogs and other fauna. At high river levels widespread inundation occurs to areas of Lignum Shrubland and Black Box woodland.

2.2 Land Use and Ownership

Landownership on the Pike floodplain can be categorised into three types:

- **Crown ownership.** The majority of the floodplain is owned by the Crown through the Minister for the Environment, with a significant portion of this land under annual lease to private operators. The remainder being used as conservation reserve.
- **Private freehold ownership** Most of the freehold ownership is in the northern section, with some small parcels around the eastern and southern edges.
- **Crown Lease** Several large sections in the centre of the floodplain are held by private operators through Crown Lease.

Sites managed for conservation include the Pike River Conservation Park and land owned by the National Trust of South Australia. Land ownership is presented in Figure 1.

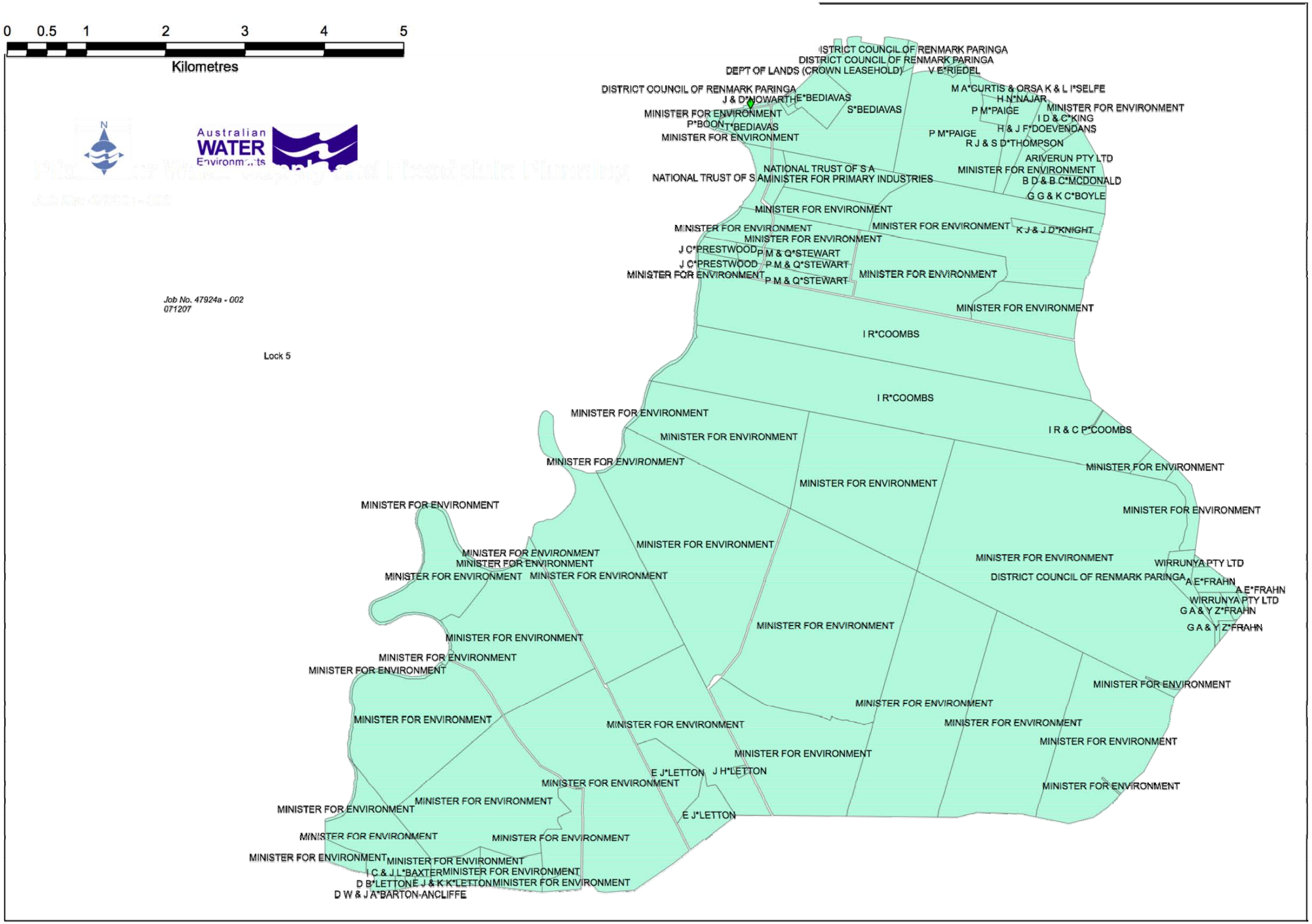

Figure 1. Pike River floodplain land ownership

2.3 Management Arrangements

This management plan has been commissioned under the Pike Implementation Plan (PIP) program. The objective of the PIP is to improve river water quality and protect the floodplain from further degradation arising from the irrigation induced and saline groundwater inflows to the waterbodies and floodplain.

Partners in this project include:

- the Department of Water, Land and Biodiversity Conservation (DWLBC);
- the Department for Environment and Heritage;
- SA Murray-Darling Basin Natural Resources Management Board (SA MDB NRM Board)
- Renmark to the Border Local Action Planning Association;
- Riverland Aboriginal Natural Resources Management Group;
- Pike River Land Management Group; and
- community members living and working in the Pike Mundic area.

2.4 Climate

The Renmark region has a semi-arid climate, characterised by hot dry summers and cool winters. The average maximum daily temperature is 24.3 ^{o}C. Temperatures generally peak in January with an average of 3 days over 40 ^{o}C, and mean temperatures of 32.5 ^{o}C. July is the coolest month on average. The average daily minimum temperature is 10.9 ^{o}C. Average daily minimums range from 5.1 ^{o}C in July to 16.7 ^{o}C in January.

Average annual rainfall is 260.6 mm, with higher rainfall and more frequent rain days in winter and spring (Table 1). Average annual evaporation is between 1600 and 1800 mm, well in excess of annual rainfall.

Table 1. Mean Monthly Minimum and Maximum Temperature (^oC, N = 45 years, 1959-2004), Rainfall (mm, N = 113 years, 1889-2004), and Days Rain at Renmark (Australian Bureau of Meteorology 2006)

	Month												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temp. (Max) ^oC	32.5	32.1	28.8	24.2	19.7	16.8	16.2	18.0	20.9	24.4	27.8	30.3	**24.3**
Temp. (Min) ^oC	16.7	16.6	14.2	10.8	8.2	5.9	5.1	6.0	8.2	10.7	13.2	15.1	**10.9**
Mean Rainfall (mm)	15.8	19.3	14.1	18.2	24.8	24.6	23.1	25.3	28.0	28.3	21.0	18.2	**260.6**
Mean Rain Days	2.9	2.8	2.9	4.3	6.3	7.7	8.2	8.5	6.9	5.8	4.4	3.5	**64.2**

2.5 Hydrostratigraphy

The River Murray in South Australia is located within a broad trench. The trench formed during the last ice age (approximately 2 million years ago) when sea levels were lower and the river accordingly cut deeper into the surrounding landscape. After sea levels rose, the trench gradually filled with the floodplain sediments of the Monoman Formation and Coonambidgal Formation (Figure 2).

The trench is cut into the Loxton-Parilla Sands which forms the unconfined or water table aquifer in highland areas. It is in direct connection with the Monoman Formation of the floodplain. Beneath the Loxton-Parilla Sands lie the Lower Loxton Clays and Bookpurnong Beds, which have low permeability and permit little groundwater flow. Below the Bookpurnong Beds lie the Murray Group Limestone which forms a regional aquifer.

Outside the floodplain, the Loxton-Parilla Sands are overlain by the Blanchetown Clay. These were laid down on the bed of an extensive paleo-lake, Lake Bungunnia and vary in thickness and extent. It frequently contributes to perched water tables and drainage problems in irrigation areas. The surface soil in the region is generally the Woorinen Formation which has characteristic orange sand which supports mallee vegetation.

The Loxton-Parilla Sands is recharged by infiltration in the broader mallee region and locally from irrigation drainage. Since the floodplain is the lowest point in the landscape, it is a natural groundwater discharge area to which groundwater flows. Groundwater from the naturally saline Loxton-Parilla Sands contributes to shallow groundwater in floodplain sediments, leading to soil and wetland salinisation.

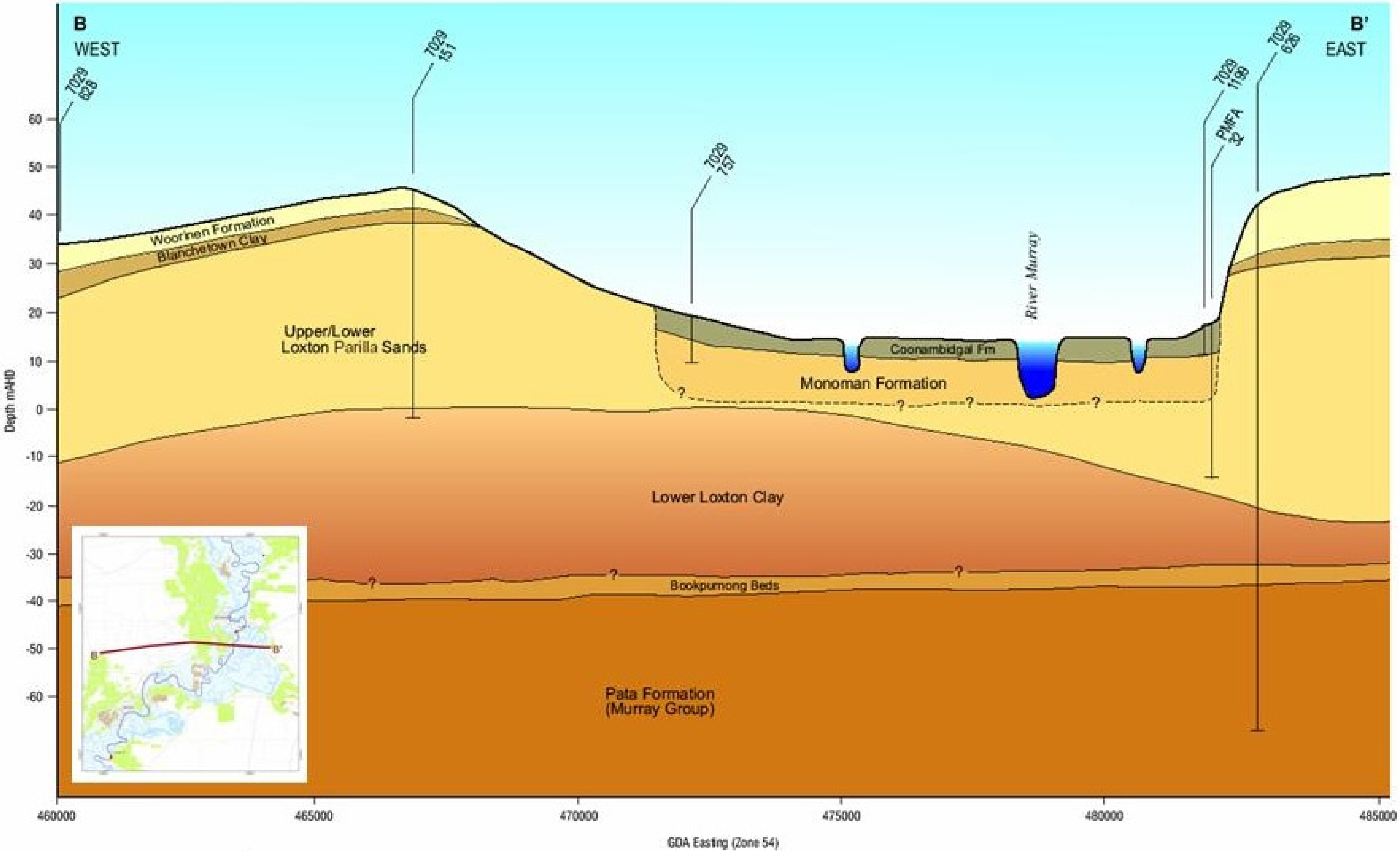

Figure 2. Cross section of the River Murray trench showing geological strata

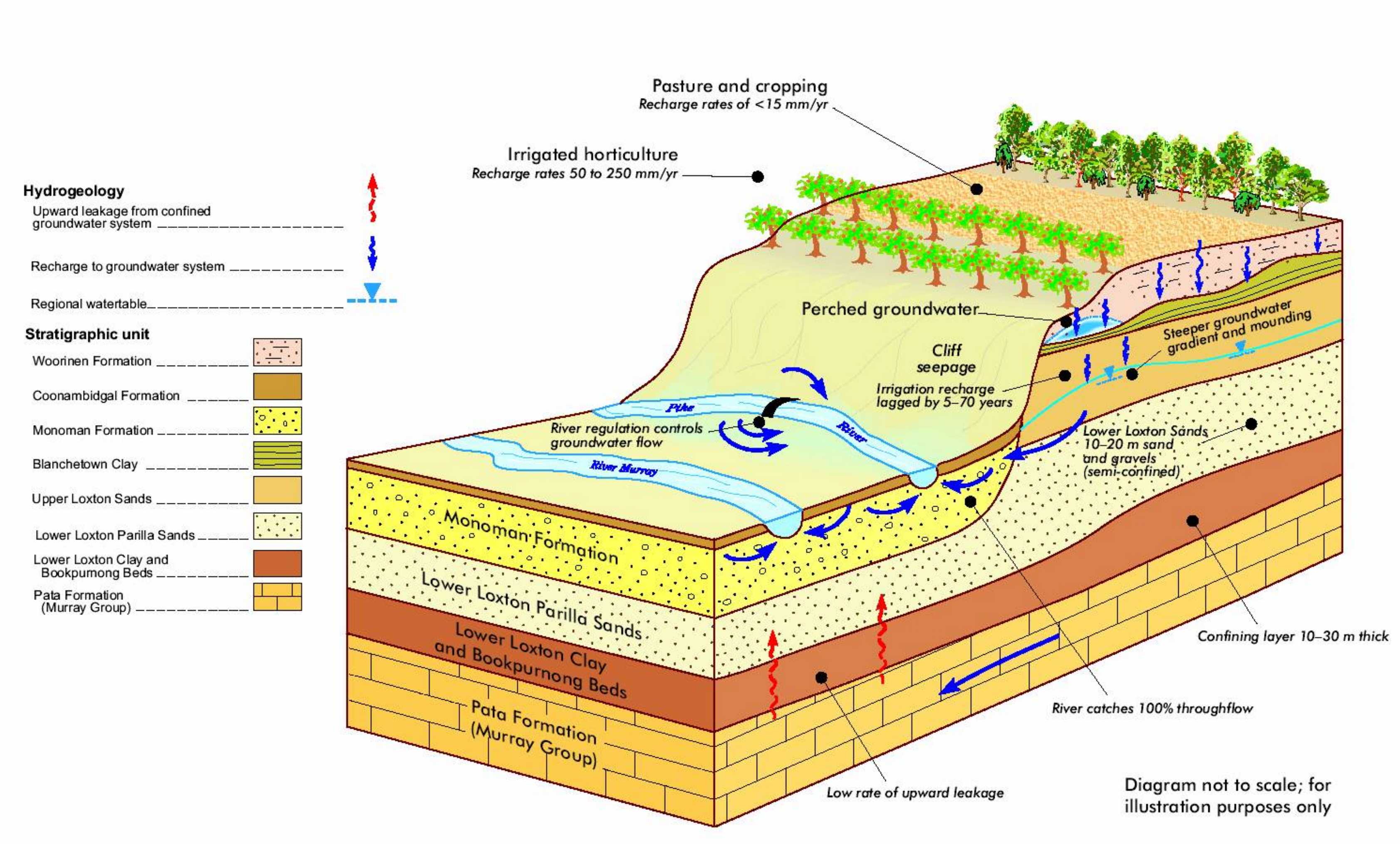

Figure 3. Hydrogeology of the Pike River

2.6 Principal Influences on the Groundwater Environment

River Murray Regulation

Water levels in the Pike River and its anabranches are predominantly controlled by Locks 4 and 5 on the main channel (Figure 4). Immediately above Lock 5, pool levels are held reasonably constant at about 16.3 m AHD, whilst downstream of Lock 5 and 'adjacent' to the Pike floodplain, pool levels are about 13.4 to 13.6 m AHD, eventually being held at about 13.2 just above Lock 4. As the intake to the Pike floodplain anabranches are just upstream of Lock 5 and the ultimate discharge from the anabranch is below Lock 5 there is a maximum head difference of about 2.9 m across the system, which provides the impetus for significant groundwater flows across the floodplain towards the mid-sections of Pike River and Rumpagunyah Creek.

Pike Anabranch Regulation

To ensure security of water supplies, irrigators have placed a regulator at Col Col Embankment (Figure 4) which holds water above the embankment at 14.3 m AHD and below the embankment at 13.4 m AHD downstream (REM-Aquaterra 2005). This has a significant effect on the 'regional' floodplain aquifer and would be responsible for some aquifer flushing and freshening locally around the regulator structure.

Floodplain Inundation

Inundation of the floodplain for extended periods provides the potential for significant flood-recession salt loads to be driven from the floodplain aquifer into either the Pike anabranch system or the main channel as a result of increased recharge to the aquifer. The location and degree of increased recharge beneath inundated areas is strongly dependent on the presence, thickness and nature of the Coonambidgal Formation clays. The distribution of the Coonambidgal Formation clays is not well known on the Pike floodplain, but is expected to be quite variable. However, a 'minimum' one metre thickness of silty clay has been recorded in all drillholes with available lithological logs. Increased salt loads from floodplain inundation may also be a result of surficial flushing of salt stores.

Flooding may have a longer term benefit for floodplain vegetation by flushing the soil profile of salts and building a lens of fresh to brackish water on the saline water table.

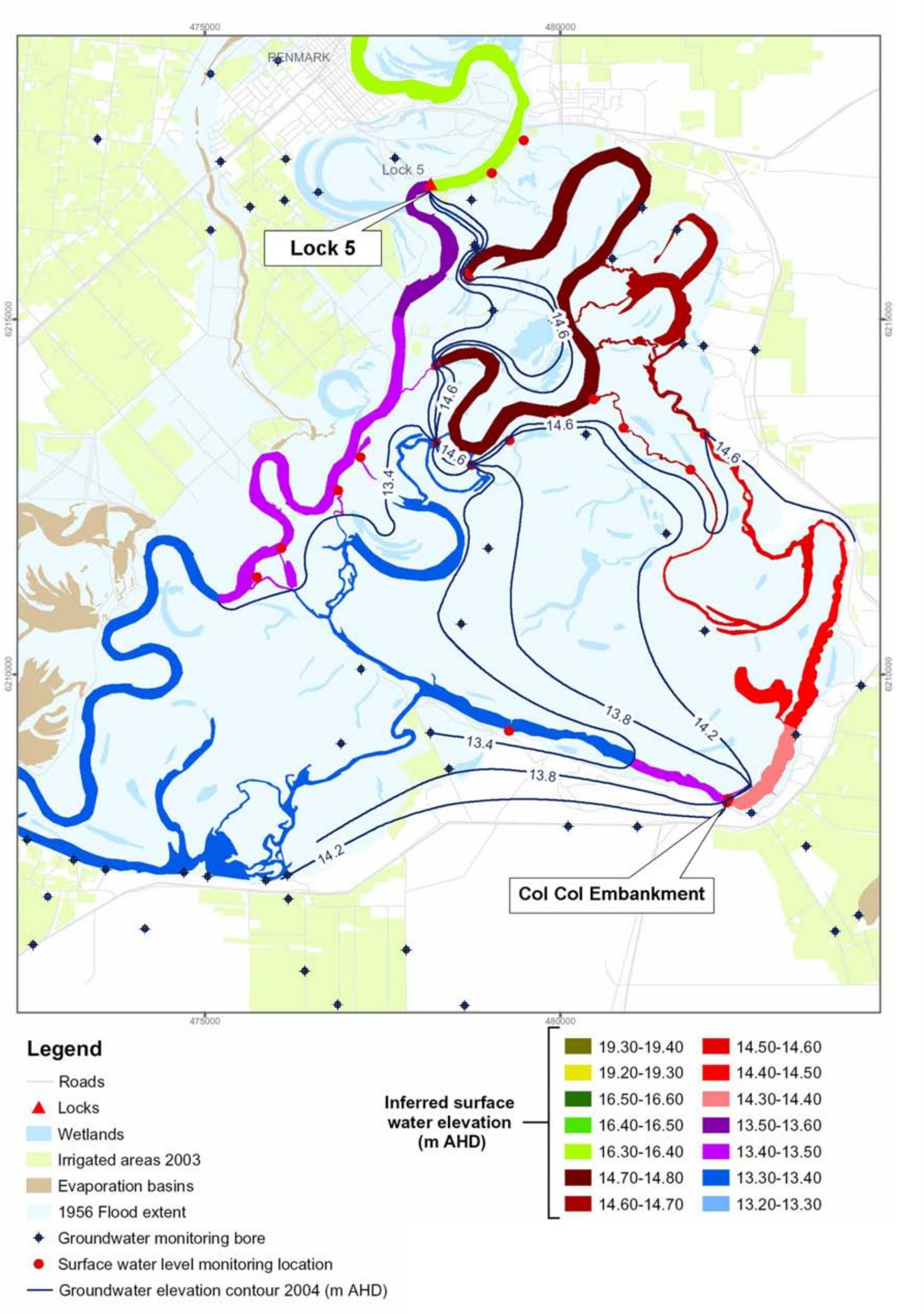

Figure 4. Pike floodplain surface water and groundwater levels (after REM-Aquaterra 2005).

Lateral Groundwater Inflows from the Loxton Sands Aquifer

Saline groundwater from the Loxton Sands aquifer beneath highland areas naturally discharges into the floodplain aquifer. Since land clearing for dryland farming and irrigation occurred in the early-mid 20th century, much greater groundwater recharge has occurred in highland areas, eventually causing water tables to rise and displace saline groundwater inflow to the floodplain environment. In the Pike region, this mounding has occurred in the Lyrup area and to a lesser extent in other areas. Figure 5 shows water table contours for 2004 with a noticeable mound about four metres high at Lyrup near the bottom of the Pike floodplain and a suggestion of some elevated levels and gradients near Simarloo and mid-Pike.

It is assumed that the main Pike River anabranch intercepts all the incoming lateral flux with the potential for salt build up on the narrow floodplains between the anabranch and the highland. The most notable areas where this can occur is the floodplain in Upper Pike and mid-lower Pike near Simarloo.

Past in-river surveys (RoR and Nanotem) support (but do not quantify) the high salt loads captured by the Pike River anabranch. Recent groundwater modelling by DWLBC indicates that about 4.8 ML/day of groundwater currently discharges to the Pike River anabranch system. At an effective salinity of about 30,000 mg/L, this groundwater flux is equivalent to a salt load of about 143 tonnes/day (Yan et al. 2006).

Whilst much of the groundwater flowing into the floodplain aquifer is about 23,000 to 27,000 mg/L Total Dissolved Solids (TDS) there is a corridor of higher salinity groundwater (about 41,000 mg/L TDS) entering the floodplain in the Mid-Pike area (Yan et al. 2006). These higher salinities are a result of natural evapo-concentration that occurs to the southeast of the Mid-Pike area where low-lying depressions in the landscape permit significant evaporation of groundwater from shallow water tables.

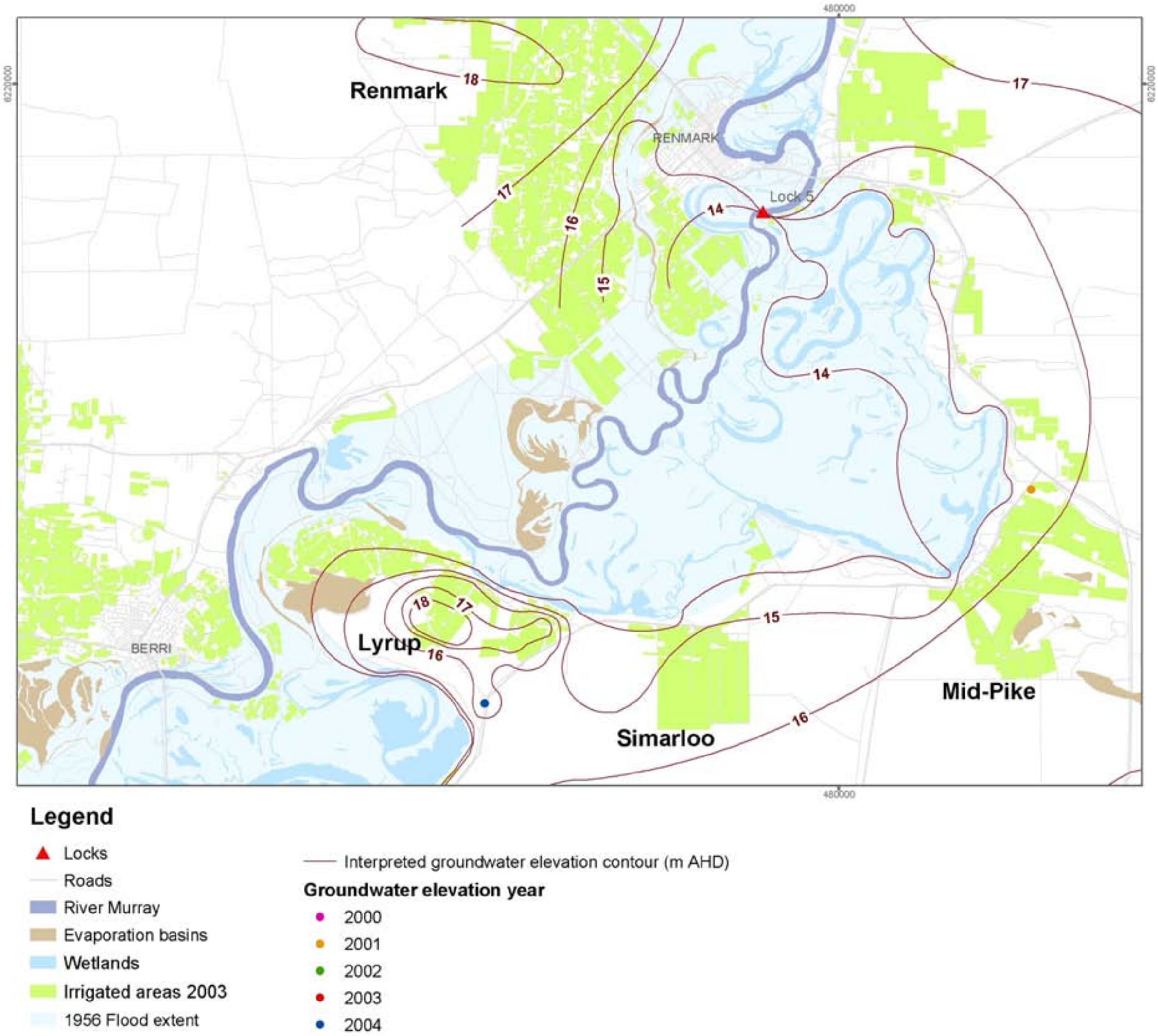

Figure 5. 2004 groundwater levels for the Loxton Sands Aquifer (after REM-Aquaterra, 2005).

Upwards Leakage from the Murray Group Limestone Aquifer

Beneath the Pike floodplain, groundwater levels in the deeper confined Murray Group Limestone (MGL) aquifer are about five to eight metres higher than the shallower Monoman Formation aquifer. This provides the potential for upwards leakage of saline groundwater from the MGL into the shallow water table. However, the actual rate of upwards leakage is considered to be insignificant as a result of the confining presence of the Bookpurnong Beds and Lower Loxton Clay beneath the entire Pike floodplain. Recent groundwater modelling by DWLBC (Yan et al. 2006) indicates that less than 2% of the current or future salt load to the river or anabranches is from vertical leakage across the entire Pike-Murtho region.

Evapo-concentration of Salts in Shallow Water tables

Across the Pike floodplain the depth to the water table is quite shallow, often within 1 - 3 m of ground surface, which gives rise to the evaporative concentration of salts in shallow groundwater. The degree of evaporation would also be influenced by the texture, thickness and nature of Coonambidgal Formation present and the extent of any transpiration by floodplain vegetation.

The salinity of groundwater sampled from shallow monitoring bores and drilling across the floodplain typically ranges from 20,000 to 40,000 mg/L TDS but can be as high as 70,000 mg/L TDS.

Recent modelling by DWLBC adopted evapo-transpiration rates of up to 250 mm/year during model calibration (assuming an extinction depth of 1.5 m).

2.7 Hydraulics

The Pike River anabranch extends over 6,700 ha of River Murray floodplain between Paringa and Lyrup village (river km 563.6 and 541.9 respectively). 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 (river km 542).

Details of the principal watercourses within the Pike / Mundic system are described below and illustrated in (Figure 6). A number of embankments and structures have been installed along the system which has resulted in a permanent waterway with a reasonably constant inflow. Under normal regulated flows, the discharge and level of water in the system is managed primarily to maintain the supply of water to the irrigators.

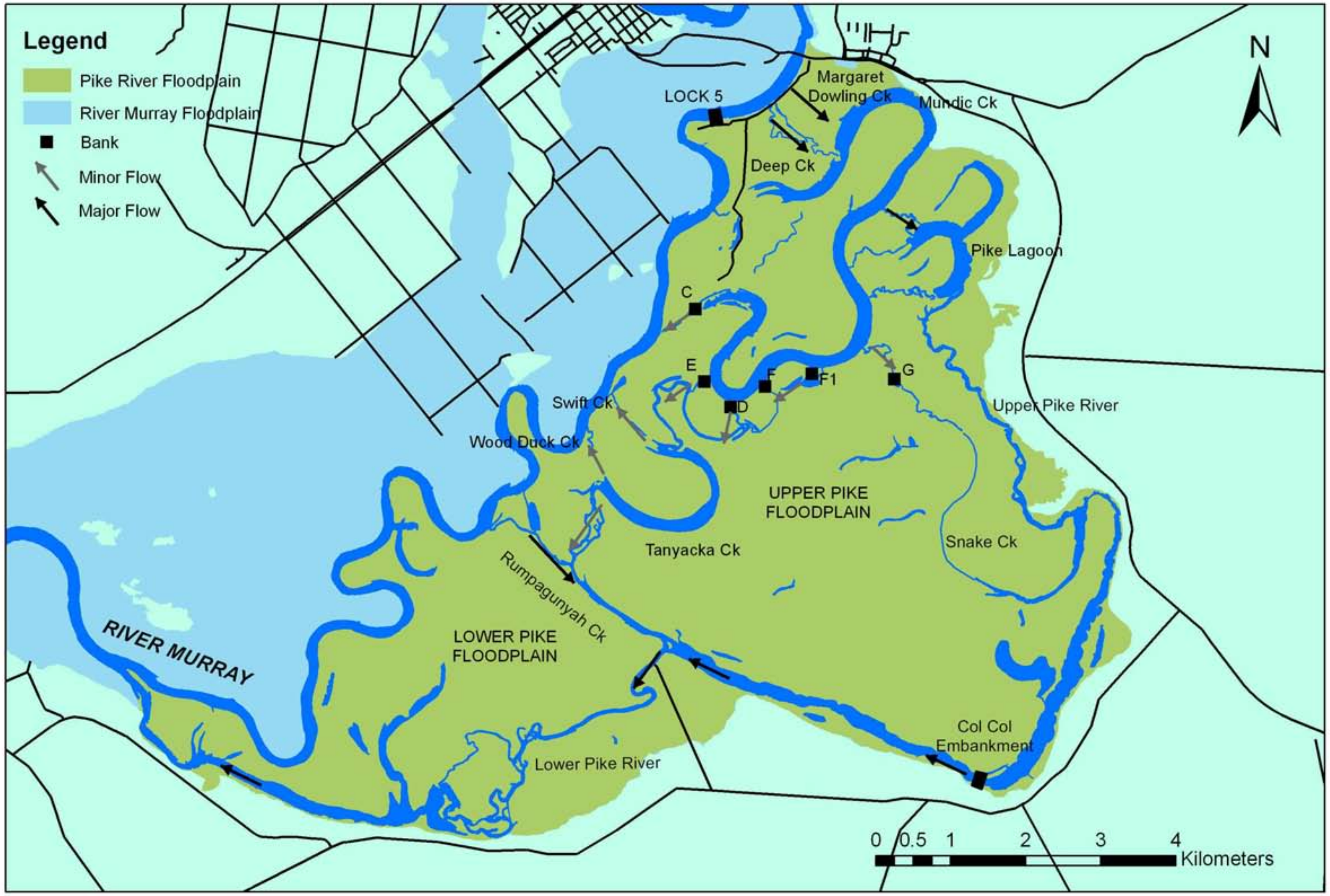

Figure 6. Hydraulic Components of the Pike River Floodplain

Water flows into the upper system from the River Murray through two inlets located between 600 m and 1,200 m upstream of Lock 5. These inlets feed into Deep Creek and Margaret Dowling Creek, both of which then connect into the Mundic Creek. Water flows from Mundic Creek to Pike Lagoon via a narrow channel and thence to the Pike River. Further downstream the Pike River is joined by Rumpagunyah Creek, which receives water directly from the River Murray and a small amount of flow from Tanyaca Creek (which in turn is fed by Mundic Creek). The majority of flow in the Lower Pike River comes from Rumpagunyah Creek. The Pike River - Mundic Creek system finally returns to the River Murray near Lyrup (river km 542). The Mundic Creek / Upper Pike River is highly regulated while the Lower Pike River section extending from the Col Col embankment is unregulated.

The system and the associated structures are described in more detail below. A long section through the Pike River system is contained in Figure 7 which illustrates the change in elevation throughout the Pike River system.

The storage of water above Lock 5 provides an opportunity to inundate the Pike River floodplain.

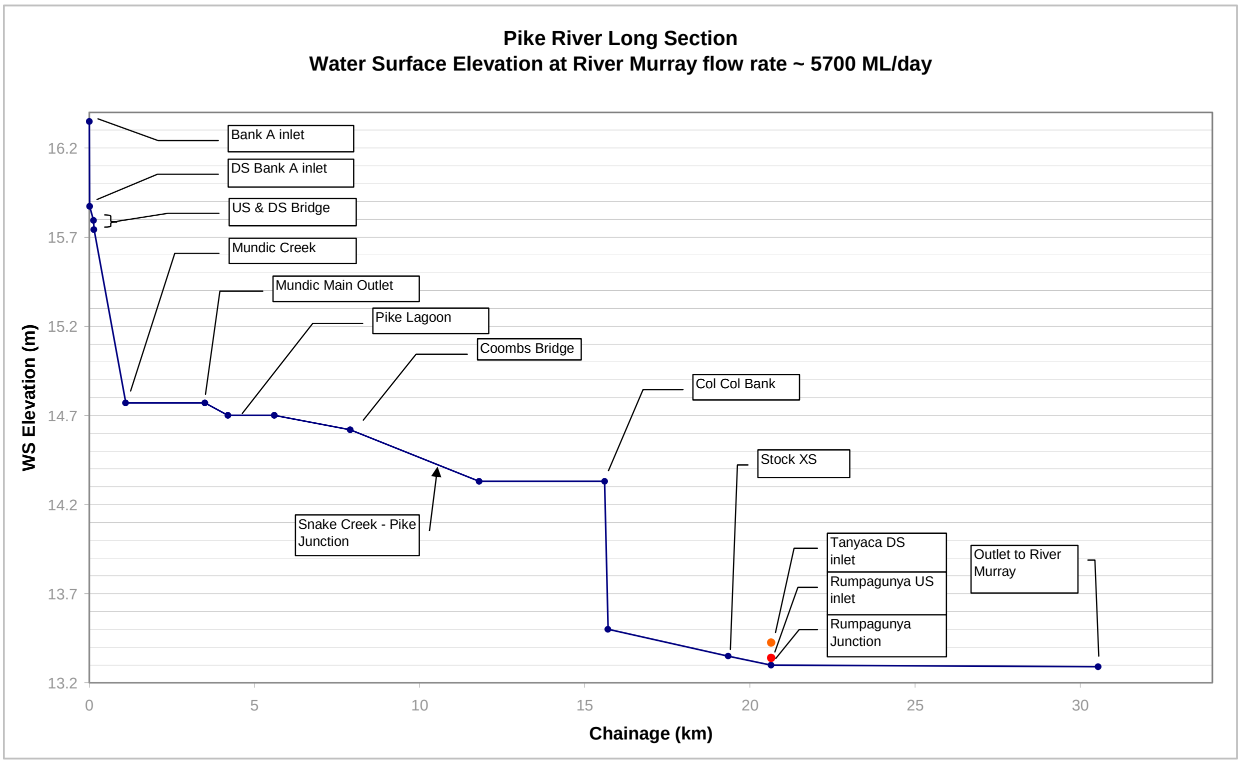

Figure 7. Long Section through the Pike-Mundic system

The Pike River system has been previously divided into a set of hydrological components that collectively describe the flow of water through the system and various key relating structures and off-take areas. These components are described in the sections that follow.

River Murray - Inflow

Flow enters the Pike River system from the River Murray via two pipe culverts into two small creeks upstream from Lock 5. Bank A inlet regulates flow from Lock 5 upper pool into Margaret Dowling Creek. Bank A1 inlet regulates flow from Lock 5 upper pool into Deep Creek. Under the normal operating regime, River Murray water level immediately upstream of Lock 5 remains relatively constant until flows exceed 44,000 ML/day when the weir is flooded out. The flow into Upper Pike is controlled by water level in the River Murray and also is relatively constant up to flows of 44,000 ML/day. Flows into Pike are normally 300 to 320 ML/day and measured regularly by DWLBC. Raising of the Lock 5 weir pool level for environmental purposes, as occurred in late 2005, increased flows into Upper Pike to 410 ML/day.

Mundic Creek

Mundic Creek is a meander isolated from the present river channel and is approximately 11 km in length (BC Tonkin and Associates, 1997). It has an area of 190 ha and a storage volume of 4,500 ML under normal flow conditions, ie 14.75 mAHD (BC Tonkin and Associates, 1997; Ken Smith Technical Services, 2005).

Changes in River Murray flow have little impact on flows and water levels in the Mundic Creek / Upper Pike River system until flow in the River Murray exceeds 35,000 ML/day, at which stage the rising Lock 4 weir pool level drowns out the banks around Mundic Creek.

Approximately 90% of the flow out of Mundic Creek is via a narrow 700 m long channel which feeds Pike Lagoon. A small volume (approximately 10%) of water flows via a small channel directly from Mundic Creek to Pike River immediately downstream of Pike Lagoon. Water flows from Mundic Creek, through Bank H, to provide minor flows to Snake Creek. The bank has been removed in the recent past, however due to extensive reed growth and sedimentation in Snake Creek, flows are still very low. There are also small flows from Mundic Creek to Tanyaca Creek (through Bank E) and directly to the River Murray via a small channel at Bank C. Bank C is a rock spall weir and road crossing with a crest of 15 m AHD with a 0.18 m diameter pipe that provides constant flow to a 23 m wide channel that discharges to the River Murray at 558.5 river km (Ken Smith Technical Services, 2005).

Pike Lagoon

Pike Lagoon is located at the eastern perimeter of the floodplain and is maintained at a constant level of 14.75 m AHD, has a storage capacity of 450 ML with an area of 54 ha (BC Tonkin and Associates, 1997). The lagoon is fed from Mundic Creek and discharges into the Pike River. Water is diverted for irrigation purposes from Pike Lagoon and the lagoon also discharges water to the Pike River where further irrigation diversions occur. The velocity in Pike Lagoon is very low and possibly contributes to the siltation of the lagoon.

Upper Pike River

The Upper Pike River extends from Pike Lagoon to the beginning of the Mid Pike Irrigation area. It has a storage of 725 ML and an area of 105 ha (BC Tonkin and Associates, 1997). Pike River is fed from Pike Lagoon and discharges into “Mid Pike”.

Coombs Bridge over the Pike River is the main access point to the major portion of the floodplain in the Mundic Creek / Pike River complex. Coombs Bridge acts as a minor constraint to flow through the Pike River section.

Mid Pike River

The Mid Pike River is the reach passing the Mid Pike Irrigation Area. It has a storage of 348 ML and an area of 50 ha (BC Tonkin and Associates, 1997). At its upstream end it is fed by “Pike River” and at the downstream end it discharges over and through the Col Col embankment. The Col Col embankment is a fixed-crest weir with a 1.2 m diameter bypass pipe. A sluice gate on the pipe is manually adjusted to maintain a relatively constant water level of 14.35 m AHD upstream of Col Col embankment. There is also a rock chute spillway along the north west of the embankment which has a crest level of approximately 13.95 mAHD.

The Col Col embankment forms a barrier between the Mid Pike and the Lower Pike River. Water levels upstream are controlled by Col Col embankment and a series of banks (termed A to F) around wetlands and watercourses. The banks maintain sufficient water depth for irrigator pumps along the river system upstream of the Col Col embankment.

Flow over the Col Col embankment varies mainly due to seasonal irrigation requirements and variable rates of evaporation which may jointly account for up to 30% of the inflow during peak summer months. Thus the flow past Col Col embankment varies between about 200 ML/day at times of high irrigation demand along the Mundic Creek / Upper Pike System to 280 ML/day during winter.

There is a fall of approximately 0.4 m along the Pike between Pike Lagoon and the pool behind Col Col embankment. The level drops a further 1.0 m across the Col Col Embankment.

Tanyaca Creek

The Tanyaca Creek complex comprises mainly a remnant oxbow that has permanent upstream and downstream connections with the River Murray, below Lock 5, at 557.2 and 556.7 km respectively. The majority of flow into Tanyaca Creek is through the downstream inlet. Tanyaca Creek is approximately 7 km in length, has an area of 79 ha and a storage volume of 593 ML (BC Tonkin and Associates, 1997). There are a number of watercourses feeding Tanyaca Creek from Mundic Creek. They have been banked off to maintain higher water levels in the Upper Pike / Mundic Creek system and to prevent Mundic Creek emptying to Lock 4 lower pool level (Bank D, Bank E, Bank F1). Flow from Mundic to Tanyaca is around 30 ML/d through a concrete pipe in F bank. Tanyaca Creek discharges into Rumpagunyah Creek.

Snake Creek

Snake Creek is a watercourse about 7 km in length between Mundic Creek and Pike River that generally runs parallel with the Pike River, but is located between 400 to 600 metres to the west. Snake Creek was banked off (Bank H) to maintain higher water levels in the Upper Pike / Mundic Creek system. Bank H was subsequently removed and small flows now enter Snake Creek from Mundic Creek with flows inhibited by downstream structures at Bank G and Snake Crossing (Ken Smith Technical Services, 2005). The creek is now very silted and overgrown with reeds in sections.

Rumpagunyah Creek

Rumpagunyah Creek is connected to the River Murray at its upstream end and feeds into the Lower Pike River at its downstream end. There are two inlets to Rumpagunyah Creek, and flow in the downstream inlet is about double the flow of the upstream inlet. Tanyaca Creek feeds into Rumpagunyah Creek about 1.5 km from the upstream end of Rumpagunyah Creek. Flow in Rumpagunyah Creek (downstream of the confluence of Tanyaca Creek) is controlled by the flow in the River Murray. A sand bar has built up at the downstream entrance to Rumpagunyah Creek. An investigation of the geomorphology of the Rumpagunyah Creek inlet (ref Fluvial Systems, 2008) concludes that the sandbar is considered to be stable and having little impact on flows under current operating regimes. Rumpagunyah Creek has an area of 25 ha and a storage volume of 375 ML (BC Tonkin and Associates, 1997).

The hydraulic relationship at the Rumpagunyah Creek /Pike River confluence is a key control point for all flows in Lower Pike. Analysis of flow gaugings of Rumpagunyah Creek and Lower Pike River undertaken by B Porter (DWLBC) has provided valuable information and indicates that flow in Rumpagunyah Creek is 6.4% of Lock 5 River Murray flow less approximately 30% of flow over Col Col (Figure 8). At times of very low River Murray flows (<1000 ML/day) as experienced in July 2007, flow in Rumpagunyah reverses and flows from Pike out into the River Murray.

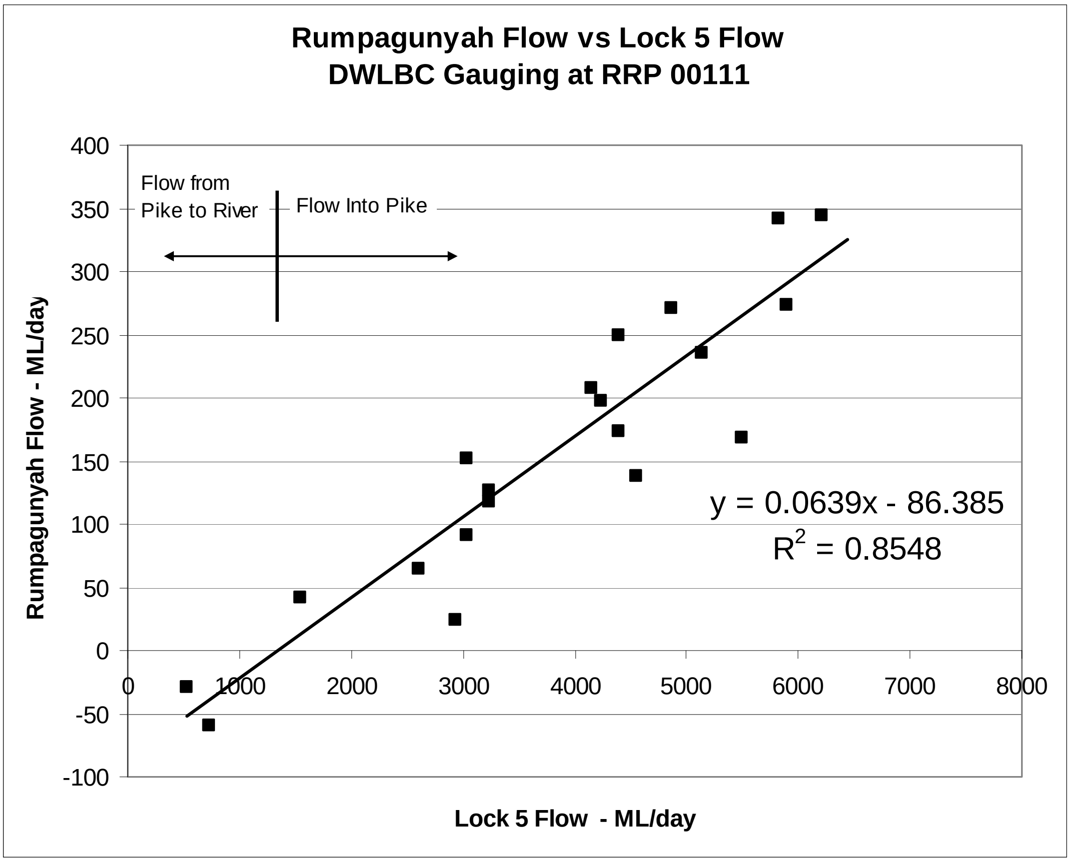

Figure 8. Hydraulic flow relationship for Rumpagunyah Creek vs River Murray Lock 5

Lower Pike River

Lower Pike River receives flows of between 200 and 280 ML/day from Col Col and a contribution from Rumpagunyah as detailed above. The confluence of the Lower Pike with Rumpagunyah Creek is about 4 km downstream of the Col Col embankment. The Lower Pike returns to the River Murray (river km 542) upstream of Lyrup.

2.8 Floodplain Inundation

The Floodplain Inundation Model (FIM) illustrates the extent of floodplain inundation at different River Murray discharges (Figure 9). Inundation commences in the floodplain areas of the Mid and Lower Pike floodplain first, affecting the Pike-Mundic areas only when downstream levels impede outflows from Col Col embankment and other structures.

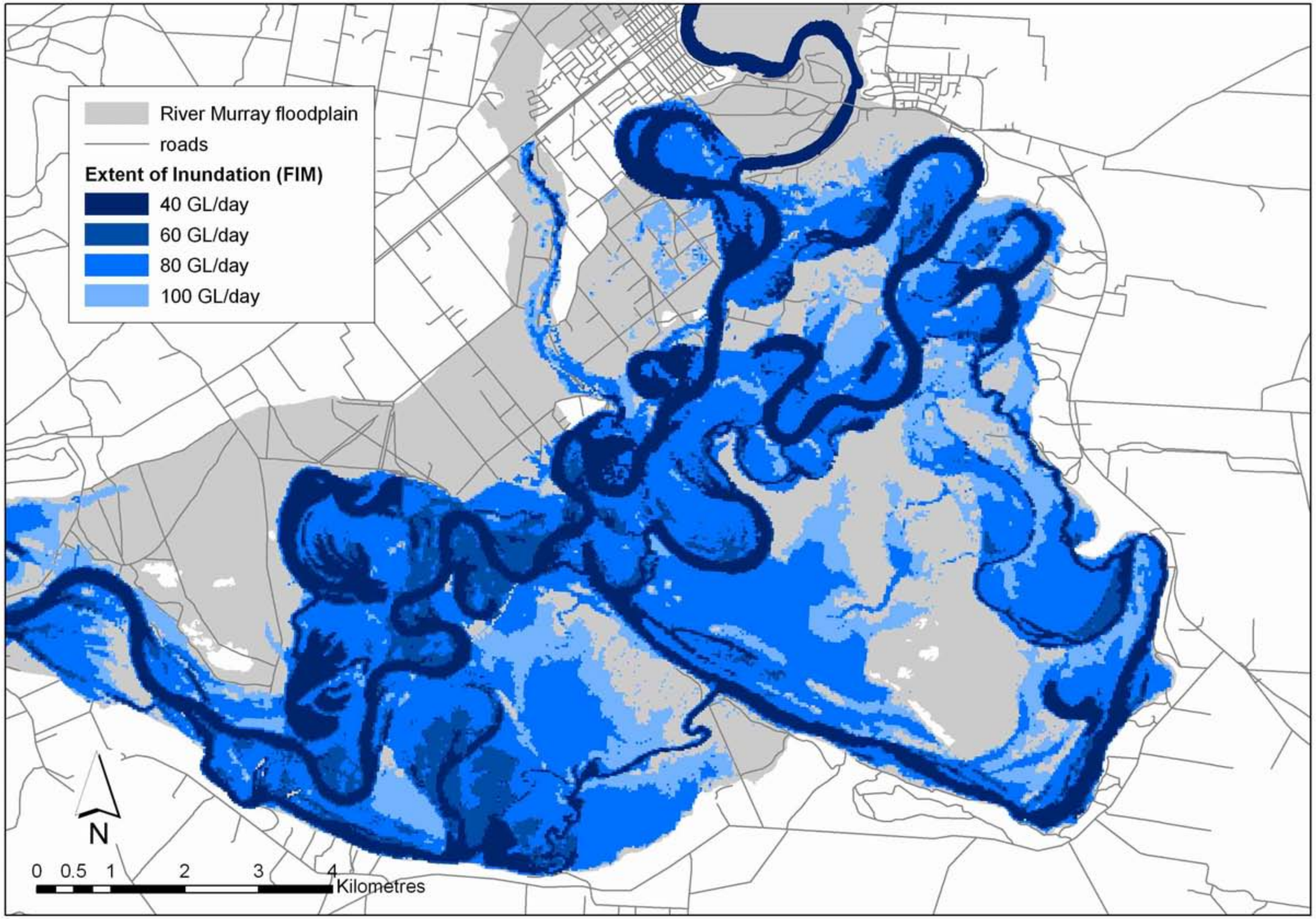

Figure 9. Floodplain Inundation

Water levels downstream of Lock 5 are elevated above the Lock 4 weir pool level of 13.2 m AHD by discharge as low as 5,000 ML/d.

Most of the permanent wetlands and watercourses of the floodplain have steeply sloping banks. Therefore river flows of 10 000 ML/day cause very little inundation beyond the extent inundated under low regulated flows.

At river flows of 20 000 ML/day inundation extends to some of the small wetlands connected directly to the main channel. Additionally low lying areas of Red Gum Woodland and Lignum/Chenopod Shrubland near the intersection of Rumpagunyah and Tanyaca Creeks and in adjacent flood runners become inundated. A floodplain wetland currently dominated by the halophyte *Halosarcia pergranulata* (probably formerly Lignum Shrubland) near Mundic Creek also becomes inundated.

Due to the topography of the Pike River floodplain the extent of inundation does not increase markedly between river flows of 20 000 ML/day and 50 000 ML/day. Only slight increases in the area inundated occur along the fringes of the permanent watercourses and wetlands.

At river flows of 60 000 ML/day the area inundated increases markedly. Areas most affected include the floodplain adjacent to the main channel, particularly downstream of the Rumpagunyah Creek inlet, the floodplain of the lower Pike River and areas at the lower end of Snake Creek, nears its junction with the Pike River.

The area inundated increases markedly again for river flows of 70 000 ML/day. At this flow the already inundated areas extend further and some additional floodplain depression begin to fill.

At 80 000 ML/day the area inundated again increases markedly. At flows of this magnitude inundation of some of the lower lying Black Box Woodland areas occurs, although the majority of this Water Regime Class remains exposed.

For river flows greater than 80 000 ML/day the area inundated does not increase markedly, although the FIM does not model inundation for flows above 100 000 ML/day. Notably, the majority of the Black Box Woodland is not inundated at flows of 100 000 ML/day, all other Water Regime Classes are completely or mostly inundated.

2.9 Hydrology

Flow in the River Murray at the South Australian border is strongly seasonal. Long term historic and modelled data indicate discharge typically increases from an annual average monthly minimum in April to reach a maximum in September (Figure 10). River regulation and diversions have not altered the seasonality of flow but have depleted flow significantly, particularly in winter. Under some circumstances discharge in low flow periods can be augmented under current conditions as water is released from storage over the irrigation season to supply consumers. When the water is available, South Australia receives a minimum entitlement flow (Figure 10).

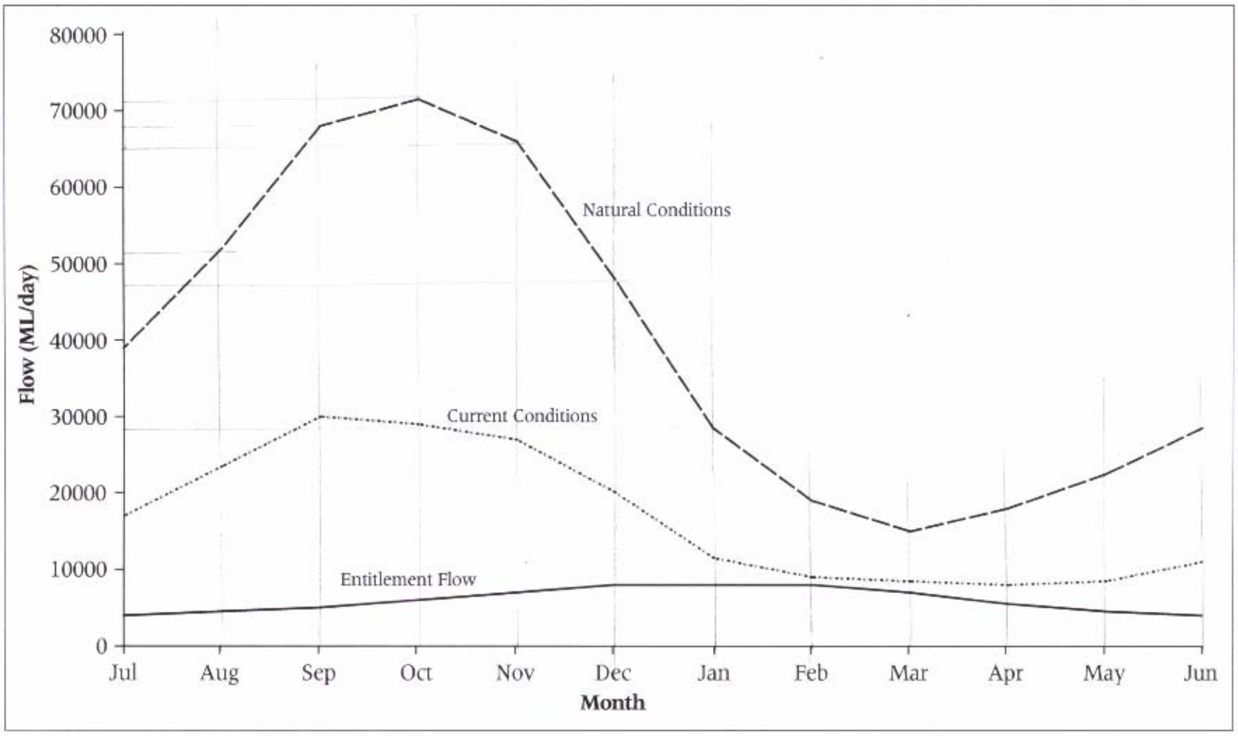

Figure 10. Average monthly inflows to South Australia (from Sharley and Huggan 1995)

Under natural conditions flow was highly variable and frequently reached levels which inundate the floodplain (Table 2). River flow exceeded 30,000 ML/d almost every year and events of 70,000 ML/d occurred in 50% of years. 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.

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 have been reduced more significantly with the frequency of events of 100,000 ML/d, which inundate most of the floodplain, reduced from 37 per 100 years to 11. The duration of these events reduced by one third.

Table 2. The effects of River Murray flows on flow frequency and duration under natura (pre-regulation) and current (regulated) conditions at Pike River

River Murray flow (ML/d)	Return Period (number of times peak flows occur in 100 years)		Duration (number of months in which river flow shown in first column is exceeded)	
	Natural	Current	Natural	Current
5000	100	100	11.8	11.9
10000	100	94	10.1	4.6
20000	99	63	7.8	4.6
30000	96	51	6.4	3.9
40000	91	40	4.9	3.3
50000	79	30	3.9	2.7
60000	59	21	3.9	2.5
70000	49	15	3.6	2.9
80000	45	12	3.2	2.6
90000	37	11	3.1	2.1
100000	32	9	2.9	2.0
120000	23	5	2.2	2.8
150000	12	4	2.2	1.5

2.10 Water Quality

Surface water monitoring is undertaken along the Pike River system by DWLBC. Electronic flow, level and salinity data has been collected along the Pike River system at various locations as shown. In addition to this monitoring data, DWLBC also carries out monthly flow gaugings along the Pike River at Col Col embankment, Rumpagunyah Creek and the Lower Pike.

The Renmark to the Border Local Action Planning group has monitored salinity along the Pike system on a monthly basis since June 2004. The average of the recorded data is shown in Figure 11 and indicates that a significant salinity increase is measured along the Pike River. The average EC more than doubles with most of this increase occurring from Pike Lagoon to just downstream of Col Col embankment. The average increase is approximately 280 EC (154 mg/L).

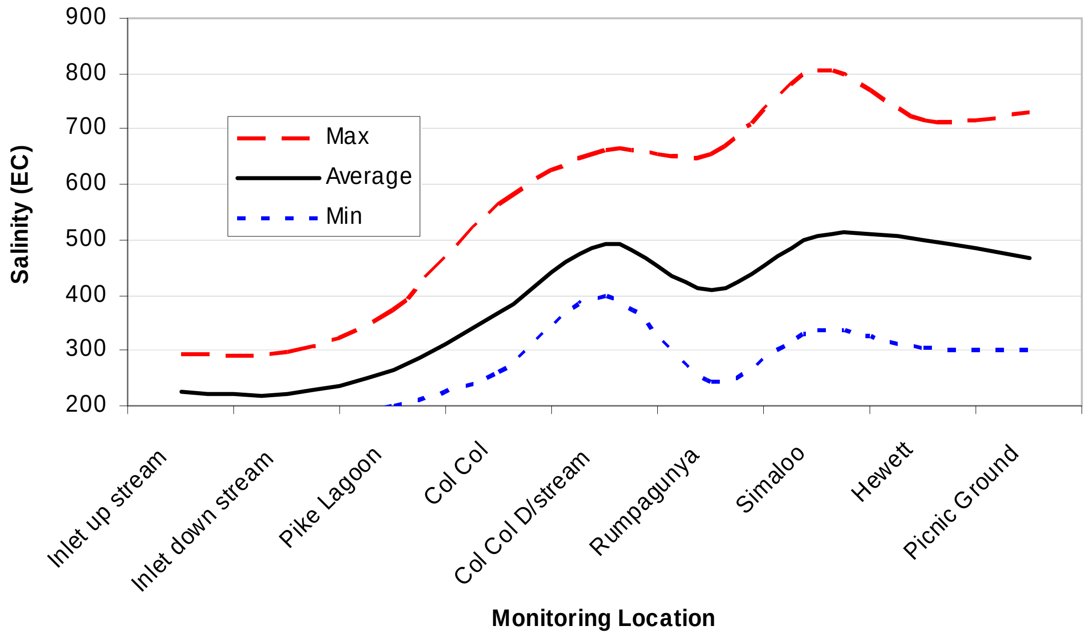

Figure 11. Pike-Mundic System Average Salinity (June 2004 – June 2006)

River salinity surveys (Run-of-River or ROR) are periodically undertaken by DWLBC in the main river channel. Data from surveys to date indicate that on average, around 70 t/d of salt discharges from the Pike River system back into the River Murray. The surveys in 2003 and 2005 indicated salt loads of 31 t/d and 27 t/d, respectively. These lower than average results may be a result of the recent drought conditions which have returned low salt loads in other regions along the River Murray, possibly due to declining rates of groundwater discharge arising from low rainfall conditions and infrequent flooding.

If it is assumed that the average ROR salt load increase of 70 t/d is discharging into the Pike River at an average flow of 480 ML/day (300 ML/day from via Mundic and 180 ML/day via Rumpagunyah), a salinity increase in the Pike River of 265 EC (146 mg/L) is implied. This closely matches the measured results.

2.11 Water Supply

Based on information supplied by DWLBC in December 2007, there are currently 41 Water Licenses in the study area extracting water from the Pike-Mundic system. The allocation (Domestic, Stock and Irrigation) associated with those licenses is a total of 22.4 GL. Irrigation accounts for more than 99% of the allocation volume. Twelve of the licenses account for 80% of the allocation volume. The peak usage year since 1999 in the Pike area has been the 2004/05 year. During this peak year usage against current allocations was 16.0 GL. There was also usage for licenses that have since been transferred giving a total usage of approximately 16.7 GL. Information would suggest that during the peak usage year of 2004/05, the corresponding allocation was 15.7 GL meaning that usage on average exceeded allocation by 2%. Allocation in the area has increased since 2004/05 however this has not been reflected in usage figures due to water restrictions imposed because of the drought.

2.12 Conservation Features and Values

EPBC Issues

The Pike Floodplain potentially provides habitat for a number of animals listed under the Commonwealth Environment Protection and Biodiversity Conservation Protection Act. The site also provides habitat for waterbirds protected under international migratory bird agreements, which are governed by the Act.

Flora

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 (Table 3). No species of national conservation significance have been reported. Plants of conservation significance include wetland, floodplain and mallee species. The plant with the highest conservation significance is *Atriplex papillata* which is endangered in South Australia.

Twenty two plant associations were identified in Department for Environment and Heritage floristic vegetation mapping (Figure 12). The mapping identifies variations within the major woodland vegetation types of *Eucalytpus camaldulensis* and *E. largiflorens* woodland based on canopy density and understorey composition. Substantial areas of the central Upper Pike and Lower Pike Floodplain is mapped as *Sporobolus virginicus* (mixed) grassland. These areas are generally very bare as a result of salinity, grazing and drought impacts. Areas of *Melaleuca lanceolata* (mixed) forest, which are unusual in the South Australian River Murray floodplain are mapped near Mundic Creek.

Table 3. Threatened plant species reported from the Pike River floodplain (source: Biological Database of South Australia)

Threatened Species	Common Name	Conservation Significance Rating (Cwth EPBC Act)	Conservation Significance Rating (SA NPW Act)
Atriplex papillata	Coral Saltbush		E
Brachyscome basaltica var. gracilis	Swamp Daisy		R
Callitriche umbonata	Water Starwort		V
Calotis scapigera	Tufted Burr-daisy		R
Cyperus nervulosus			R
Dianella porracea	Pale Flax-lily		V
Elatine gratioloides	Waterwort		R
Eragrostis lacunaria	Purple Love-grass		R
Eremophila polyclada	Twiggy Emubush		R
Exocarpos strictus	Pale-fruit Cherry		R
Hakea tephrosperma	Hooked Needlewood		R
Maireana rohrlachii	Rohrlach's Bluebush		R
Myoporum parvifolium	Creeping Boobialla		R
Myriophyllum papillosum	Robust Milfoil		R
Ottelia ovalifolia ssp. ovalifolia	Swamp Lily		R
Picris squarrosa	Squat Picris		R
Zannichellia palustris			R

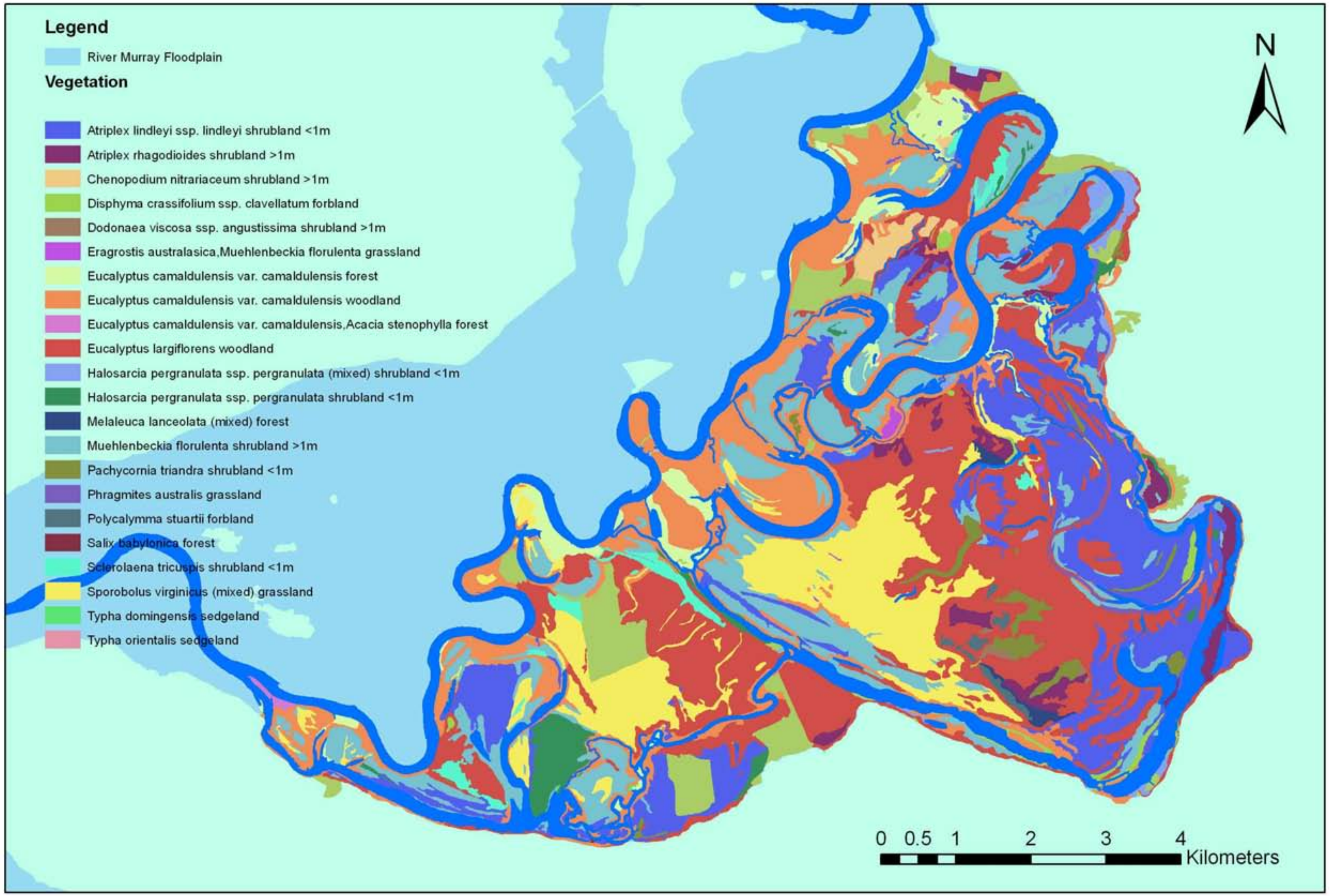

Figure 12. Map of Pike River floodplain vegetation communities (DEH 2003)

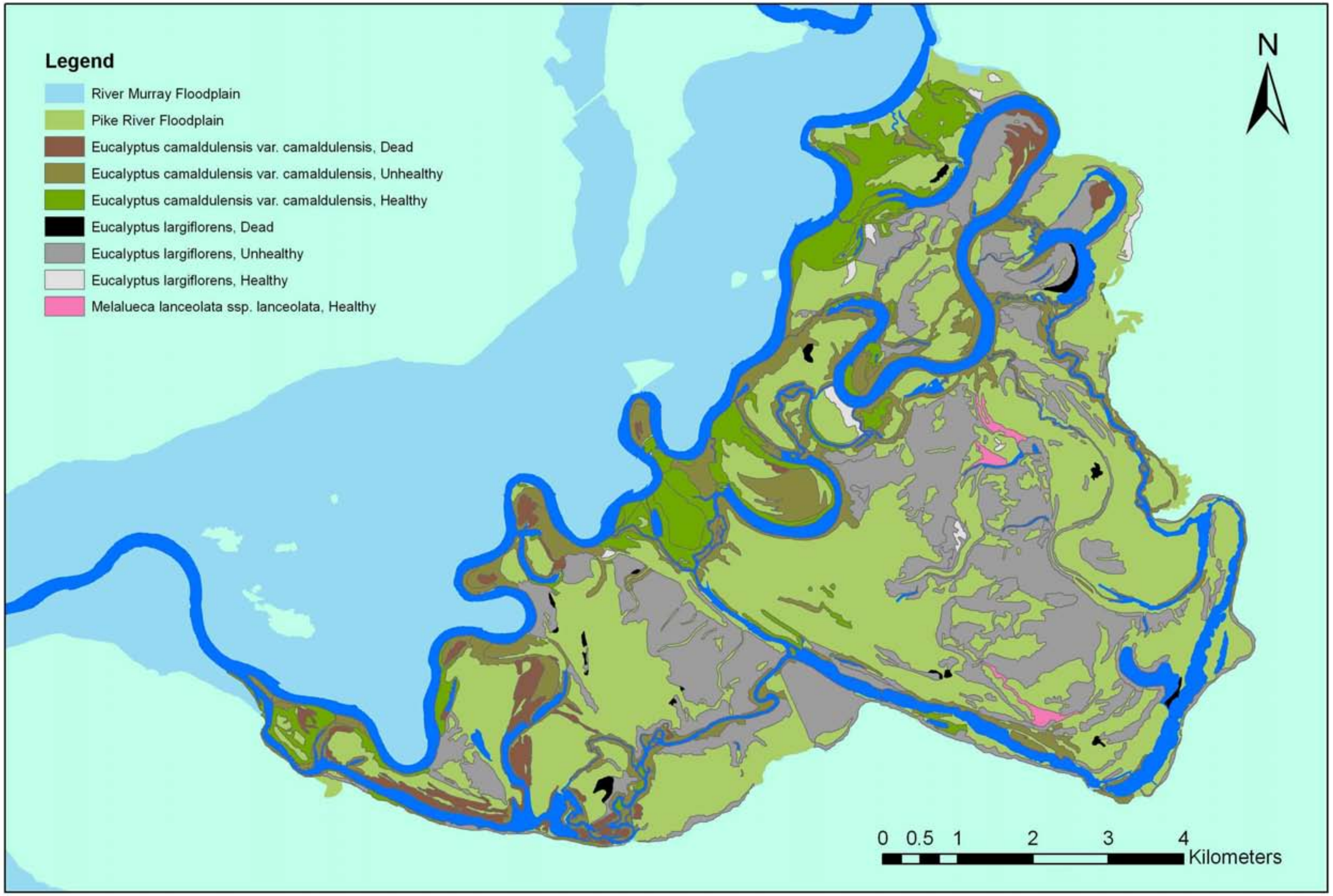

Figure 13. Map of Pike River floodplain vegetation community health (DEH 2003)

Tree health was mapped by the Department for Environment and Heritage in 2002 (Figure 13). The mapping reported the condition of *Eucalyptus camaldulensis, E. largiflorens* and *Melaleuca lancelolata* vegetation. Red Gum trees were in the best condition in areas close to the River Murray, with health declining at greater distances from the river channel. Black Box health, which occupies central floodplain areas subject to salinisation and most severely affected by drought, was generally poor. Areas of dead trees were most pronounced near Pike Lagoon , the northern part of Mundic Creek and on the Lower Pike River. The Dryland Tea Tree woodland was in good health.

Fauna

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 (Table 4). The three species of national significance are the Golden Bell Frog, the Malleefowl and the Regent Parrot. Golden Bell Frog 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. Malleefowl is present in extensive mallee vegetation in highland areas near the floodplain, but is not a floodplain species and is not relevant to this management plan. Regent Parrot feeds in mallee vegetation and relies on the hollows provided by large floodplain eucalypts to nest and shelter. The species of highest conservation significance in South Australia is the Azure Kingfisher (endangered). This species preys on large invertebrates and small vertebrates such as frogs and fish which live in and around water.

Key habitat components required by the threatened animal species include:

- tree hollows (e.g. Regent Parrot, Tree Goanna);
- permanent water with reeds (e.g. Golden Bell Frog)
- shallow water with small vertebrate prey (e.g. Intermediate Egret);
- deep water with submerged aquatic vegetation (e.g. Australasian Shoveller, Great Crested Grebe);
- open water (e.g. Musk Duck); and
- woodland (e.g. Koala, Tree Goanna, Common Bandy Bandy, Little Friarbird).

Table 4. Threatened animal species reported from the Pike River floodplain

Order	Threatened Species	Common Name	Conservation Significance Rating (Cwth EPBC Act)	Conservation Significance Rating (SA NPW Act)
AMPHIBIA	*Litoria raniformis*	Golden Bell Frog	VU	V
AVES	*Alcedo azurea*	Azure Kingfisher		E
AVES	*Amytornis striatus*	Striated Grasswren		V
AVES	*Anas rhynchotis*	Australasian Shoveler		R
AVES	*Ardea intermedia*	Intermediate Egret		R
AVES	*Biziura lobata*	Musk Duck		R
AVES	*Cinclosoma castanotus*	Chestnut Quail-thrush		R
AVES	*Climacteris affinis*	White-browed Treecreeper		R
AVES	*Entomyzon cyanotis*	Blue-faced Honeyeater		R
AVES	*Falco peregrinus*	Peregrine Falcon		R
AVES	*Leipoa ocellata*	Malleefowl	VU	V
AVES	*Philemon citreogularis*	Little Friarbird		R
AVES	*Plectorhyncha lanceolata*	Striped Honeyeater		R
AVES	*Podiceps cristatus*	Great Crested Grebe		R
AVES	*Polytelis anthopeplus*	Regent Parrot	VU	V
AVES	*Pyrrholaemus brunneus*	Redthroat		R
AVES	*Stictonetta naevosa*	Freckled Duck		V
MAMMALIA	*Phascolarctos cinereus*	Koala		R
REPTILIA	*Chelodina expansa*	Broad-shelled Tortoise		V
REPTILIA	*Varanus varius*	Tree Goanna		R
REPTILIA	*Vermicella annulata*	Common Bandy-Bandy		R

2.13 Winds Modelling

WINDS (Water Inundation and Drought Salinisation) is a GIS-based model used to predict floodplain tree health over time. The model spatially incorporates groundwater salinity, groundwater depth, soil type, water source, flooding, rainfall and vegetation type to make predictions about soil salinity from a combination of salt leaching and groundwater discharge. The model makes predictions of tree health based on the salinity tolerances of floodplain tree species.

A model was created for the Pike Floodplain based on 2003 tree health measurements and was used to predict tree health under various flow scenarios for current (2007) and the future (2035).

WINDS modelling of tree health, based on the continuation of flows typical of the last 15 years, predicts an increase in dead trees from 39% currently to 49% of the floodplain area by 2037. Scenarios involving the provision of additional flow in the River Murray provide little benefit.

By 2035 only 3% of the area of trees will be in good health if current conditions persist (Overton and Jolly 2008, Table 5). Enhance flooding, in the form of the Living Murray's 1,500 GL first step decision environmental flow provides negligible improvement by 2037, with only 3% of the woodland area classified in good health and 50% dead. However, the lowering of groundwater levels by 2 m combined with enhance flooding leads to an improvement with 11% in good health and 23% dead (Table 5).

Therefore groundwater lowering will be an important component of strategies to improve floodplain health.

Table 5. WINDS modelling of tree health class extent for historic (2003), modelled current (2007) and modelled future (2035) scenarios. From Overton and Jolly 2008.

Year	Dead	Poor	Good
2003 (measured)	753	1830	237
2007 (modelled)	1101	1613	105
2035 do nothing (modelled)	1392	1330	97
2037 1,500 GL (modelled)	1268	1302	97
2037 1,500 GL groundwater lowered 2 m (modelled)	625	1742	300

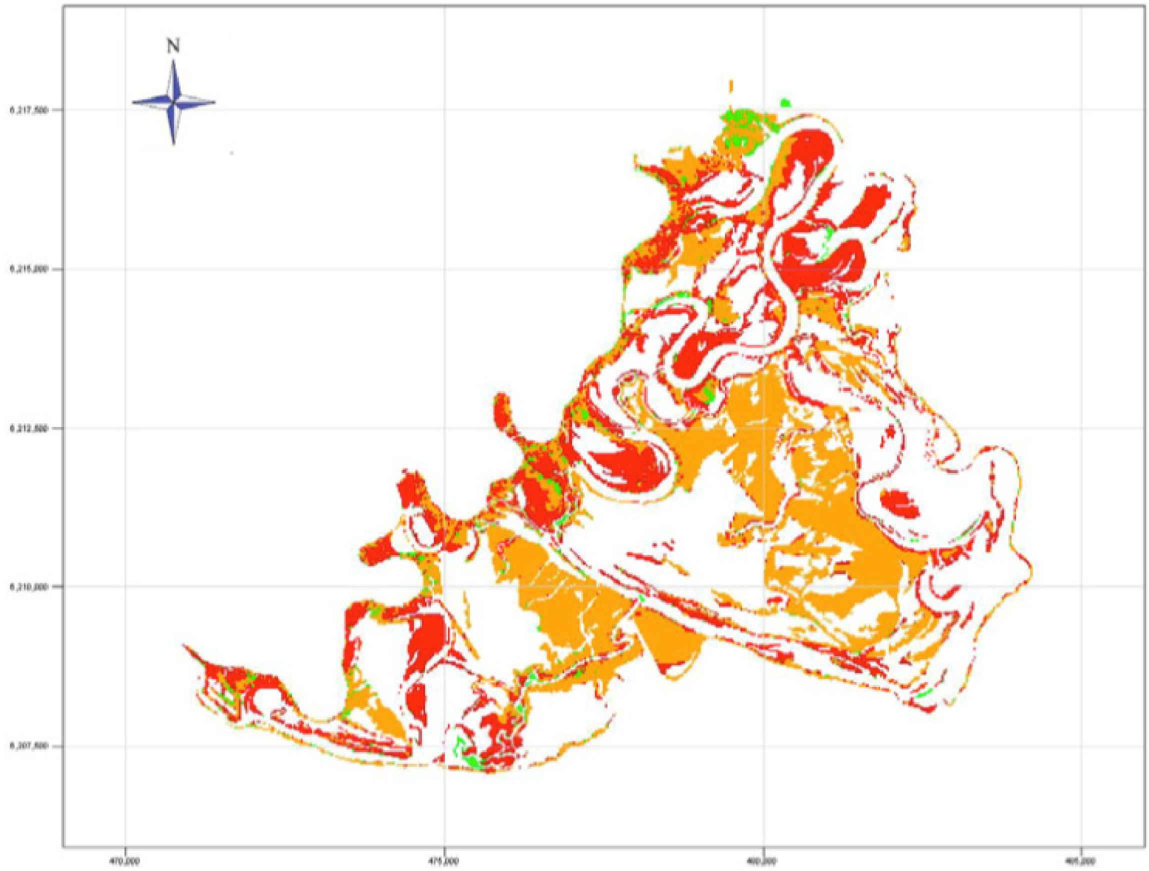

Figure 14. WINDS modelled tree health, 2007 (tree health dead-red, poor-orange, good-green) from Overton and Jolly (2008).

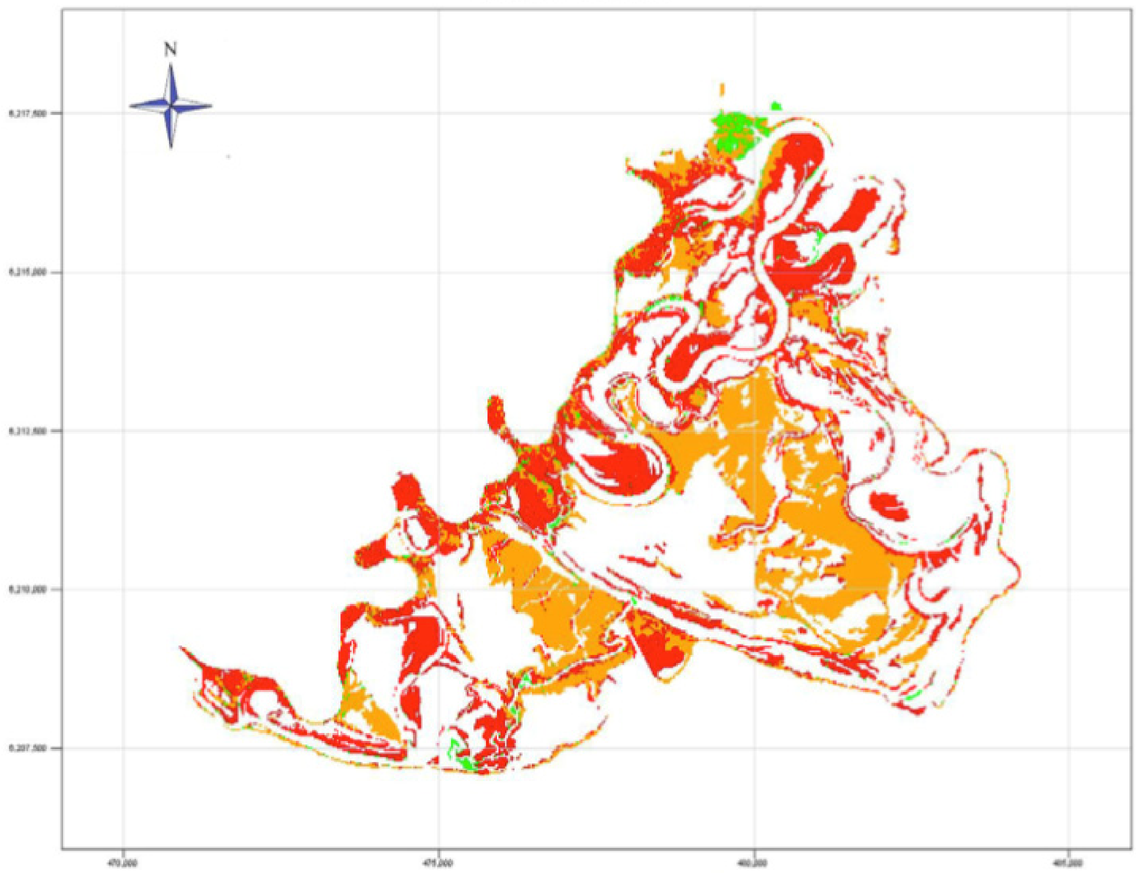

Figure 15. WINDS modelled tree health, 2037 for do nothing scenario (tree health dead-red, poor-orange, good-green) from Overton and Jolly (2008).

Overton and Jolly (2008) identified locations where groundwater lowering, combined with enhanced flooding would be most effective (Figure 16). These are sites where:

- vegetation is in poor health;
- groundwater needs to be lowered by 4.5 m to reduce discharge to negligible amounts; and
- improved inundation is possible up to flows of 70,000 ML/d.

The identified sites are generally located close to the River Murray which presents difficulties for the design of a future groundwater interception scheme.

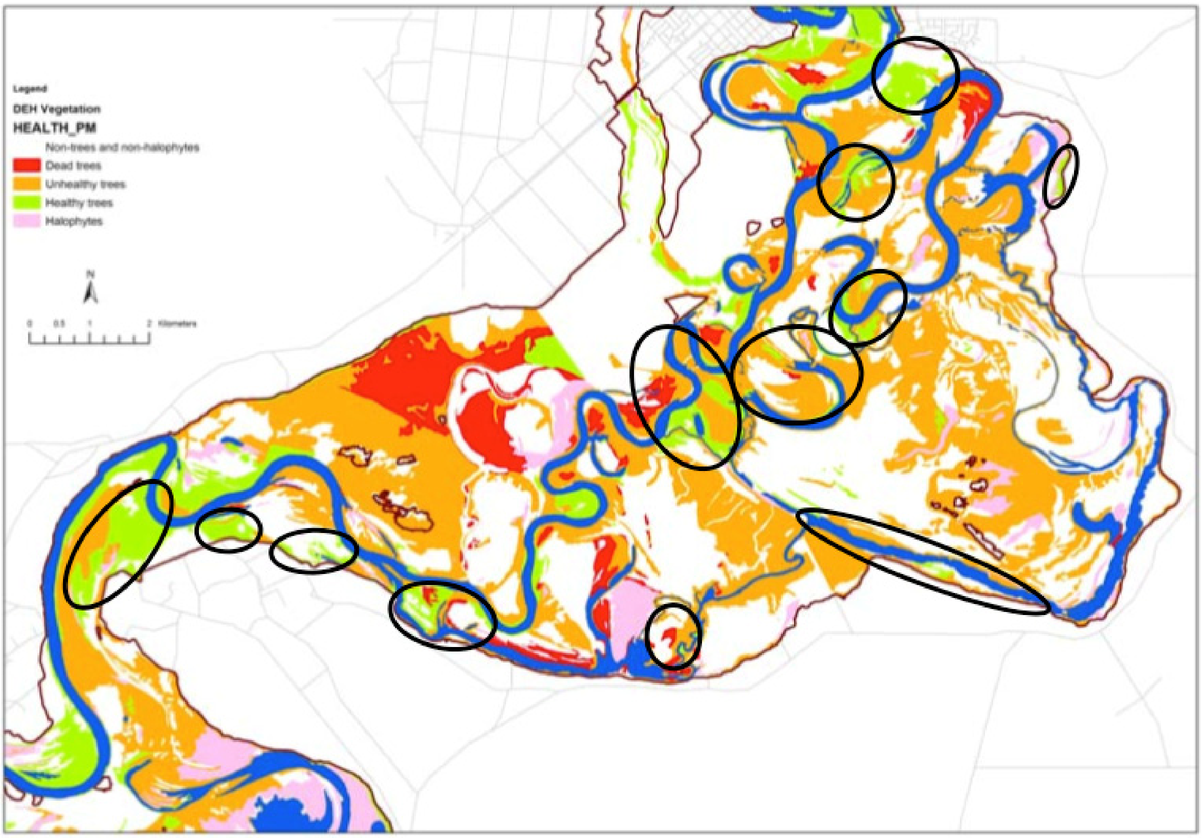

Figure 16. Map of the Pike River floodplain showing tree health. Black circles identify priority areas for protection or rehabilitation using groundwater lowering.

2.14 Economic, Social and Cultural Features

Archaeological

The gathering of baseline data for the Floodplain Management Plan includes sites and areas of Indigenous or European cultural significance. The proposed project approach has not included an allowance for undertaking independent cultural investigations. However, there is much historical documentation of the use of the local environments by Aboriginal people and the descriptions tend to reflect the varied nature of food and other resources provided by the river and surrounding floodplain and highland environments.

The following detailed review and presentation of this material was prepared by Pring (2006) for the upgrade of the Pike River Land and Water Management Plan.

Aboriginal occupation along the River Murray system dates back more than 30,000 years at Lake Mungo to the east. The Dreaming story of Ngurunderi, tells of the creation of the River Murray, from the junction of the Darling and Murray to the Murray Mouth and Coorong. According to Tindale (1974) the local Aboriginal peoples around Renmark were known as Erawirung and Ngintait, sub-groups of the Meru (men).

The most detailed description of Aboriginal interaction with the local environment is sourced from Edward John Eyre (1845). The following paragraphs are provided as a sample of the ways in which Aboriginal people interacted with and depended on the environmental resources of the district:

- ‘Fish are procured in different ways, eg ‘weirs or dams, large seines (nets) made of string manufactured from the rush, and buoyed up with dry reeds, bound into bundles, and weighted by stones tied to the bottom.’
- Watercress was collected from the borders of lagoons at the Murray. The tops, leaves and stalks were steamed in a ground oven, providing a favourite and inexhaustible supply of food.
- ‘the bulbous roots of a reed called the belillah (probably bulrush) , certain kinds of fungi dug out of the ground, fresh-water mussels …’ were eaten.
- ‘Fresh water turtles, varying in weight from three to twelve pounds’ were caught similarly to fish.
- Small individual hooped nets were used by the group as well to scoop fish. Other types of nets and fish traps were also used seasonally ‘catching fish weighing from twenty to seventy pounds’. As a group between 5 and 40 men dived to spear fish when the water levels were low.
- At flood time, spearing of fish was practiced from canoes made from the bark of the gum tree. The spears were made from native pine. Freshwater lobsters weighing from two to four pounds are also speared, sometimes ten to sixteen in an hour or two.
- Frogs, rats, lizards and other reptiles are eaten as well as grubs from trees and the ground.
- The roots of various plants are eaten including the ‘flag’ or cooper’s reed ‘which grows in marshes or alluvial soils that are subject to periodical inundations. It is used all year but best after floods. The root is roasted in hot ashes. The ‘belillah’ is another, about the size of a walnut, hard and oily and roasted and pounded into a thin cake. ‘Immense tracts of country are covered with this plant on the flats of the Murray …’.
- A small berry or currant, called by the natives of Moorunde ‘eertapko’, coloured red and an agreeable acid flavour, growing upon a low creeping tap-rooted plant, of a salsolaceous character, found in the alluvial flats of the Murray, among the polygonum bushes and other places.
- When hunting possum up in a smooth trunked tree, a stone hatchet or strong sharp-pointed stick is used to make notches in the bark for toe holds.
- Swans and brolga (native companions) were speared or killed with clubs. Swans were caught easily in the waterholes or lakes when mounting, as they are then unable to fly.
- Birds are killed with clubs, by spearing, snaring, by noosing and by netting.
- Nets for netting birds are as large as thirty to sixty feet broad and from twenty to forty deep, formed from lacing together pieces of old fishing nets.

There are recordings of burial places in the Cobdogla area so it could be assumed that this would be the case along the river to the east. Burials are often in sand, rather than clay, for ease of digging.

There are many sites of cultural significance along the River Murray and consideration must be given to these when developing environmental management options.

Irrigation Water Supply

The Pike River floodplain is the only source of water for many irrigators. It is used to provide a reliable source of water throughout the year. The water supply is threatened by high salinities, which are unsuitable for crops and low water levels, which make pumps inoperable. The system is therefore managed to provide a minimum supply of water by maintaining channels which are subject to congestion by reeds, particularly Margaret Dowling Creek and Deep Creek, and by maintaining culverts, such as Coombs Bridge. The water level in the system is managed by maintaining the banks which raise levels within the Pike-Mundic system.

Rumpagunyah Creek contributes to the water supply of irrigators on the Lower Pike River. Flow through Rumpagunyah Creek is determined mainly by the elevation of the River Murray water surface and the slope of the River Murray water surface. It is possible that silt has accumulated in Rumpagunyah Creek and contributed to high sill levels. Removing silt would make little difference to flow which depends mainly on the head difference between the upstream and downstream ends of the creek (Gippel 2008).

Grazing and Horticulture

Most of the Pike River floodplain supports grazing by sheep and cattle (Figure 17). Cattle are excluded from most of the floodplain between Mundic Creek and the River Murray, which includes the Pike River Conservation Park and land owned by the National Trust. Historically the upper and lower floodplains supported extensive areas irrigated agriculture, particularly between Tanyaca Creek and Col Col Embankment and in the central part of the Lower Pike Floodplain. Irrigated agriculture is now limited to small plots near Woodcutters Bridge wetland (near Bank C) and parts of the floodplain between the Lower Pike River and the highland.

Figure 17. Stock Access to the Pike River Floodplain

Irrigated Horticulture

Areas of the floodplain have been developed for irrigated horticulture and pasture (Figure 18). Active areas of irrigation are now limited to the sites between Mundic Creek and the River Murray and sites between the Lower Pike River and the highland.

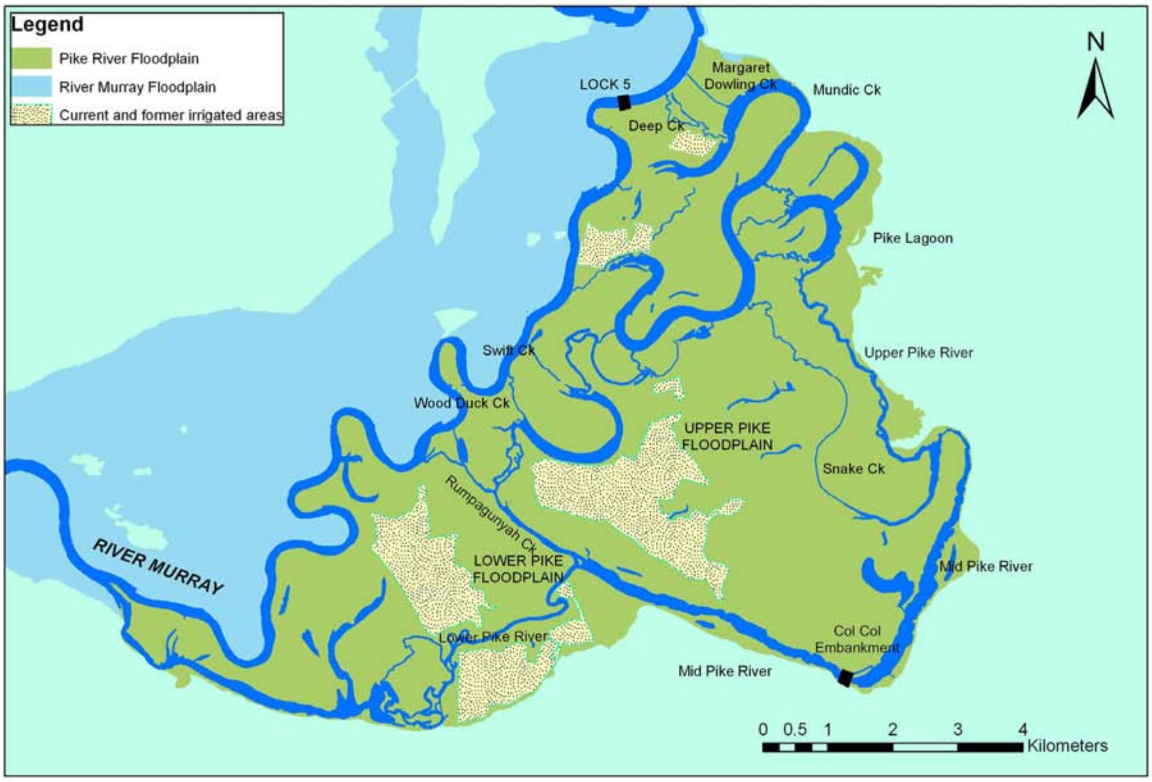

Figure 18. Areas of current and former irrigation on the floodplain.

Recreational Uses

The Pike River Conservation Park and National Trust property in the northern part of the floodplain provide recreational opportunities for bush walking and nature appreciation.

Recreational fishing takes place in the larger waterbodies and is particularly appreciated by visitors to Mundic Grove holiday cottages.

In the past, Mundic Creek has supported a recreational motor boat race, but this has not been held for several years.

The public do not have access to most of the floodplain.

Overview of Values and Threats

The Pike River floodplain provides a diverse range of aquatic and floodplain habitats and a correspondingly diverse flora and fauna. Many of the habitat features of the Pike River floodplain have been degraded elsewhere, and the system provides the potential to preserve an important complex of inter-related habitats at one location.

Although isolated from the River Murray by a series of barriers, Mundic Creek provides a deep, permanent water body which supports a diverse fish population and a healthy macroinvertebrate community. Other watercourses and wetlands 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 Red Gum woodland communities, which in places have a diverse understorey of native grasses and herbs. Red Gum provides 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 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. Macroinvertebrates and zooplankton quickly populate vegetated and open water areas. Fish graze on decaying plant matter and spawn in the flooded vegetation. Lignum, which is relatively dormant during dry periods, grows new shoots and provides nesting platforms for waterbirds such as Ibis.

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 is generally intolerant of flooding, but provides a valuable habitat for aquatic fauna as it decays when flooded. The flowers and new shoots provided by Black Box trees after flooding supports a food web based on nectar- and sap-eating insects and birds, and their predators.

Despite these values, there are significant threats to these values in the Pike River floodplain.

Extensive areas of the floodplain are degraded by salinisation which occurs through groundwater discharge and the evaporative concentration of salts in floodplain soils. Salinity threatens habitat values in watercourses and threatens the health of vegetation over extensive areas of the floodplain.

Floods are essential to many important conservation values of the floodplain, but have become less frequent as a result of the storage and diversion of water upstream. Insufficient flooding has led to low productivity on the floodplain, poor vegetation health and low rates of germination and recruitment of floodplain trees.

Significant areas of the floodplain are grazed by stock, feral animals and kangaroos. Grazing has exacerbated the vegetation impacts associated with salt and flooding and has completely degraded vegetation in some areas.

The free movement of fish between the floodplain and the river is important to successful breeding, dispersal and migration. There are several blockages to fish passage which reduce the habitat value of the floodplain.

Watercourses and wetlands in the Pike River floodplain are becoming filled with sediment. Siltation has resulted from increased sediment in water entering the system from the River Murray upstream, from the impoundment of water in the Pike-Mundic pool and the Lock 4 weir pool and by the loss of frequent floods which used to scour watercourses and wetlands and maintain their shape {Gell, 2006 #1459}.

These issues are explored in more detail later in the plan.

3.1 Assessment Process

The methodology to identify conservation assets and assess their viability was adopted from the Conservation Action Planning (CAP) process (The Nature Conservancy 2007).

The Pike River Floodplain was divided into eight ecological assets for the assessment process:

- flowing watercourses;
- permanent wetlands;
- temporary wetlands;
- Red Gum woodlands;
- Lignum shrublands;
- Chenopod Shrublands / Grasslands;
- Black Box woodlands; and
- dunes.

The assets each correspond to a different hydrological regime and together they comprise all of the terrestrial and aquatic habitats present in the ecosystem. The assets were selected on a hydrological basis to identify and classify hydrological and other threats and to link management options directly to the assets. Each of the assets is described in the following section.

The long-term viability of the assets was described as a function of their extent, condition and landscape context. Based on the best available knowledge and informed judgement, the following key ecological attributes relevant for each asset were identified.

- Size is a measure of the area or abundance of the conservation asset's occurrence.
- Condition is a measure of the composition, structure and biotic interactions which characterise the asset's occurrence.
- Landscape Context includes two factors: the ecological processes that maintain the asset occurrence and connectivity.
- Ecological Processes include hydrological (flooding and flow regime), fire regimes and many kinds of natural disturbance.
- Connectivity includes such factors as the movement of species between various habitat components, for feeding, sheltering, breeding, dispersal and migration.

Ecological Attributes were selected that are critical to each asset's long-term viability and describe some characteristic of the asset. The key attributes were rated for current status. These ratings essentially define the health, or long-term viability, of each asset. They also provide a long-term measure of management success (monitoring program).

Indicators to measure each ecological attribute were established. Indicators can be some type of quantitative assessment, such as hectares of habitat or percentage of healthy trees. They can also involve measurable elements that are non-numerical, such as flooding regime or recruitment of a species.

Current status of each indicator was rated for current health, and desired health, using the following grading scale:

Very Good -- Functioning at an ecologically desirable status, and requires little human intervention.

Good -- Functioning within its range of acceptable variation; it may require some human intervention.

Fair -- Lies outside of its range of acceptable variation and requires human intervention. If unchecked, the target will be vulnerable to serious degradation.

Poor -- Allowing the indicator to remain in this condition for an extended period will make restoration or preventing complete loss practically impossible.

Critical threats were determined by ranking the stresses on an asset and then ranking the sources of the stress. A threat is a combination of a stress and the source of a stress.

Stresses destroy, degrade or impair conservation assets by impacting a key ecological attribute relating to their size, condition or landscape context. A source is the proximate cause of a stress. It is important to understand both the *stresses* affecting the conservation assets and the *sources* of stress in order to ensure that effective conservation strategies are developed.

Rank the stresses

The relative seriousness of a stress is a function of the following two factors:

- *Severity of damage.* What level of damage to the conservation asset can reasonably be expected within 10 years under current circumstances? Total destruction, serious or moderate degradation, or slight impairment?

- *Scope of damage***.** What is the geographic scope of impact to the conservation asset expected within 10 years under current circumstances? Is the stress pervasive throughout the target occurrences or localised?

Based upon the best available knowledge and expert judgments, each stress was ranked to each conservation target. Ranking the stresses was based on the following scale: *Very High, High, Medium or Low*.

4.1 Asset 1 Flowing Watercourses

Asset Description

Flowing water habitat is provided in Margaret Dowling Creek and Deep Creek. It is potentially provided in Tanyaca Creek downstream of Mundic Creek and Snake Creek.

Flow in these channels is generated by the flow of water from the Lock 5 weir pool and its distribution through the floodplain channel system. Flow rates are controlled by the weir level and are therefore largely constant. Flow through the channels can be reduced if River Murray levels below Lock 5 are elevated (due to moderately high river flows) which can spill water into Mundic Creek and impede outflows at Col Col. Flow through the channels can be elevated if the Lock 5 is raised.

Margaret Dowling Creek and Deep Creek are narrow channels, less than 10 m wide and deeply incised. The creeks are subject to dense growth from *Typha* sp. and *Phragmites australis* on submerged benches, however reeds are regularly controlled by dredging and spraying to maintain the flow of water to the Pike River. *Potamogeton* sp. is present in quieter backwaters. The inlets from Lock 5 feature pipe culverts and the Lock 5 Road culvert and are barriers to the passage of fish between Lock 4 and Lock 5 (Leigh and Zampatti 2005). The creeks provide a rare fast-flowing environment in the lower River Murray that is potentially a high-value habitat for native fish and other flow-dependent aquatic species such as the locally extinct River Mussel (*Alathyria jacksoni*), River Murray Crayfish (*Eustacus armatus*) and River Snail (*Notopala hanlyie*).

Bank G provides a constant trickle flow to Snake Creek. The creek bed is approximately 15 m wide. The creek channel is 2 m deep and 35 m wide at top-of-bank. The saturated bed supports dense *Typha* sp., *Myriophyllum* sp. and *Paspalum distichum* with *Cyperus gymnocaulos* at the fringes. Waterlogged conditions persist along the length of Snake Creek. The creek is deeper near the junction with Pike River where water from Pike River backs up. At this location the creek also supports *Ludwigia peploides* and *Scheonplectus validus*. Snake Creek is lined by Black Box in moderate health; trees set back from the creek are in poor health.

Banks E, F and F1 provide flow from Mundic Creek to two creeks that join before discharging to Tanyaca Creek. The creeks are in a similar condition to Snake Creek. An additional creek branch of this system joins Mundic Lagoon at Bank D but is blocked and does not contribute flow. Between Bank D and E the creek widens out to 70 m wide and is set 5 m into the floodplain. The creek has abundant woody debris and a narrow fringe of *Cyperus gymnocaulos* and *Typha* sp. with *Myriophyllum* sp. and *Azolla* sp.

Deep Creek

Snake Creek

Tanyaca Creek below Bank F1

Flowing water provides an essential habitat component for a number of River Murray fauna. Prior to the construction of the weirs, flowing water habitat was available in both the river and the floodplain, but now only occurs in some floodplain watercourses.

Flowing watercourses provide a contrasting flowing, relatively well-oxygenated aquatic habitat to the River Murray. The flow of water also reduces the potential for high water temperatures that can occur in shallow standing water in wetlands. Anabranches potentially provide habitat for a number of flow-dependent invertebrates including the locally extinct River Murray Crayfish (*Euastacus armatus*), which is favoured by the relatively cool temperatures and high oxygen levels of flowing water (McCarthy 2005). This species grazes epiphytes and other organic debris and preys on aquatic invertebrates. Other flow-dependent invertebrates include the River Snail (*Notopala hanlyie*), the Shrimp (*Macrobrachium australiense*) and River Mussel (*Alathyria jacksoni*). The River Snail and River Mussel have not been recorded from the Pike River Floodplain, however the restoration of flowing habitat provides an opportunity for the recolonisation or reintroduction of these species if they are indeed currently absent.

Small fish will be favoured by the in-stream vegetation of narrow watercourses whereas larger fish species will occur in open watercourses (Leigh and Zampatti 2005). Deep holes in open watercourses can provide habitat for large bodied fish including Murray Cod (*Maccullochella peelii*) which benefit from the cooler water than occurs in wetlands.

Water flowing from watercourses into wetlands provides attractant flows for fish, encouraging their upstream migration (Leigh and Zampatti 2005). Flowing water provides an important breeding habitat for Australian Smelt.

In addition to the flow-dependent species, permanently flowing watercourses provide a permanent aquatic habitat for a range of generalist aquatic fauna. Compared with the wetlands, the watercourses will support a species-poor climax community of aquatic invertebrates comprising large zooplankton, Shrimp (*Parataya* sp. and *Macrobrachium* sp.) and large insect larvae such as mayfly and dragonfly. Together with small bodied fish living in the fringing macrophytes, these provide prey for large bodied fish that live in the deep open water in the central parts of semi-permanent wetlands, e.g. Silver Perch, Golden Perch and Bony Bream. Large bodied fish will also visit the fringing vegetation and snags, which provide benthic invertebrate prey and shelter from predators. Watercourses may support resident populations of tortoise. The watercourses represent an alternative habitat to the River Murray for these large aquatic species, which move between the floodplain and the river during peaks in river flow.

The bird fauna is dominated by fish-eating species such as Intermediate Egret (*Ardea intermedia*) and Pelican. Watercourses also provide a semi-permanent habitat for a wide range of waterbirds, which would become more abundant and diverse during drought periods. They provide permanent watering points for terrestrial vertebrates and bush birds.

To achieve the ecological objectives, the floodplain should provide contrasting habitats with narrow channels and in-stream vegetation and open channels with riparian vegetation.

Water Regime Targets

A key characteristic of the watercourses is flowing water which provides increased oxygen levels (through turbulence) and decreased temperatures (through deeper, flowing water), both of which will be beneficial to Murray Crayfish, River Mussel and River Snail. McCarthy (2004; 2005) showed that crayfish in the Mallee tract of the Murray River were only caught in flow velocities of between 0.25 $m.S^{-1}$ and 0.49 $m.S^{-1}$, indicating the critical nature of flow velocity for the survival of this species.

Flowing watercourses may be permanent or may dry out seasonally. Flow should predominantly occur during the fish breeding and migration period June and December. The depth should be between 0.5 and 1 m deep 75% of the time when the channel is flowing. The mean cross-sectional velocity should be less than 0.5 m/s 75% of the time and the depth may need to be adjusted accordingly.

4.2 Asset 2 Permanent Wetlands

Asset Description

Permanent Wetlands are present in areas impounded by Lock 4 or the Pike-Mundic system.

Tanyaca Creek is connected to the River Murray via two unobstructed channels, Swift Creek and Wood Duck Creek. Both creeks flow into Tanyaca Creek at normal regulated river levels. The creeks have steep or vertical banks up to 2 m deep but have shallow and exposed benches within the channel. The creeks support stands of *Typha* sp. on the benches and *Potamogeton* sp. and *Vallisneria spiralis* in deeper water.

Tanyaca Creek discharges via a channel to Rumpagunyah Creek. The watercourse has a shallow channel (approximately 1 m deep) with an exposed bench 30 m wide and less than 1.5 m above the channel level. The creek supports patches of *Typha* sp. and *Phragmites australis* and is lined by Red Gum in moderate health.

The Upper Pike River conveys most of the flow diverted from the Lock 5 weir pool. Flow is gradually depleted by extractions along its length but some discharge is maintained over the Col Col embankment at all times. The creek banks are shallow and broad and support dense stands of *Typha* sp. and *Phragmites australis* that can extend back several metres from the water's edge. *Scheonoplectus validus* and other macrophytes may be present less abundantly. The creek is lined by scattered Red Gum in moderate health. Immediately beyond the reeds the vegetation is sparse with halophytes and salt-encrusted bare ground present.

Mundic Creek is an impounded wetland which is largely incidental to water supply. It conveys water from Margaret Dowling and Deep Creek to diverters on Pike River, but has no significant economic water uses. The banks have narrow fringing vegetation, which reflects a history of stable water levels. The River Murray Baseline Survey reported a healthy and diverse fish assemblage which is dominated by native species. The survey emphasised the importance of the current stable water regime to the high value of the fish habitat.

The River Murray Baseline Survey reports that parts of Mundic Creek are more than 2 m deep. The creek has a diverse and healthy fish community which is dominated by native species, with high abundances of Carp Gudgeon Complex. Other native fish present include Silver Perch, Australian Smelt, Bony Bream, Callop, Dwarf Flathead Gudgeon, Flathead Gudgeon, Fly-specked Hardyhead and Murray River Rainbow Fish. Exotic fish species present were Carp, Gambusia, Goldfish and Redfin.

The Lower Pike is similar to the Upper Pike but tends to have an incised bank with a drop of up to 1 m. Dense meadows of *Myriophyllum* sp. are present in places. Below its confluence with Rumpagunyah Creek the Lower Pike River diverges into two convoluted anabranches, which converge again further downstream to form a deep, wide channel that has a water level equal to that of the Lock 4 weir pool. A substantial backwater extends from the creek into the Lower Pike floodplain.

Rumpagunyah Creek contributes flow to the lower Pike River from the River Murray. The creek provides an alternative flow path for the river and diverts a proportion of river flow even at low, regulated discharges. The creek is approximately 30 m wide near the River Murray and broadens towards the confluence with Lower Pike River. Water is also drawn into the creek by extractions from the Lower Pike River. Riparian vegetation is in relatively good health with meadows of semi-emergent macrophytes, emergent macrophytes and Red Gum in moderate health. Rumpagunyah Creek was considered to provide the best fish habitat in the Pike-Mundic system due to its unregulated flows, healthy vegetation, width, depth and abundance of snags (Leigh and Zampatti 2005). There is a perception that silt is accumulating among some irrigators where Rumpagunyah Creek diverges from the River Murray, but shallow conditions are more likely to have resulted from low river levels than a rising bed level (Gippel 2008).

Letton's Wetland is a wetland on the Lower Pike Floodplain with a permanent connection to the River Murray near Rumpagunyah Creek. The wetland supports extensive beds of semi-emergent aquatic macrophytes and has a relatively healthy community of fringing River Red Gum trees.

	
Mundic Creek	Letton's Wetland

Permanent wetlands provide a reliable aquatic habitat for a range of generalist aquatic fauna. Permanent wetlands will support a species poor climax community of aquatic invertebrates comprising large zooplankton, shrimp (*Parataya* sp. and *Macrobrachium* sp.) and large insect larvae such as mayfly and dragonfly. Together with small bodied fish living in the fringing macrophytes, these provide prey for large bodied fish that live in the deep open water in the central parts of semi-permanent wetlands, e.g. Silver Perch, Callop and Bony Bream. Large bodied fish will also visit the fringing vegetation and snags, which provide benthic invertebrate prey and shelter from predators. Permanent wetlands may support resident populations of tortoise. The wetlands represent an alternative habitat to the River Murray for these large aquatic species, which move between the floodplain and the river during peaks in river flow.

The bird fauna is dominated by fish-eating species such as Intermediate Egret (*Ardea intermedia*) and Pelican. Permanent wetlands also provide a reliable habitat for a wide range of waterbirds, which would become more abundant and diverse during drought periods. They provide permanent watering points for terrestrial vertebrates and bush birds.

Water Regime Targets

Broad channels should be permanent but should incorporate a seasonal fluctuation. The watercourse should reach or exceed the bank-full level between August and December in 75% of years. The level should fall to 75% of the bank full level between February and May in 75% of years. The level should never fall below 50% full.

4.3 Asset 3 Temporary Wetlands

Asset Description

Although most the Pike River floodplain is freely draining, there are a number of depressions which retain water after floods recede. The ecology of temporary wetlands varies according to flood frequency.

Low lying shallow depressions are filled frequently by small fluctuations in river flow. They support meadows of Milfoil and beds of sedges and rushes. These wetlands are highly productive grazing and breeding habitat for waterbirds, frogs and small fish which make use of the abundant vegetation cover, food and macroinvertebrate prey.

Former river channels in the centre of the Upper Pike and Lower Pike floodplain provide deep (more than 3 m deep) wetland habitat. These require flows of more than 80,000 ML/d to fill but will retain water for one or more years. In contrast, shallow basins that lie close to normal water levels may be inundated from time to time under normal river flows (e.g. Woodcutters Wetland). Wetlands to which a temporary water regime could be introduced are presented in Figure 19.

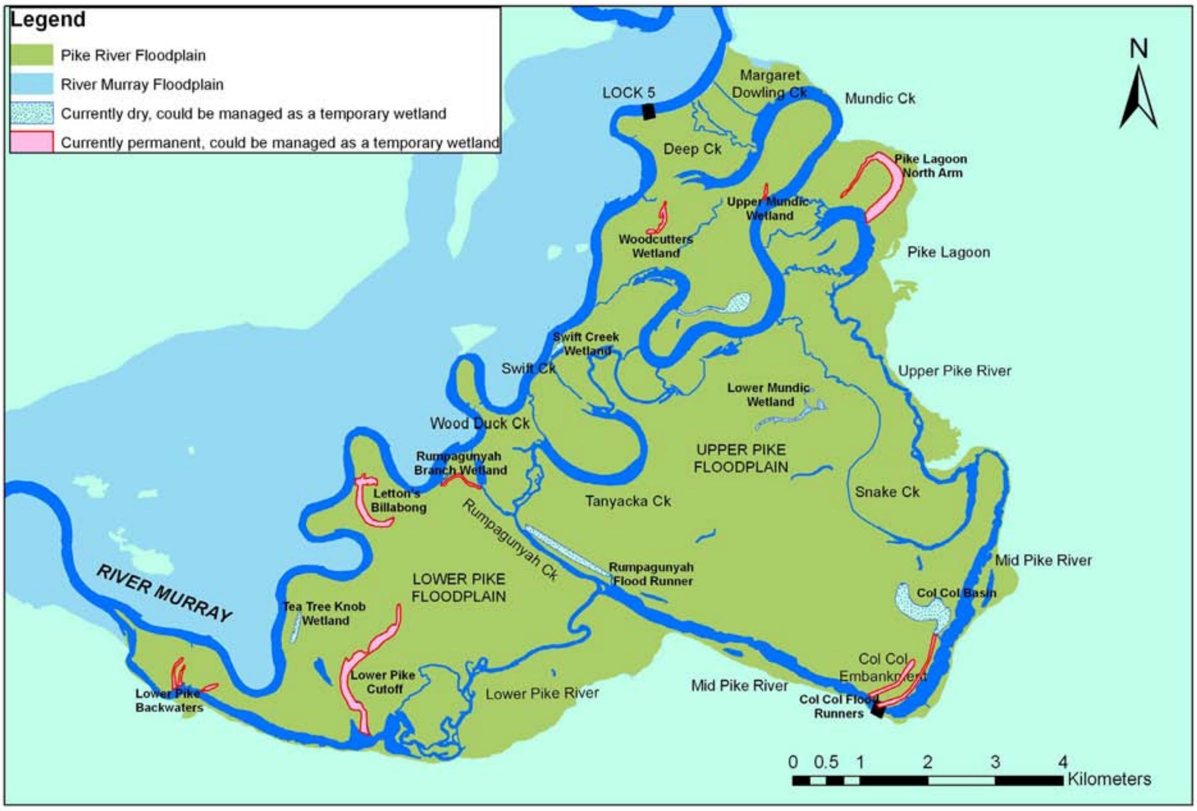

Figure 19. Temporary wetlands

Wetland condition varies considerably. Wetlands in the vicinity of the highland cliff and in central floodplain areas are severely drought affected and salinised. Low lying wetlands near Mundic Creek and Tanyaca Creek in close proximity to the River Murray are less saline but at risk of grazing impacts.

Swift Creek Wetland

A wetland in the north of Mundic Island

Lower Pike Cutoff

Woodcutters Wetland

Water Regime Targets

The water regimes applied to temporary wetlands will vary according to their shape, elevation and the feasibility of water management. A range of water regimes should be provided to create a mosaic of wetland habitats that will support diverse plant and animal communities. The water regimes should include:

- wetlands which are normally flooded but dried out for 3 months every two years;
- wetlands which are flooded annually for periods of 3 to 6 months; and
- wetlands which are normally dry but flooded for 3 to 6 months every two years; and
- wetlands which are filled to capacity (they may retain water for more than one year) every 5 to 10 years.

4.4 Asset 4 Red Gum Woodlands

Asset Description

Red Gum Woodland predominantly occurs on meander loops near the main channel of the River Murray. Smaller patches and scattered trees occur along watercourses, particularly Pike River below the Col Col embankment. The best examples of Red Gum woodland occur on islands between Tanyaca Creek and the main channel, where the vegetation is not grazed and where groundwater conditions are less hostile (Figure 13). At such locations both healthy trees and an intact understorey exist. Tree health is poor along the anabranches of the central floodplain, such as Snake Creek. Understorey vegetation is typically in poor condition, a likely consequence of the combined effects of grazing, reduced frequency of inundation and shallow, saline groundwater. The floodplain inundation model indicates that these areas are flooded at 60,000 ML/d.

	
Island at the junction of Pike River and Rumpagunyah Creek	Red Gum woodland with healthy diverse understorey

Red Gum Woodland is an important water regime class on Pike River floodplain because it is critical to the growth and reproduction of many fauna species. Optimally, Red Gum Woodland is inundated by peaks in river flow in winter and spring. The beds of emergent macrophytes present at the edge of the river channel, watercourses and wetlands continue to some extent in the understorey of the woodland, and include perennial species such as *Juncus aridicola* and *Cyperus gymnocaulos.*

Flooding supports growth and recruitment of the dominant trees *Eucalyptus camaldulensis* subsp. *camaldulensis* and *Acacia stenophylla*. When inundated, the understorey may include wetland plants such as *Crassula helmsii*, *Setaria jubiflora* and *Sporobolus mitchellii.* The damp understorey condition that follows floods in spring and summer promotes the growth of a variety of understorey grasses and herbs including *Senecio cunninghamii* ssp. *cunninghamii, Alternanthera denticulata*, *Lachnagrostis filiformes, Setaria jubiflora* and *Wahlenbergia fluminalis.* Waterwort, *Elatine gratioloides*, rated as rare under the

NPW Act, has been recorded from Red Gum Woodland on the Pike River floodplain. Less frequently flooded areas of Red Gum Woodland exhibit an understorey vegetation that may include shrubs such as Lignum, *Chenopodium nitrariaceum* and *Enchylaena tomentosa* var. *tomentosa*.

Red Gum Woodland is flooded by the spread of water to the floodplain when river levels exceed 60,000 ML/d. This increases the habitat available for aquatic fauna, particularly small bodied fish. Many larval fish are believed to use the floodplain as a nursery habitat (Schiller and Harris 2001).

The habitat for terrestrial frogs, which is normally limited to the reeds fringing the lakes, will expand into the Red Gum Woodland when flooded. In addition, burrowing frogs, which aestivate in the floodplain soil, will become active. Other lake species that will extend into the flooded woodland will include Yabby (*Cherax destructor*), tortoise and Water Rat (*Hydromys chrysogaster*).

The flooding events are too brief and intermittent to sustain the large populations of small floodplain fauna they generate. However, they represent pulses in plant and animal growth and reproduction that are important to the long term productivity of the river-floodplain ecosystem and the viability of fauna with longer life cycles.

The additional food will support significant waterbird breeding events while the Red Gum is flooded. The trees will support a range of water birds that only breed over water such as Little Egret, White-necked Heron (*Ardea pacifica*), White-faced Heron (*Egretta novaehollandiae*), Great Cormorant (*Phalacrocorax carbo*) and Little Black Cormorant (*Phalacrocorax sulcirostris*). It should be noted that successful breeding in these species depends critically on the duration of flooding. A range of other waterbird guilds are also likely to breed, including waterfowl, large waders and small waders.

The flood recession will bring much of the small floodplain aquatic fauna and other organic matter to the river channel and wetlands where it represents an influx of food. In Mundic Creek, a semi-permanent wetland which has relatively low productivity, this will sustain a predator-dominated fauna that includes large bodied fish, large predatory macro-invertebrates and fish eating waterbirds. The food provided by the flood recession is also important to the seasonal wetlands and the River Murray, where the prey is likely to support breeding events in large aquatic fauna with long life cycles, such as Murray Cod.

Red Gum Woodland has an important role in providing structural habitat for aquatic and floodplain fauna, particularly snags which are used for grazing and shelter by fish such as Silver Perch, and in providing tree hollows for nesting Australian Wood Duck, bats, Brush-tailed Possum and a wide range of other animals. There are unconfirmed reports of the hollow dwelling Carpet Python (*Morelia spilota variegata*) from the Pike River floodplain. This species is listed as vulnerable under the *NPW Act 1972*. Fringing Red Gum also provide perches for nesting waterbirds and raptors such as White-bellied Sea-eagle. The tree growth triggered by flooding will provide much of the leafy and woody material on which the floodplain ecosystem depends and will also increase flowering that supports nectar-eating insects and birds and insectivorous birds (Bacon *et al.* 1993; Robertson *et al.* 2001).

Water Regime Targets

The minimum requirement for inundation of Red Gum Woodland (forestry stand quality II) at Barmah-Millewa is a frequency of 5 times every 10 years with a duration of 1 month (Dexter 1978). At Chowilla, flows of 82,000 ML/d, which inundate 83% of Red Gum Woodland occurred in 4.5 times every 10 years and were exceeded on average for 3.2 months (Sharley and Huggan 1995). At Lindsay, Mulcra and Wallpolla Islands events of 80,000 ML/d have a median duration of approximately 50 days under both natural and current conditions and occurred in 6 times every 10 years under natural conditions (Ecological Associates 2006).

Fringing Red Gum and Red Gum Forest provide important waterbird breeding habitat. Colonial nesting waterbirds are particularly sensitive to flood duration. They only breed successfully when their nests are surrounded by water. If water levels drop before the young birds fledge, adult birds often abandon their nests. Species such as darters, cormorants, herons, egrets, ibis and spoonbills take around 3-4 months to build their nests, lay, incubate their eggs and fledge their young. This means that for successful breeding these waterbirds require inundation for 5-7 months following spring floods and 6-10 months for autumn-winter floods (Briggs and Thornton, 1999).

The composition of the understorey is influenced by flooding frequency and duration. Spiny Mudgrass would be expected in the understorey of Red Gum Forest and requires floods of two to three months (Ward 1991). *Carex tereticaulis*, which is an indicative understorey species of less-frequently inundated areas has an optimal inundation duration of two months and tolerates floods of up to 4 months duration (Roberts and Marston 2000).

Relatively brief floods will maintain tree health, the floristic composition of Red Gum Woodland and ecosystem productivity for fauna. It is recommended that floods of 1 to 3 months duration are provided in at least 50% of years.

Longer floods will support breeding by flood-dependent fauna. It is recommended that floods of 5 months duration are provided in at least 20% of years.

To support vegetation growth and fauna breeding requirements, the peak in flood depth should match the natural timing and occur between September and November in most years.

4.5 Asset 5 Lignum Shrublands

Asset Description

Lignum Shrubland occurs in floodplain depressions where rainfall provides seasonally waterlogged conditions and water is retained after flood events. Lignum Shrubland occurs in the scroll-belt systems associated with Mundic Creek, Tanyaca Lagoon and to a lesser extent, Snake Creek, in high-level floodplain depressions at the edge of these wetlands. Lignum Shrubland also occurs in the elongated floodplain depressions that extend from Tanyaca Creek, near where it joins Rumpagunyah Creek into the Upper Pike floodplain, parallel to Pike River. Due to the effects of shallow saline groundwater and the reduced flooding frequency, Lignum is in poor health throughout the study area, with many shrubs dying back to stumps.

Lignum Shrubland near Bank C

The vegetation of this water regime class is dominated by *Muehlenbeckia florulenta* and can include *Eragrostis australasica.* It tends to occur in floodplain depressions away from watercourses which are only flooded during widespread inundation events. They may also be seasonally waterlogged by local rainfall, which will maintain the waterlogging-dependent species present between floods. In the absence of flooding this water regime class will gradually deteriorate. The health and density of *Muehlenbeckia florulenta* will decline and more terrestrial species, particularly chenopods such as *Atriplex lindleyi, Atriplex rhagodioides, Enchylaena tomentosa* var. *tomentosa* and *Chenopodium nitrariacum* become more common. When flooded this area supports aquatic species such as *Marselia drummondii* and *Eleocharis acuta*.

Inundation of Lignum Shrubland represents an extension of the habitat for aquatic floodplain fauna such as small and large bodied fish, reptiles and macro-invertebrates. The dense vegetation may favour vegetation-dependent fish. Waterbird that breed over water, such as Ibis and Spoonbill, are likely to nest in Lignum Shrublands when flooded.

Water Regime Targets

Lignum tolerates a wide range of flooding frequencies and durations. A minimum flood requirement to maintain shrub growth and recruitment has been reported as 1 month in 40% of years (Roberts and Marston 2000). At Chowilla, 74% of Lignum shrubland was inundated by flows exceeding 82,000 ML/d. Under natural conditions this threshold was exceeded 4.5 times every 10 years with an average duration of 3.2 months (Sharley and Huggan 1995).

Relatively brief floods will maintain vegetation health. It is recommended that Lignum Shrublands are flooded for 1 month in 30% of years with a minimum event separation of 5 years.

Longer floods will support waterbird, frog and fish breeding. It is recommended that in 20% of years the duration of flooding exceeds 3 months.

4.6 Asset 6 Chenopod Shrublands / Grasslands

Asset Description

Chenopod Shrubland occupy high-level floodplain areas subject to salinisation. *Atriplex lindleyii* shrubland occupies significant areas adjacent to Snake Creek and the southern half of the lower Pike floodplain. Chenopod Shrublands also occupies much of the area enclosed by the bend of Mundic Creek.

Chenopod shrubland near Woodcutters Wetland

Chenopod Shrubland near Mundic Creek

The Pike River floodplain features large areas naturally devoid of trees and shrubs that are dominated by native floodplain grasses, predominantly *Sporobolus virginicus*, forbs such as *Polycalymma stuartii*, and chenopods, predominantly *Atriplex lindleyii* and *Sclerolaena triscuspis*. These areas typically occur at elevations intermediate between Lignum shrubland and Black Box woodland. In the absence of domestic grazing the grassland sward persists between flood events providing a distinct habitat feature on the floodplain. The ecological significance of floodplain grassland has not been well studied (Young 2001). Floodplain grassland supports large grazing mammals such as the Western Grey Kangaroo (*Macropus fuliginosus*) and is likely to provide feeding habitat for ground dwelling granivorous birds such as Zebra Finch (*Taeniopygia guttata*) that feed on grass seeds. Birds of prey may hunt for small mammals and reptiles within the grassy vegetation. When flooded, and immediately following flood recession, floodplain grassland is highly productive, contributing large quantities of plant material to support the river-floodplain food web. Wetland invertebrates and small bodied fish would be among the fauna groups to take advantage of this pulse of productivity.

Samphire is salt and inundation tolerant vegetation that, on the Pike River floodplain, is typically dominated by the low shrub *Halosarcia pergranulata ssp. pergranulata*. Samphire is a naturally occurring vegetation type on the River Murray floodplain, however it has increased in area as a consequence of human-induced salinisation (Kahrimanis et al. 2001). Samphire can provide feeding habitat for large and small waders, including migratory species, and some parrot species. Samphire occurs at low elevations in floodplain depressions that would have been more frequently inundated prior to river regulation. The extent of samphire on the Pike River is almost certainly an artefact of artificially high groundwater levels, causing soil salinisation, and reduced frequency of floodplain inundation. It is reported to have displaced large areas of Lignum, Back Box and grasses (Woodward-Clyde 2000). Samphire is an undesirable component of the Pike River floodplain ecosystem and management actions should be aimed at reducing its extent.

Water Regime Targets

The plants of this water regime class persist in rarely flooded areas. It is recommended that floods of 1 month are provided in 30% of years to maintain vegetation health with a minimum event separation of 5 years.

Longer floods will support waterbird and fish breeding. It is recommended that in 20% of years the duration of flooding exceeds 3 months.

The current extent of samphire reflects the reduced flooding frequencies and elevated soil salinities the floodplain experiences. Management strategies which address these threats (see Section 5 below)will contribute to a decline in samphire shrublands.

4.7 Asset 7 Black Box Woodlands

Asset Description

Black Box Woodland is a substantial component of the floodplain vegetation and occurs on high terraces. The largest woodland area, with an understorey of chenopod shrubs, extends south-east from Mundic Creek through the central part of the Pike floodplain. A large woodland area also occurs on the lower Pike floodplain adjacent to Rumpagunyah Creek. Smaller patches, with an understorey of Lignum, occur in the north of the floodplain near Pike Lagoon and Mundic Creek.

The understorey includes Dryland Tea Tree, Lignum, chenopod shrubs, grasses and herbs.

Woodlands in the vicinity of Lock 5 and the western part of Mundic Island are generally in very good condition. Trees are in poor condition at the edge of the Lower Pike floodplain and at the foot of the highland near Lettons Rd. Elsewhere trees are dead or dying.

Black Box woodlands are extensively grazed.

Black Box woodland near Lock 5 Road

Brown's Camp eastern side of Mundic Island

Dead Black Box trees on Upper Pike Floodplain near Rumpagunyah Creek

Black Box Woodland occupies the least frequently inundated areas of the floodplain at river discharges exceeding 100,000 ML/d. This water regime class is dominated by Black Box (*Eucalyptus largiflorens*), which occurs over a diverse shrubby understorey that may include *Muehlenbeckia florulenta* and a variety of chenopods including *Atriplex rhagodioides, Enchylaena tomentosa* var. *tomentosa* and *Chenopodium nitrariaceum. Eremophila divaricata* ssp. *divaricata, Disphyma crassifolium* ssp. *clavellatum* and various grasses may also be present. When flooded, aquatic species are present including *Marselia drummondii, Eleocharis acuta* and *Sporobolus mitchellii*. In some areas of this water regime class *E. largiflorens* gives way to a low open shrubland dominated by *Pachycornia triandra*.

The woodland develops a mature terrestrial flora between flood events and briefly changes to an aquatic habitat during floods. Tree recruitment and the productivity of trees is strongly linked to flooding, and regular floods are required to maintain a diverse age structure in the tree population. Trees grow very slowly when not inundated. When flooded, Black Box provides an extension of the habitat provided in Red Gum Woodland. Flooding also supports breeding in many floodplain biota and is likely to be important to maintaining populations of long-lived species that depend on intermittent flooding events.

An important contrast with the adjacent Red Gum Woodland is the importance of Black Box for canopy feeders. The avifauna includes species that found along the river that are typical of high-rainfall areas such as Superb Fairy-wren, Little Friarbird and Blue-faced Honeyeater. Black Box woodland also supports seasonal migrants normally associated with higher rainfall areas such as Grey Fantail and White-bellied Cuckoo-shrike.

Water Regime Targets

Flooding promotes the growth of Black Box trees, promotes tree recruitment and increases the productivity of the woodland for dependent fauna. If the duration of events between floods is too long Black Box trees will suffer poor health and trees will die.

Floods are required to provide regular recruitment events and to provide a productive habitat for fauna. At Chowilla, 75% of Black Box is interpreted to be inundated by flows of 100,000 ML/d. Under natural conditions events of this magnitude occurred 32 times every 100 years and have an average duration of 3 months (Sharley and Huggan 1995). At Barmah Forest, Black Box grows in areas flooded for 1 month by events occurring 10 years in 100 (Dexter 1978). A similar flooding frequency has occurred at Hattah Lakes where areas occupied by Black Box were inundated approximately 20% of years for 2 to 5 weeks under natural conditions (Ecological Associates 2006).

An indication of the absolute tolerance of Black Box to periods without flooding is provided at Hattah Lakes where trees recruited high on the floodplain at the limit of the 1974 flood event were observed to die in 2006. Flood water had not reached these trees since they were recruited, indicating that tree survival depends on floods less than 30 years apart (Ecological Associates 2006).

Floods must be provided with sufficient frequency to support not only tree survival, but the productivity of the ecosystem on which other plants and animals depend. A flood frequency of 20 events per 100 years is recommended for low-lying Black Box and 10 events per 100 years is recommended for Black Box near the upper limit of flooding. A median event duration of 6 weeks is recommended.

4.8 Asset 8 Dunes

Mallee vegetation is present on isolated dune soils (Woorinen Sands) on the floodplain. This vegetation lies at high elevations and is not subject to flooding.

Dunes comprising wind-blown deposits of Woorinen Sand occur on the Upper Pike floodplain. The dunes directly overlie the Coonambidgal Formation, above the 1956 flood level. They are vegetated with terrestrial mallee species but are severely degraded by a long history of grazing. Some woody weeds are present including African Boxthorn and Tobacco Bush.

The dunes potentially provide a refuge for birds, mammals and reptiles during flood events. They also provide habitat for mallee fauna such as reptiles and bush birds.

	
Dryland Tea Tree on floodplain dune	Degraded vegetation on floodplain dune

4.9 Conservation Asset Viability (condition)

The viability of the eight conservation assets was assessed by determining the current status of each ecological attribute. Appendix A describes the ecological attributes and the indicators for each asset and gives an individual rating of present and desired condition. Table 6 below summarises the individual asset and overall project viability.

Table 6. Summary of individual asset and project viability (condition)

Conservation Targets		Landscape Context		Condition		Size		Viability Rank
		Grade	Weight	Grade	Weight	Grade	Weight	
1	Flowing Watercourses (Habitat for Flow Dependent Species)	Fair	1	Fair	1	Poor	1	**Fair**
2	Permanent Wetland (static)	Fair	1	Poor	1	-	1	**Fair**
3	Temporary Wetlands (floodplain depressions)	Poor	1	Poor	1	-	1	**Poor**
4	Red Gum Woodlands	Fair	1	Fair	1	Fair	1	**Fair**
5	Lignum Shrublands	Poor	1	Poor	1	Fair	1	**Poor**
6	Chenopod Shrublands / Grasslands (temporarily inundated floodplain)	Fair	1	Poor	1	-	1	**Fair**
7	Black Box Woodlands	Fair	1	Fair	1	Fair	1	**Fair**
8	Dunes	Fair	1	Poor	1	-	1	**Fair**
Project Biodiversity Health Rank								**Fair**

Overall, the Pike River Floodplain is in fair to poor condition. None of the assets are in good condition. The floodplain has been degraded over many years by a wide range of threatening processes which have combined to reduce vegetation health, cover, and habitat value.

However the floodplain has significant rehabilitation potential. Lock 5 provides the opportunity to manipulate water regimes throughout the system to a much greater degree than other, similar floodplain systems. The weir provides the scope to create flowing watercourses and to inundate floodplain areas. If water regime manipulation is accompanied by actions to reduce grazing pressure and a salt interception scheme, it is reasonable to expect that the overall objective of a healthy floodplain ecosystem can be achieved.

4.10 Threat Assessment

Lack of Environmental Flows

River regulation and the diversion of water throughout the Murray-Darling Basin has resulted in a significant reduction in the frequency and duration of the flow peaks required for floodplain inundation. The river is principally managed to conserve and supply water for consumptive uses, with some allowances made to maintain water quality and support ecosystems. Storages are operated to capture water generated during high flows and to slowly release that water as consumers require. There has been a shift from a highly variable hydrograph with large, frequent peaks in flow which generate widespread floodplain inundation, to a hydrograph where flow is normally contained within the river channel.

The high degree of flow variability prior to regulation created a continuous gradient in ecosystem structure from the river channel to the floodplain. The frequently flooded fringes of the floodplain supported wetland and Red Gum woodland vegetation and higher floodplain areas supported Lignum shrublands and Black Box woodlands. As a result of stable water levels, wetland and Red Gum woodland communities are now restricted to a very narrow zone at the edges of permanent watercourses and wetlands. There is an immediate and striking distinction between the aquatic vegetation of the narrow riparian zone and the largely dryland vegetation of the central floodplain.

Inundation also contributes to the health and viability of floodplain vegetation and aquatic ecosystems by mitigating salinisation. Flood waters dissolve and export salts which have accumulated on the soil surface and floodplain depressions. In areas with porous soils, downward infiltration will dissolve and remove salts from the capillary zone. Furthermore, fresh flood water stored in floodplain soils provides an alternative water sources for vegetation to saline groundwater.

The Pike River floodplain has few low-lying areas and substantial flow peaks are required to achieve significant inundation.

Flow peaks of 40,000 ML/d are required to inundate the riparian zone and low lying wetlands on the Pike River floodplain. Under natural conditions this threshold would have been exceeded in 91 years out of 100 with a mean event duration of 4.9 months. Currently this threshold is exceeded in 40 years out of 100 with a mean duration of 3.3 months.

Flow peaks of 80,000 ML/d inundate Red Gum woodland communities and most Lignum shrublands. The large remnant river channel in the central part of the Upper Pike Floodplain is filled at this flow. Under natural conditions this threshold was exceeded in 45 years out of every 100 with a mean event duration of 3.2 months. Under current conditions these events occur 12 years in every 100 with a mean duration of 2.6 months.

Flow peaks of over 100,000 ML/d inundate grassland plains, all Red Gum Woodland and most Lignum shrublands. Black Box woodlands are inundated by flows above this threshold. Under natural conditions events of this magnitude occurred in 32 years in every 100 with a mean duration of 2.9 months. They currently occur in 9 years in every 100 with a mean duration of 2 months.

Impounding Structures

Banks and blockages maintain stable water levels in the Pike-Mundic system which includes the Upper Pike River, Pike Lagoon and Mundic Lagoon. Below these structures, water levels are maintained at fairly constant levels by the Lock 4 weir pool. The primary objective of the banks, blockages and weirs is to support irrigation diversions and navigation. Water levels must be sufficiently deep to allow pumps to draw water without taking in sediment. These structures are illustrated in Figure 6.

High water levels contribute to floodplain salinisation. Impounding structures maintain water levels in the Pike-Mundic system approximately 1 m higher than the River Murray at the corresponding position below Lock 5. The groundwater table is therefore 1 m closer to the floodplain surface than it would otherwise be. Lock 4 raises water levels by 3.2 m AHD above the Lock 3 weir pool level and also raises the floodplain water table. When the water table is close to the floodplain surface, groundwater can evaporate and deposit salts in the soil profile. In the Pike Floodplain salts have accumulated over many years to the extent where the original floodplain vegetation is dead or in poor health and a salt crust has formed on the soil surface. The most severely affected areas are low lying areas (floodplain wetlands) where the water table is closest to the surface.

Impounding structures have contributed to the salinisation of some permanently inundated, dead-end wetlands. These wetlands are connected to the impounded water bodies but have no through-flow. As water evaporates from their surfaces, they draw water in. They are salinised by a combination of dilute salts brought in with surface water and more concentrated salts in the local water table.

Flowing watercourses were an important component of the River Murray ecosystem prior to regulation. Most flow passed through the main river channel, but a proportion of flow was diverted through small floodplain anabranches and creeks. Narrow, shallow channels could generate significant velocities which were maintained most of the time. A number of aquatic fauna occur only in fast flowing environments possibly due to requirements for high dissolved oxygen concentrations or turbulent water, including River Mussel, River Snail and Murray Crayfish. Flowing watercourses are also associated with high-quality Murray Cod habitat. Impounding structures have eliminated flowing water habitat from much of the Pike Floodplain.

Irrigation Drainage

The flow of groundwater from highland areas to the floodplain contributes to floodplain salinisation. The River Murray is the lowest point in the regional landscape and the natural destination for groundwater flow. The regional aquifer is naturally saline.

The gradient in groundwater levels between the highland and the floodplain is increased by irrigation drainage. Excess irrigation water, which passes the root zone and contributes to the aquifer, increases groundwater and salt flux to the floodplain.

Regional Land Clearance

Recharge to the regional aquifer has also been increased by land clearance. Native mallee vegetation intercepts almost all rainfall and allows little seepage to reach the aquifer. In cleared areas or areas supporting dryland crops a higher proportion of rainfall contributes to the aquifer, elevating groundwater levels. Land clearance in the vicinity of the Pike Floodplain has accelerated the flux of groundwater and salt to the floodplain and has contributed to the salinisation of floodplain soils and waterbodies.

Grazing

Grazing by sheep, goats and cattle contributes significantly to the degradation of the Pike Floodplain.

Sheep have access to most of the Upper Pike Floodplain and graze grasses, chenopods and other understorey forbs shrubs. Vegetation in grazed areas is generally sparse and restricted to mature overstorey vegetation of Red Gum, Black Box and Lignum. Lower vegetation strata are generally only present in watercourses where riparian and aquatic vegetation is retained, although this is often severely impacted. Sheep are excluded from the floodplain in the vicinity of Tanyaca Creek, most of Mundic Island and the floodplain between Mundic Island and Lock 5. In these areas the understorey vegetation is diverse and abundant. The best preserved understorey vegetation in the system is at the southern end of Mundic Island where a complex range of herbs, forbs and grasses are present as an understorey to the Red Gum woodland. The high quality of the vegetation in this area is likely to reflect a relatively low salinity threat as well as the exclusion of stock.

The Lower Pike Floodplain is grazed by cattle. Some escaped cattle grazed the Upper Pike Floodplain in the vicinity of Tanyaca Creek.

One landholder maintains a herd of 20 to 30 goats.

Grazing adds to the existing stresses on understorey vegetation of drought and salinity.

Pest Animals

A small number of loose goats occupy the Pike Floodplain in the vicinity of Rumpagunyah Creek.

A number of stray cattle occupy the floodplain in the vicinity of Tanyaca Creek. These cattle are believed to have escaped from the grazing lease on the floodplain south of Rumpagunyah Creek. The stock are able to walk through Rumpagunyah Creek in the shallow reaches.

Landholders report that rabbits are not abundant on the floodplain, but do occur in high numbers on the sandy soils of the cliffs surrounding the floodplain. The South Australian Murray-Darling Basin Natural

Resources Management Board undertook a major rabbit control program in this area between December 2006 and January 2007. Rabbits are likely to be present in the dunes on the floodplain.

Pest animals are believed to be a minor threat to native plant community diversity and fauna habitat quality.

Lack of Fish Passage

Migration and dispersal are important habitat requirements of a number of native fish species. Barriers can interrupt breeding cycles for fish such as Silver Perch and Callop which migrate to spawn. Both of these species are both reported from Mundic Creek (SKM 2004). Barriers can limit the movement of fish with large home ranges and can prevent the dispersal of larval and juveniles, leading to fragmented and unstable fish populations (Schiller and Harris 2001). A number of fish species depend on habitat components in both the main river channel and floodplain wetlands. Fish passage is blocked at a number of places in the Pike Floodplain (Figure 20).

Figure 20. Blockages to Fish Passage

Deep Creek and Margaret Dowling Creek present an opportunity to allow the movement of fish between the Lock 4 and Lock 5 weir pools. Fish passage is currently restricted by pipe culverts on the banks of the

Lock 5 weir pool which are narrow and dark and have very high velocities. The culverts under the Lock 5 Road are also dark and discourage fish movement (Leigh and Zampatti 2005).

The rock structures which contain the Pike-Mundic waterbodies are barriers to fish movement between the River Murray in the Lock 4 weir pool and floodplain wetland habitats.

Fish passage between waterbodies within the system is restricted at two places, between Mundic Creek and Woodcutters Wetland (at Woodcutters Bridge) and in the shallow upper reaches of Snake Creek.

Despite the lack of fish passage, the native fish assemblage in Mundic Creek is diverse and in a healthy condition (SKM 2004).

Pest Fish Species

Pest fish species reported by the River Murray Baseline Survey in Mundic Creek in 2004 were Carp, Gambusia, Goldfish and Redfin (SKM 2004). All of these fish are widespread in the South Australian River Murray and it is reasonable to expect that they are present elsewhere in the system as well. However, the Baseline Survey reported that Mundic Creek is dominated by native species and the native fish fauna was unusually healthy and diverse.

Pest fish degrade aquatic habitat by competing with native fish for food and physical habitat and by preying on native fish and macroinvertebrates.

Weeds

Weeds are a minor issue on the Pike Floodplain. Noogoora Burr occurs in relatively frequently inundated low-lying areas. African Boxthorn and Tobacco Bush both occur in the sand dunes. Weeds potentially degrade floodplain habitat by displacing native plant species and providing poor-quality forage or physical habitat for native fauna. Weeds are likely to be suppressed by the current dry conditions and by grazing by stock and kangaroos.

Recreational Use

The Pike Floodplain has provided an important recreational resource for the local community. Important recreational activities have include picnicking and camping on the Lower Pike River, boating (including competitive boat races) on Mundic Creek and fishing.

Recreational activities potentially impact on floodplain health by disturbing native fauna (particularly nesting waterbirds), rubbish dumping, trampling vegetation and depleting fish stocks.

Over-abundant Kangaroos

Landholders report high densities of Western Grey Kangaroo on the floodplain between the Lower Pike River and Loxton Main Road, in the vicinity of Tanyaca Creek and on the Lower Pike Floodplain. High kangaroo densities are supported by the availability of fresh water in the river and watercourses. However forage is limited and kangaroo grazing contributes to poor vegetation cover, low plant diversity and poor habitat quality for other native fauna which depend on native plants for food or physical habitat.

4.11 Analysis of Threats

The threat with the most severe impacts to the greatest number of assets is the lack of environmental flows. The reduced frequency and duration of flows sufficient to inundate the floodplain has contributed to drought stress, a lack of floodplain productivity, a lack of wetland productivity and salinity stress.

The next highest three threats are impounding structures, irrigation drainage and regional land clearance. The threats promote floodplain and surface water salinisation. The most severely impacted areas are therefore low-lying floodplain areas (i.e. temporary wetlands) and permanent wetlands which have no through-flow.

The effects of grazing are not as severe as a lack of flooding or salinisation, but they are widespread and exacerbate these existing threats. The most severely impacted areas are chenopod shrublands and grasslands and the dunes on the Upper Pike floodplain.

Other threats have a relatively low priority. Lack of fish passage and pest fish affect only two assets. Weeds, recreational uses and over-abundant kangaroos have localised effects which are relatively minor.

Table 7. Threats across targets

	Threats Across Targets	Flowing Watercourses (Habitat for Flow Dependent Species)	Permanent Wetland (static)	Temporary Wetlands (floodplain depressions)	Red Gum Woodlands	Lignum Shrublands	Chenopod Shrublands / Grasslands (temporarily inundated floodplain)	Black Box Woodlands	Dunes	Overall Threat Rank
	Project-specific threats	1	2	3	4	5	6	7	8	
1	Lack of environmental flows (over extraction, river regulation)	Medium	High	Very High	Very High	Very High	Low	Very High	Medium	Very High
2	Impounding Structures (ponded water for irrigation - groundwater / salinity impacts, restricts connectivity)	High	Medium	Very High	High	High	High	High	-	Very High
3	Irrigation drainage (groundwater rise resulting in saline soils)	Medium	High	Very High	High	High	High	High	-	Very High
4	Regional land clearance (groundwater rise resulting in saline soils)	Medium	High	Very High	High	High	High	High	-	Very High
5	Stock grazing	Low	Medium	Medium	Medium	Medium	High	Medium	High	High
6	Pest animals (grazing - pigs, goats, rabbits)	-	-	-	-	Medium	Low	Low	Low	Low
7	Lack of fish passages	Medium	Low	-	-	-	-	-	-	Low
8	Pest fish species (Carp, Gambusia)	Medium	Low	-	-	-	-	-	-	Low
9	Weeds	-	-	Low	Low	-	-	Low	Low	Low
10	Recreational Use (Tracks, Camping, Firewood collection)	-	Low	-	Low	-	-	Low	-	Low
11	Over-abundant kangaroos	-	-	-	-	-	-	Low	-	Low
	Threat Status for Targets and Project	High	High	Very High	Very High	Very High	High	Very High	Medium	Very High

5.1 Introduction

Threats to the health of the Pike River Floodplain will be controlled by establishing new environmental conditions which promote, rather than degrade the conservation assets. Objectives have been established for eight environmental conditions (Table 8). The required physical conditions for each objective is described and an outline given of how they might be achieved in the study area (Section 5.2).

The measures to achieve the objectives are termed strategies. A number of strategies potentially contribute to each objective and strategies can contribute to more than one objective. Strategies will be implemented through on-ground works. Strategies and implementation options are outlined below (Section 5.3).

Table 8. Management Objectives and Strategies

Objective	Strategies
Increase floodplain inundation	Promote the restoration of high river flows to inundate the Pike Floodplain Local water management
Reduce floodplain soil and water salinities	Promote the restoration of high river flows to inundate the Pike Floodplain Regional water management Local water management Reduce groundwater inflows to the Pike Floodplain
Restore flowing habitat	Local water management
Seasonally variable water levels	Local water management
Provide fish passage	Local water management
Maintain permanent wetlands	Local water management
Reduce grazing pressures	Pest animal management plan Stock management plan Native fauna management plan
Sustainable recreational uses	Recreational uses management plan

5.2 Management Objectives

Increase Floodplain Inundation

Floodplain inundation has been reduced by the storage and diversion of water upstream and, more recently, by a sustained period of low catchment inflows. The principal measures to restore floodplain inundation therefore involve changes to catchment management. Storages and diversions must be managed to allow flood flows to occur more frequently. This will impact on the availability of water for diversion, the security of water supply and flood risks to low-lying properties on the River Murray. It will involve basin-wide management decisions by state and federal government agencies.

The requirements of the Pike Floodplain can be promoted in this process by the raising the conservation values at risk by continued deficiencies in floodplain inundation.

Conceptually, water can be managed at a local scale to promote floodplain inundation. Lock 5 provides a local source of water at 16.3 m AHD which could be used to inundate most of the floodplain. Substantial structures would be required to manage the water so that it is held within the floodplain system before being returned to the river. The structures would involve a levee bank along the river and removable blockages on all the main watercourses from the floodplain to the river.

Management strategies:

- Promote the restoration of high river flows to inundate the Pike Floodplain.
- Local water management.

Reduce Floodplain Soil and Water Salinities

High floodplain soil salinities are a principal cause of poor vegetation health {Overton, 2008 #1458} and high salinities in shallow wetlands. Salts have accumulated in the floodplain as a result of reduced floodplain inundation, depletion of freshwater lenses, elevated groundwater levels and an increase in the flow of groundwater from the highland to the floodplain.

Floodplain inundation reduces soil salinity by flushing salts from the soil profile where soils are sufficiently porous. Flooding also removes salts from the soil surface, which would benefit salinised temporary wetlands where thick crusts of salt have accumulated. Floodplain inundation can be promoted by restoring high flow events to the river hydrograph and local management actions to store water on the floodplain.

The accumulation of salt in the soil profile has been accelerated by high groundwater levels beneath the floodplain. Weirs have been used to raise water levels upstream of the Col Col Embankment in the Pike-Mundic system and upstream of Lock 4 in the River Murray. Both of these weir pools bring the floodplain groundwater level closer to the surface where groundwater can evaporate and salts can build up. Lowering the level of these weir pools will also lower groundwater levels and will slow the future accumulation of salts in the soil.

The flow of groundwater from the highland to the floodplain also contributes to high floodplain groundwater levels. Groundwater flow is driven by the elevation of the regional water table. Lock 5, which holds water approximately 1.6 m above the Pike-Mundic water level and this gradient generates significant groundwater flow to the Pike Floodplain. Drainage water from the irrigated areas of the nearby highland and recharge from cleared areas of the regional landscape also contribute to high regional groundwater levels. These processes can be managed by controls on the extent of the nearby irrigated area, controls on irrigation efficiency and the replacement of annual crops with perennial vegetation in the groundwater catchment.

Management strategies:

- Promote the restoration of high river flows to inundate the Pike Floodplain.
- Regional water management.
- Local water management.
- Reduce groundwater inflows to the Pike Floodplain.

Restore Flowing Habitat

Regulation of the River Murray has promoted stable water levels with extensive slow-flowing or completely lentic habitats. Many native fish species and macroinvertebrate fauna depend on relatively fast flowing water which is well-oxygenated, cool and turbulent. The Pike floodplain provides an opportunity to restore these habitat components using the head difference between Lock 5 and Lock 4 and the long flow paths on the floodplain. Flowing habitat would be promoted by increasing flow in existing channels and reconfiguring banks and regulators.

Flowing water habitat is an important habitat component for many aquatic fauna which potentially occur at the Pike Floodplain. The head difference from Lock 5 to the Pike-Mundic system currently provides flowing water habitat at only two sites, but flowing water can potentially be introduced to other watercourses using the head difference from Pike-Mundic to Lock 4. To be achieved, water would have to be released at greater flow rates and some structures would need to be modified.

Management strategies:

- Local water management.

Seasonally Variable Water Levels

Seasonal inundation is a requirement of a number of riparian and wetland plants native to the Pike River floodplain. Emergent and semi-emergent plants initiate growth when flooded in early spring and then reproduce vegetatively and by seed as water levels fall in summer. The gradual fall in water levels over spring creates broad macrophyte beds. These beds merge with the understorey of floodplain woodlands at high levels and aquatic vegetation at lower levels. Flooded vegetation provides breeding and sheltering sites for fish, macroinvertebrates and waterbirds and the gradual exposure of wetland banks provides feeding habitat for wading birds.

Water levels in the Pike floodplain are largely stable. Structures could be built or modified to restore a seasonal flooding cycle to wetlands and watercourses.

Management strategies:

- Local water management.

Provide Fish Passage

Barriers to fish passage restrict the home-range of native fish, reduce opportunities for dispersal and disrupt the breeding of migratory species. Barriers between the river and the wetlands of the Pike floodplain impact on species which require both riverine and floodplain habitats. Barriers between the Lock 4 and Lock 5 weir pools prevent fish migration, dispersal and restrict home ranges. These impacts could be reduced by removing or modifying blockages.

Management strategies:

- Local water management

Maintain Permanent Wetlands

The Pike-Mundic system provides a large, deep, permanent waterbody with important habitat values. It supports a diverse community of native fish and a reliable aquatic habitat for waterbirds (SKM 2004). The habitat values associated with permanent aquatic habitat need to be sustained in the Pike-Mundic system.

Management strategies:

- Local water management.

Reduce Grazing Pressures

High grazing pressures from stock, kangaroos, and, in the dunes and cliff areas, rabbits impact significant on understorey vegetation cover and tree recruitment. Goats and escaped stock also contribute to grazing impacts. Areas from which stock have been excluded are more botanically diverse and have higher vegetation cover with correspondingly high habitat value for fauna.

Management strategies are required to control grazing pressures to a sustainable level, i.e. where ongoing grazing does not impact on vegetation condition. A sustainable grazing regime will reflect the vegetation growth which can be expected under a regime of high salinity and low flooding frequencies. A management plan needs to be developed with stakeholders with responsibility for native fauna, stock and pest animal management.

Management strategies:

- Pest Animal Management Plan.
- Stock Management Plan.

- Native Fauna Management Plan

Sustainable Recreational Uses

The Pike floodplain potentially supports a number of recreational uses including fishing, camping and boating. These activities can impact on floodplain and aquatic habitat by trampling vegetation and disturbing native fauna through noise and traffic. Recreation must be managed to protect the important conservation values of the system including fish diversity, the abundance of threatened fish, vegetation condition, threatened plant habitat and waterbird breeding. Sustainable recreational uses of the floodplain would protect sensitive areas and manage the times and locations at which various activities take place.

Management strategies:

- Recreational Uses Management Plan.

5.3 Management Strategies and Options

Strategy 1 - Catchment Water Management	**Objectives Addressed**	**Conservation Targets Addressed**
Option 1.1 Promote the restoration of high river flows to inundate the Pike Floodplain The Council of Australian Governments' decision to form a new Murray-Darling Basin Authority has led to a review of water management in the Murray-Darling Basin. One of the preparatory tasks to the formation of the Authority is the determination of a Sustainable Diversion Limit for the basin. This involves consideration of the needs of wetlands and floodplains for water and the protection of environmental water requirements in a environmental water reserve. The importance of catchment management to the frequency and duration of floodplain areas is also being given greater consideration as a result of the Living Murray Initiative, which seeks to address flooding requirements at similar icon sites. State government agencies, particularly the Department for Water, Land and Biodiversity Conservation and the South Australian Murray Darling Basin Natural Resources Management Board, can promote the flooding requirements of the Pike River in basin-wide water management forums. Decisions on environmental flows can be influenced by raising, where possible, the requirements for the Pike floodplain for particular flow magnitudes, durations and frequencies.	Increase floodplain inundation Reduce floodplain salinities	Red Gum Woodlands Lignum Shrublands Chenopod Shrublands / Grasslands Black Box Woodlands

Strategy 2 - Regional Water Management	Objectives Addressed	Conservation Targets Addressed
Option 2.1 Inundate Floodplain from Lock 4 Lock 4 provides some scope to manipulate water levels in the Pike River floodplain. Lock 4 contributes to higher water levels upstream, particularly in the Lower Pike. If Lock 4 were operated at lower levels the groundwater surface below the floodplain would be lower and the accumulation of salts in floodplain soils would be slower. There would also be greater scope for floodplain inundation events to freshen the soil profile and provide a reservoir of low salinity soil water.	Seasonally variable water levels Increase floodplain inundation Reduce floodplain salinities	Red Gum Woodlands Lignum Shrublands Chenopod Shrublands / Grasslands Black Box Woodlands

Strategy 3 - Reduce Groundwater Inflows to the Pike Floodplain	Objectives Addressed	Conservation Targets Addressed
Option 3.1 Reduce recharge from the local irrigation area to the regional aquifer Irrigation drainage water in the highland areas surrounding the Pike floodplain contributes to elevated groundwater flow. Irrigation drainage is potentially reduced by: • increasing irrigation efficiency to the point where recharge is minimised; and • limiting or reducing the area available for irrigated horticulture in the future. These actions are addressed in the Pike River Land and Water Management Plan (REF) which set out to minimise the impacts of irrigation on the floodplain ecosystem.	Reduce floodplain soil and water salinities	Permanent Wetlands Temporary Wetlands Red Gum Woodlands Lignum Shrublands Chenopod Shrublands / Grasslands Black Box Woodlands
Option 3.2 Reduce recharge from the mallee landscape to the regional aquifer Groundwater recharge from the broader agricultural landscape also contributes to elevated groundwater flux to the floodplain. Annual crops are less effective at intercepting rainfall recharge than native vegetation and the loss of native vegetation from the landscape has led to higher groundwater levels and flow to the floodplain. Regional recharge rates are potentially managed by increasing the area in the groundwater catchment with perennial, rather than annual, crops and with native vegetation. The role of these land management initiatives are incorporated in the Pike River Land and Water Management Plan (REF).	Reduce floodplain soil and water salinities	Permanent Wetlands Temporary Wetlands Red Gum Woodlands Lignum Shrublands Chenopod Shrublands / Grasslands Black Box Woodlands
Option 3.3 Intercept saline groundwater flows to the floodplain A Salt Interception Scheme is proposed for the Pike River to extract groundwater at the perimeter of the floodplain. The scheme will reduce the flow of groundwater to the floodplain and is primarily intended to reduce the impact of saline groundwater on River Murray water quality. The scheme potentially benefits the environment by slowing or halting the movement of salt to the floodplain, thereby increasing the effectiveness of other salinity mitigation measures such as floodplain inundation and water level variation.	Reduce floodplain soil and water salinities	Permanent Wetlands Temporary Wetlands Red Gum Woodlands Lignum Shrublands Chenopod Shrublands / Grasslands Black Box Woodlands

Option 3.4 Lower Lock 5 Lock 5 is an important local source of groundwater recharge and elevated floodplain groundwater inflows. Lock 5 is maintained at 16.3 m AHD, approximately 1 m higher than much of the upper Pike floodplain surface. Recharge from weir contributes to shallow groundwater levels in the northern part of the Upper Pike system, particularly around Mundic Creek. Recharge from the weir would be less if it were operated at a lower level. However there is little practical scope to operate the weir at a sufficiently lower level to significantly lower groundwater flows.	Reduce floodplain soil and water salinities	Permanent Wetlands Temporary Wetlands Red Gum Woodlands Lignum Shrublands Chenopod Shrublands / Grasslands Black Box Woodlands

Strategy 4 - Local Water Management	Objectives Addressed	Conservation Targets Addressed
Option 4.1 Inundate Floodplain from Lock 5 Lock 5 provides a high enough water level to inundate most of the Pike River floodplain. Substantial structures would be required to detain the water released from the lock on the floodplain and prevent its re-entry to the River Murray. Two approaches have previously been proposed: • a levee along the entire river bank from Lock 5 to the mouth of the Lower Pike with regulating structures at the mouth of each creek; or • a levee to create substantially higher water levels around the relatively low-lying floodplain at Mundic Creek with regulating structures where creeks intersect this structure.	Increased floodplain inundation Reduced floodplain salinities	Red Gum Woodlands Lignum Shrublands Chenopod Shrublands / Grasslands Black Box Woodlands
Option 4.2 Modify regulating structures and banks to provide fish passage Fish passage from the Pike-Mundic system to the Lock 5 weir pool is currently restricted at the pipes which divert water off the weir pool and the bridges under the Lock 5 Road. These structures could be redesigned to accommodate native fish requirements for light and flow velocity. Each of the banks which enclose the Pike-Mundic system is a barrier to fish passage to or from the Lock 4 weir pool. Fish passage could be provided by modifying one or more existing structures. Alternatively, fish passage could be incorporated in replacement structures which also address objectives for water level manipulation and flowing water habitat.	Provide fish passage	Permanent Wetlands Temporary Wetlands Flowing Watercourses
4.3 Seasonally manipulate wetland water levels The head difference between the Lock 5 and Lock 4 weir pools provides scope to manipulate water levels over a range of almost 3.1 m. Water levels in the Pike-Mundic system can be lowered closer to the Lock 4 level and, depending on the scale of controlling structures, raised to the Lock 5 level. Structures could be designed to regulate levels in the watercourses which join the River Murray (Lower Pike River, Rumpagunyah Creek, Wood Duck Creek and Swift Creek) so that they could also be raised and lowered.	Seasonally variable water levels Maintain permanent wetlands Reduced floodplain salinities	Permanent Wetlands Temporary Wetlands Red Gum Woodlands Lignum Shrublands

Option 4.4 Maximise flowing habitat Flowing water habitat can be provided in watercourses which have a narrow channel and also have a significant head difference along their length. Flowing water is currently provided in Deep Creek and Margaret Dowling Creek which channel water from Lock 5 to Mundic Creek. Flowing water is also potentially provided in the channels between Mundic Creek and Tanyaca Creek (via Bank F1), Snake Creek and the channels between Mundic Creek and Pike Lagoon. Elsewhere channels are likely to be too broad to practically allow significant velocities to be created. A facility to regulate flow in these channels could be included, to provide fish with cues for breeding and migration. Options to seasonally lower wetland water levels would interact with this strategy. It may not be possible to provide flow in the period that wetland water levels were lowered.	Restore flowing habitat	Flowing Watercourses

Strategy 5 - Grazing Management	Objectives Addressed	Conservation Targets Addressed
Option 5.1 Implement Grazing Management Plan Grazing by stock, escaped stock, rabbits and kangaroos should be managed at levels where native vegetation abundance is optimal for plant biodiversity and fauna habitat quality. Sustainable grazing management will involve a reduction in stock numbers and control of kangaroo and feral animal numbers. The plan will involve public, private and leasehold land and should be monitored to demonstrate improvements and to identify emergent management needs, such as for weed control.	Reduce Grazing Pressures	Temporary Wetlands Red Gum Woodlands Lignum Shrublands Chenopod Shrublands / Grasslands Black Box Woodlands Dunes

Strategy 6 - Manage Recreational Uses	Objectives Addressed	Conservation Targets Addressed
Option 6.1 Recreational Management Plan Recreational uses are a minor threat to the Pike River Floodplain. They potentially contribute to localised impacts in some areas. A recreational management plan would identify the current and potential recreational activities and establish controls on their impacts.	Sustainable Recreational Uses	Permanent Wetlands Temporary Wetlands Red Gum Woodlands Lignum Shrublands Chenopod Shrublands / Grasslands Black Box Woodlands

6.1 Introduction

Scope of Water Management Option Assessment

Some of the water management options outlined in Section 5 have been investigated in a previous investigation by a team comprising Ecological Associates, Australian Water Environments and Resource and Environmental Management (Ecological Associates 2008). The purpose of this study was to estimate the salt loads and evaporative water losses associated with environmental water management options.

These options were chosen to assess the sensitivity of the system to major changes in water regime. They do not represent a comprehensive range of management scenarios. For further details on the required engineering works see Ecological Associates (2008).

An overall comparison of the costs and inundation effects of the options is presented in Table 9. A description of the options follows.

Rationale for Varying Water Levels

Some of the options involved varying water levels seasonally. The timing and magnitude of the variations used in the modelling were indicative only and would be refined in detailed option design. For reference it is useful to note that below Lock 5 River Murray levels change by:

- 1.0 m when flow varies from 5,000 ML/d (13.3 m AHD) to 25,000 ML/d and this flow occurred approximately 100 times every 100 years under natural conditions; and
- 1.5 m when flow varies from 5,000 ML/d to 45,000 ML/d and this flow occurred approximately 85 times every 100 years under natural conditions (SA Water backwater curves; Sharley and Huggan 1996).

Risks

Options to lower water levels potentially create acidified areas by exposing soils which have been inundated for many decades. It is also possible that the water quality of waterbodies will deteriorate if water levels are lowered as saline groundwater discharges from the banks.

Options to raise water levels potentially inundate floodplain soils which are already acidic. Contaminated water could then be introduced to floodplain waterbodies when water levels are lowered.

Detailed option design would involve clarification and management of these risks.

Salt and Water Impacts

The impact of proposed options on salt loads to the River Murray were estimated using the DWLBC Lock 3 to Border numerical groundwater model combined with a floodplain hydraulic model and water balance model (Ecological Associates 2008). The groundwater model was extended to describe groundwater processes on the floodplain and to predict the effect of changing surface water levels on groundwater salinity and discharge to surface water bodies. Changes in salt load were quantified by comparing salt inputs from River Murray water and groundwater with outputs to irrigation extractions and returns to the River Murray. The water balance model estimated the change in evaporative losses in the system under the proposed options.

The model was based on a 10 year run from January 1990 to December 1999 which incorporated a sequences of high flow and low flow years.

The groundwater component of the model incorporated significant assumptions regarding interactions with watercourses. The outputs of the model provide a useful comparison between scenarios but should be considered only as indicative until empirical data is available to better characterise floodplain groundwater dynamics.

Table 9. Estimates of water loss and salt load impacts and of the cost of on-ground works for representative environmental water management options (Ecological Associates 2008)

Option	Evaporative Water Losses (ML per year)	Salt Load to River Murray (tonnes / day)[1]	Indicative Costing of On-ground Works	Disruption to Irrigators[2]	Disruption to Floodplain Landuses[3]	Major Additional Risks	Floodplain Area Affected (ha)								
							Flowing Watercourse	Permanent Wetland	Red Gum Woodland	Lignum Shrubland	Black Box Woodland	Chenopod Shrubland / Grassland	Samphire Shrubland	Other	Total
Base Case	238	286.4	$0	No	No			1593	1112	800	1451	1784	253	49	**7042**
Additional Option Impacts															
Seasonally raise levels in Upper Pike / Mundic System (+1.0 m)	-3	-34.5	$2,500,000	No	Yes	Inundate acidified soils Raise floodplain water table	+ 0	0	+ 83	+ 178	+ 39	+ 167	+ 37	+ 5.1	**- 0** **+ 509**
Seasonally raise and lower levels in Upper Pike / Mundic System (+0.5, -1.0 m)	-1	-15.2	$2,400,000	Yes	Yes	Inundate and expose acidified soils High salinity in surface water at seasonal low point	+ 0	- 148 + 0	+ 29	+ 64	+ 10	+ 58	+ 19	+ 4.4	**- 148** **+ 185**
Seasonally raise and lower levels in Tanyaca Creek system (+0.5, -1.0 m)	0	+4.7	$1,300,000	No	Yes	None	+ 0	- 24 + 0	+ 5.8	+ 1.1	+ 0	+ 0	0.4	+ 0	**- 24** **+ 7.4**
Seasonally raise and lower levels in Upper Pike / Mundic and Tanyaca Creek system (+0.5, -1.0 m)	0	+4.7	$1,800,000	Yes	Yes	Inundate and expose acidified soils High salinity in surface water at seasonal low point	+ 0	- 67 + 0	+ 32	+ 46	+ 0.9	+ 17	+ 16	+ 3.4	**- 67** **+ 115**
Inundate upper Pike River floodplain (+1.0 m)	0	+4.4	$3,800,000	No	Yes	Inundate acidified soils	+ 0	+ 0	+ 122	+ 189	+ 39	+ 186	+ 44	+ 5.1	**+ 1369**
Inundate upper Pike River floodplain (+3.1 m)	0	not modelled	$5,900,000	No	Yes	Inundate acidified soils	+ 0	+ 0	+ 421	+ 569	+ 194	+ 902	+ 105	+ 5.6	**+ 2060**

Notes.

1. The estimates for salt loads to the River Murray were based on amendments made to the DWLBC Border to Lock 3 groundwater model for the purpose of the water management impact investigations. The values do not match salt loads estimates made for the Salt Interception Scheme which did not include detailed floodplain components.
2. Irrigator water supply is only considered disrupted when water levels are lowered. Other aspects of option design may also disrupt irrigators but are not reported here.
3. Floodplain uses include vehicle access, horticulture and grazing. These are potentially disrupted by raised water levels.

6.2 Do Nothing (Base Case)

The processes which are degrading the Pike River ecosystem will persist if the current arrangements are maintained. Although the river has experienced an unprecedented period of low flows in recent years, the degradation of the system was already underway. It can be argued that the capacity of the system to accommodate the drought was reduced by historic management.

The key processes which will continue to degrade the ecosystem are:

- the intensification and spread of soil salinisation, particularly in low-lying floodplain areas near the north of Mundic Creek and along the Upper and Lower Pike River;
- floodplain inundation insufficient for the survival of floodplain Black Box, Lignum and Red Gum and insufficient to maintain the primary productivity on which floodplain fauna depend;
- insufficient soil moisture to maintain tree health except along the flushed zone of the River Murray and the zone immediately adjacent to permanent watercourses; and
- depletion of native vegetation through grazing.

WINDS modelling of tree health, based on the continuation of flows typical of the last 15 years, predicts an increase in dead trees from 39% currently to 49% of the floodplain area by 2035. By 2035 only 3% of the area of trees will be in good health (Overton and Jolly 2008, see Table 5).

Some of the effects of existing degrading processes will be difficult or impossible to reverse. Salts which have accumulated in the capillary zone above the water table cannot readily be flushed by inundation if soils are impermeable. Therefore ongoing floodplain salinisation may create significant areas where vegetation cannot be restored. In addition, the accumulation of acid-forming minerals in waterlogged soils may create permanently acidified areas.

In contrast, aquatic habitat and fish and macroinvertebrate communities are likely to remain in good health, as reported in the Baseline Survey (SKM 2004). Aquatic habitat is maintained by flushing flows from Lock 5 and is not expected to degrade.

6.3 Increase flow from Mundic Creek to Lock 4 via Creeks

Flowing water habitat required by fish could be provided in the channel between Mundic Creek and Tanyaca Creek (Figure 21).

The flow and velocity of water passing could be increased by modifying the structures which control outflows from Mundic Creek. To achieve significant benefits, flows from the River Murray into Mundic would need to be increased and the distribution of flow out of Mundic between Tanyaca Creek and Pike River be controlled.

Preliminary HECRAS modelling indicates flows into Mundic can be increased substantially (from 300 ML/day to more than 1000 ML/day) with the removal of the inlet control structures at Margaret Dowling Creek and Deep Creek. Additional analysis is required to determine the best combination of flow velocities and water depths in the three creeks flowing between Mundic and Tanyaca.

The scale of works can vary significantly and costs will need to be assessed against benefits.

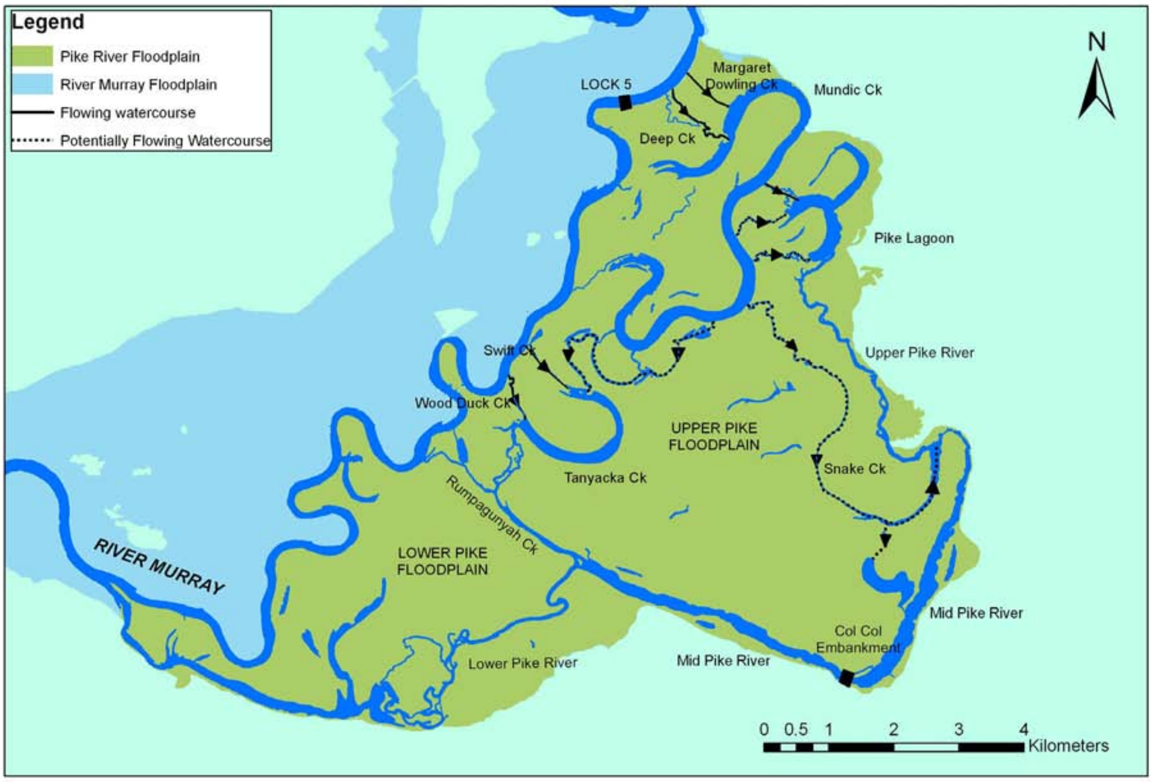

Figure 21. Watercourses where flowing water habitat is potentially introduced.

6.4 Create Flowing Habitat in Snake Creek

The scope to increase flow through the 7.5 km Snake Creek has been examined (Figure 21). There are three hydraulic impediments this option:

- in the current arrangements there is little head difference to generate flow from the top of the creek and the bottom;
- the bed level of Snake Creek is close to the level of Mundic Creek and provides little capacity for flow; and
- flow would be impeded by dense reeds which have benefited from the trickle flow the creek currently receives.

However, the potential to modify Snake Creek should be investigated further because it provides a rare opportunity to provide a flowing water habitat in the South Australian River Murray. Flow could be introduced seasonally while levels in Mundic Creek are elevated. Surveyed cross sections and a Hecras model, which was developed by Australian Water Environments to assist with these preliminary investigations would be valuable to any future analysis.

6.5 Raise and Lower Water Levels in Upper Pike / Mundic System

Raising water levels on a seasonal basis within the Upper Pike / Mundic and Mid Pike systems requires modifications to the existing flow control structures. Two possible scenarios are summarised below.

Seasonally Raise Water Levels

Water levels could be varied by raising levels up to 1.0 m for part of the year (Figure 22). Water levels would be raised by slowing outflows to the Lower Pike and detaining water within the Upper Pike system with structures and levee banks. Existing structures would be replaced and levee banks which control outflows to the River Murray and Mundic Creek would be modified. A new structure at the Col Col embankment would control water levels immediately upstream A second in-channel structure would be required in the Pike River upstream of the Rumpagunyah Creek confluence to regulate water levels in the Mid Pike.

The indicative cost of these works is $2,500,000.

By increasing the area of surface water on a seasonal basis, this proposal involves the loss of an additional 3,000 ML per year from the system. The model indicates that this proposal initially reduces salt loads to the River Murray but after 10 years loads return to a similar level as currently occur.

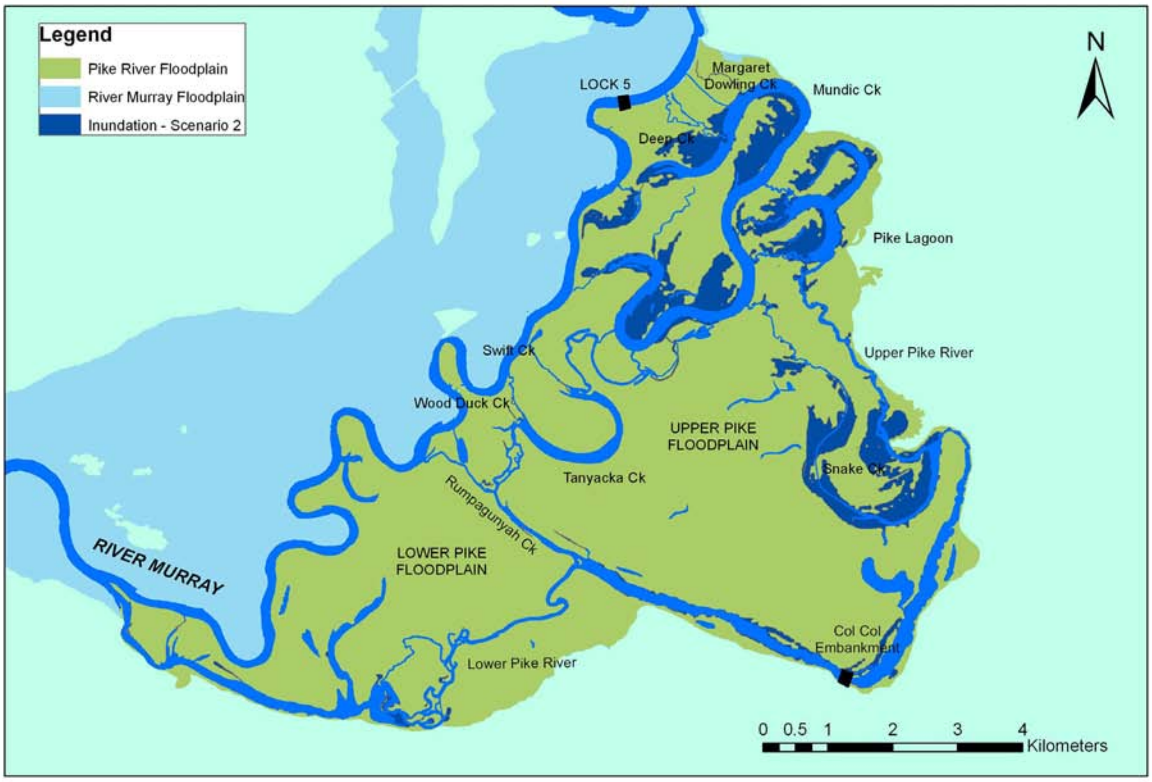

Figure 22. Area inundated by raising upper Pike and Mundic system by 1.0 m

Seasonally Raise and Lower Water Levels

A proposal to vary water levels annually over a 1.5 m range has been assessed. Water levels would be raised annually by 0.5 m and lowered by 1.0 m. The same range of structures outlined above would be required, but would be constructed to a lower elevation. This proposal affects a smaller extent of floodplain woodland communities but allows for their recovery on the wetland fringes which are currently permanently inundated (Figure 23).

The indicative cost of these works is the same as above, $2,500,000.

Overall this proposal increases evaporation from the system by 1,000 ML per year compared with the current arrangements.

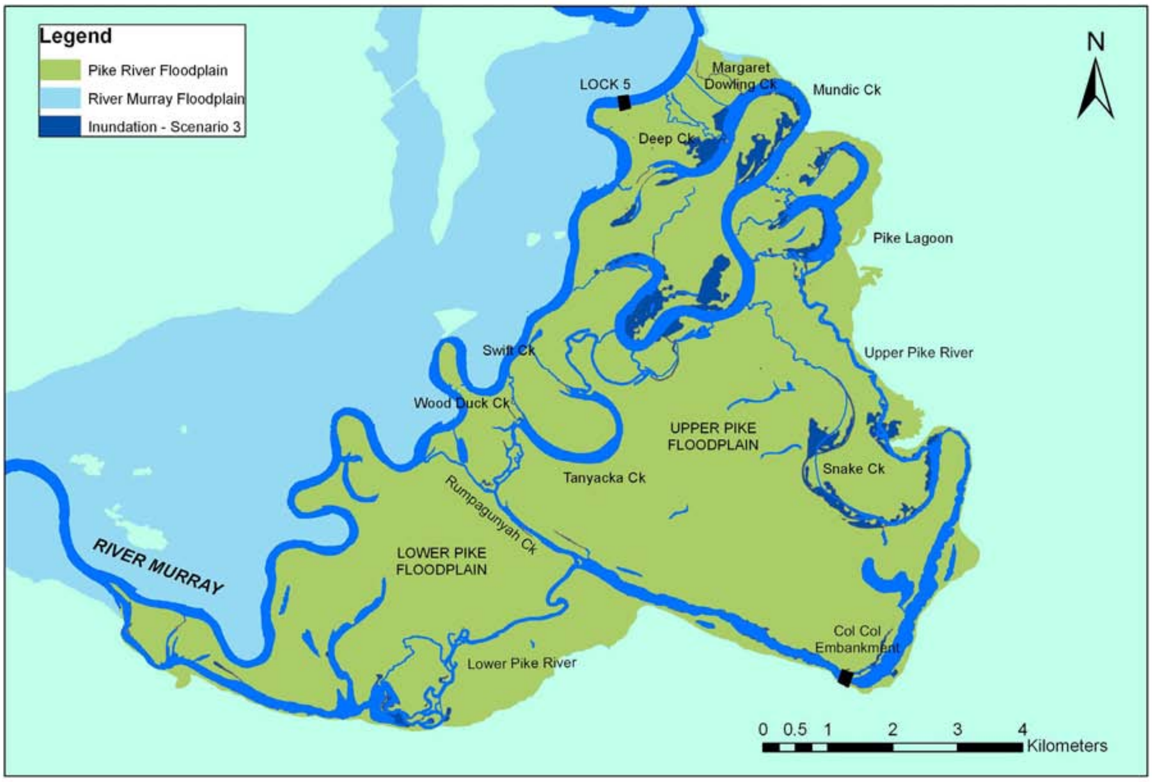

Figure 23. Area inundated by raising upper Pike and Mundic system by 0.5 m

6.6 Seasonally Raise Water Levels in Tanyaca Creek

Tanyaca Creek provides a wetland / watercourse / floodplain system where water levels can be manipulated independently of the Pike-Mundic system and without disruption to diverters.

A scenario to seasonally raise water levels by 0.5 m and to lower water levels by 1.0 m has been assessed (Figure 24). Inflow points from Mundic Creek would be modified with structures which allow more control of inflow and provide fish passage. Regulated levees, which provide for fish passage, would be required to control inflows from the River Murray on Wood Duck Creek and Swift Creek. A regulated levee would also be required on Tanyaca Creek just upstream of the junction with Rumpagunyah Creek to control outflows at this point.

By regulating the connection between Tanyaca Creek and the River Murray level, the structures would allow the water level to be lowered and raised.

The indicative cost of these works is $1,300,000.

Figure 24. Area inundated by raising Tanyaca Creek by 0.5 m

6.7 Inundate the Floodplain

The storage of water in the Lock 5 weir pool, above the Pike River floodplain surface, provides the opportunity to inundate large areas of the Pike River floodplain. Water could be released from Lock 5 and detained on the floodplain by a series of banks and regulators up to the weir pool level.

There are no significant depressions on the Pike River floodplain which could be targeted for flooding. Inundation could only be achieved by introducing water to the entire system. A proposal to hold water 1 m above current levels in Mundic Creek, Upper Pike, Mid Pike, Tanyaca and Rumpagunyah systems would require substantial banks at the mouth of Mundic Creek, Swift Creek, Wood Duck Creek, Rumpagunyah Creek and the Pike River. It would also be necessary to construct levees between the flooded area and the River Murray (ideally along the river bank) over a distance of several kilometres (Figure 25). Similar, but more extensive works are required to hold water at the maximum possible level of 16.3 m AHD (the Lock 5 weir pool level) (Figure 27).

The indicative cost of works to inundate the floodplain at 1 m above current levels is $3,800,000. The cost to achieve a level of 16.3 m AHD is $5,900,000.

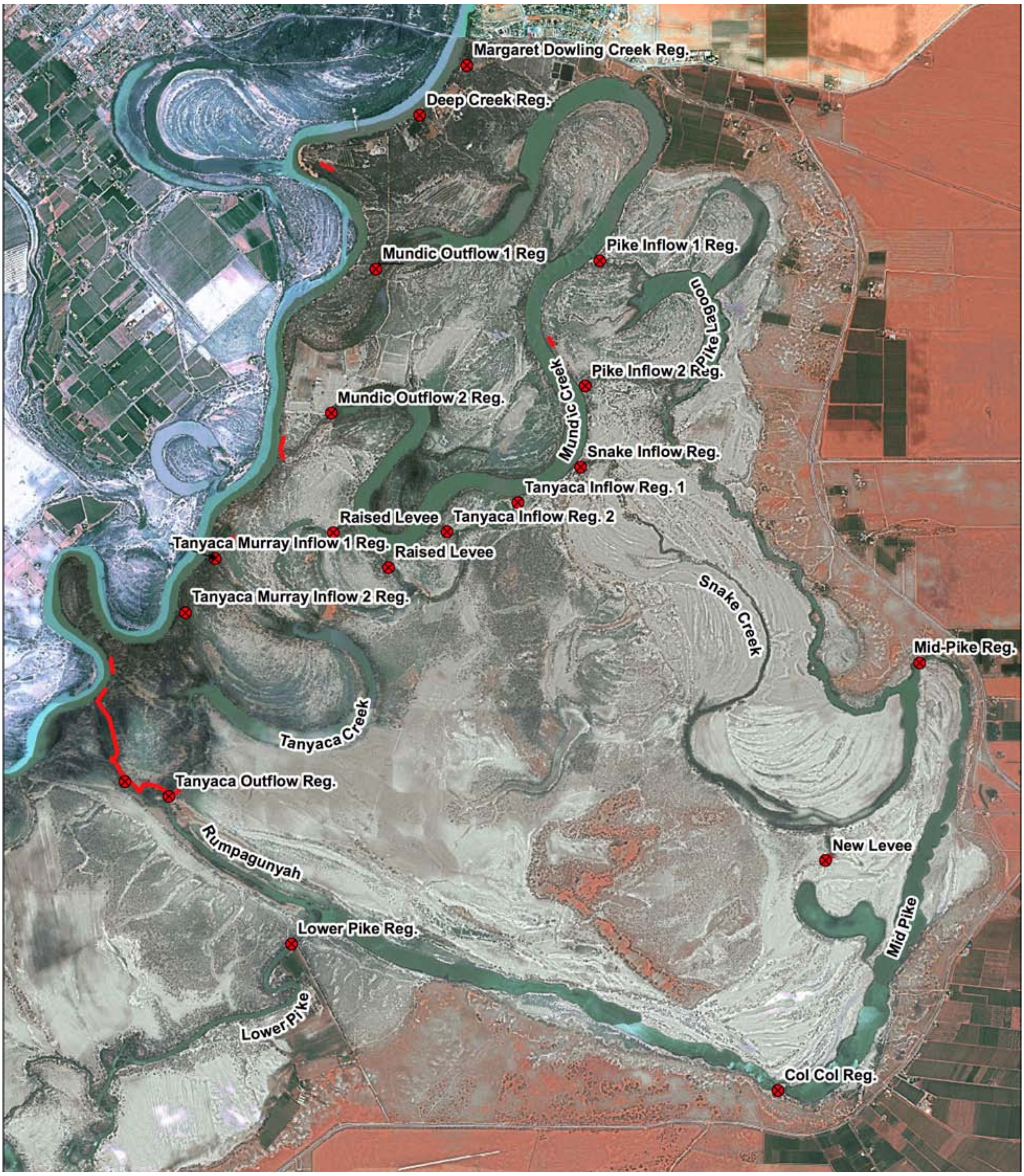

Figure 25. Works required to raise water levels by 1 m in Upper Pike. Structures are labelled. A new levee is represented by a red line.

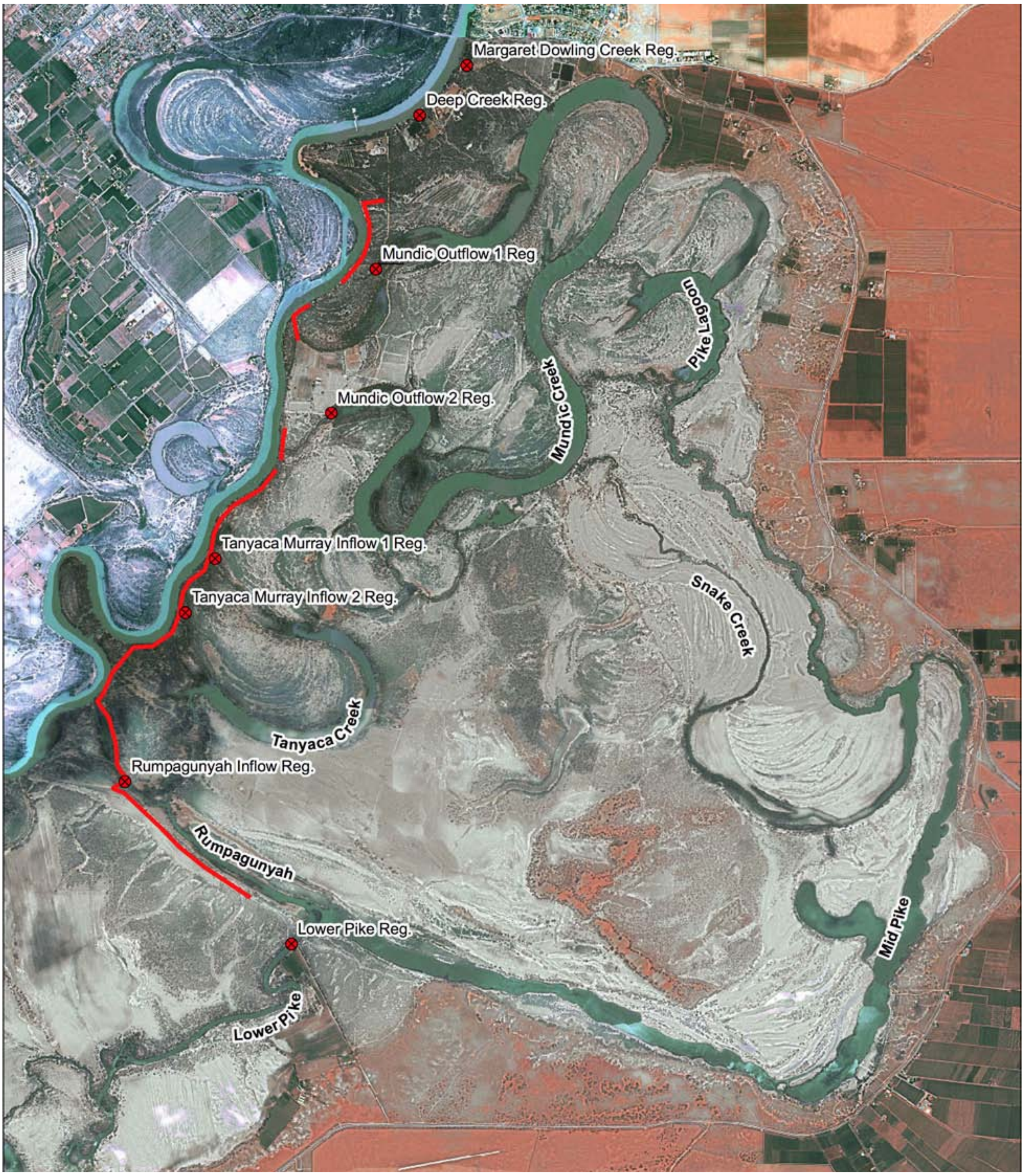

Figure 26. Works required to raise water levels to 16.3 m AHD. Structures are labelled. A new levee is represented by a red line.

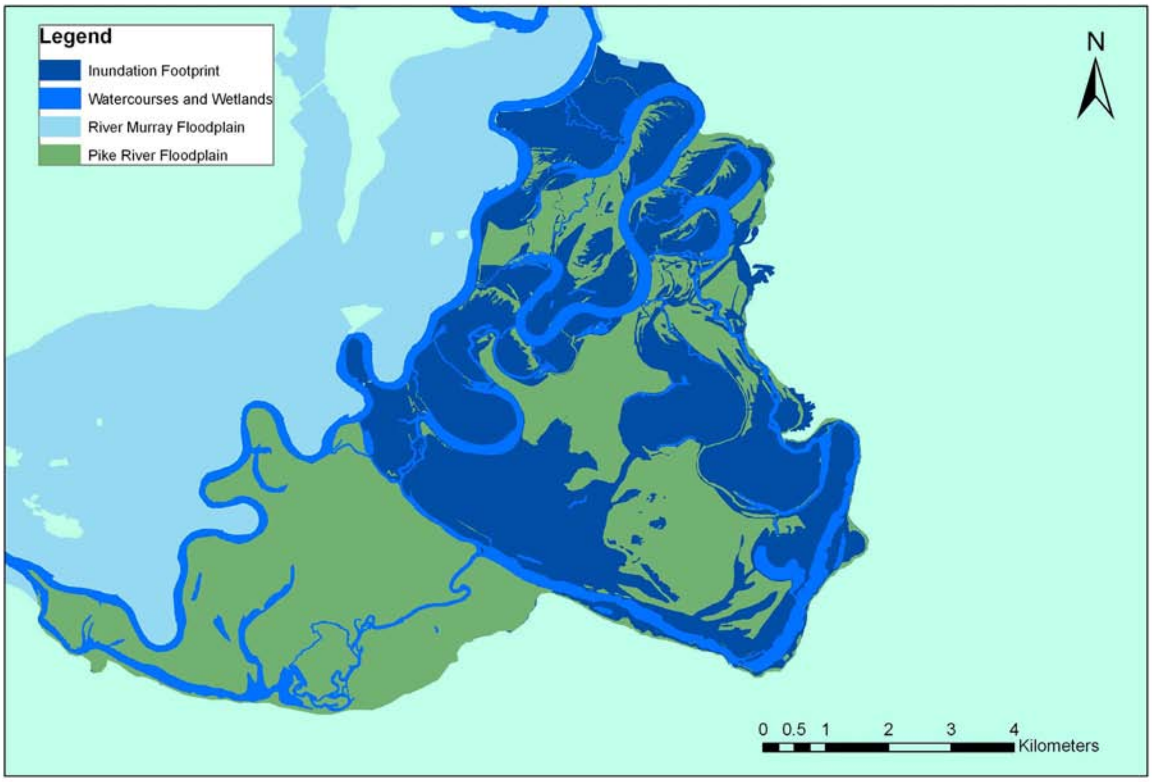

Figure 27. Area inundated by raising water levels to 16.3 m AHD in the Upper Pike Floodplain

The inclusion of the Lower Pike Floodplain was examined, but dismissed due to the extent of floodplain levee banks required. The inclusion of the Lower Pike Floodplain could be re-examined in the future.

Inundation of such a large floodplain area increases the potential for significant salt loads to the River Murray as a result of increased recharge to the saline floodplain aquifer. A proposal to hold water levels 1 m above the normal level (i.e. at 14.2 m AHD) for 3 months every five years was examined for a 10 year modelling period by Ecological Associates (2008). Overall, the total salt load over the 10 year period is little different to the do-nothing scenario (less than 1%). Salt loads are initially suppressed during the three month period when pool levels are raised, then become elevated as saline groundwater in the recharged floodplain aquifer, discharges to watercourses.

6.8 Raise and Lower Lock 4

There is no scope to achieve significant floodplain by raising Lock 4 water levels. Weir manipulation has the greatest effect immediately upstream of the weir and would only marginally raise water level at the Pike Floodplain.

6.9 Fish Passage

Upstream fish passage is completely blocked at all regulating structures except Col Col embankment where the rock weir provides some scope for fish movement. In addition the Lock 5 Road crossings represent an unfavourable environment for migrating fish.

Fish passage should be considered in the design of any new regulating structures. An overall plan of future works is required to identify the sites where fish passage is most important. Structures cannot be modified for fish passage until the functionality of the structure (maximum and minimum regulating level) is determined.

Two sites where fish passage does not interact with future water management options are the two culverts beneath the Lock 5 Road. An indicative costing to make these sites suitable for fish is $500,000 (Ecological Associates 2008).

6.10 Regulate Individual Wetlands

There is a number of wetland basins within the Pike River Floodplain which could be individually regulated to introduce seasonal wetting and drying regimes (Figure 28). Water levels could be raised by capturing water during high river levels or by pumping. Water levels could be lowered by releasing water or through losses to evaporation and seepage.

Works at individual wetlands would only be appropriate if the sites could not benefit from one of the larger scale water manipulation proposals outlined above. Potential sites for manipulation include:

- Woodcutters Wetland
- Lower Snake Creek Wetland;
- Letton's Homestead Wetland;
- Letton's Flat Wetland;
- Swift Creek Wetland; and
- Rumpagunyah Flood Runner.

At each of these sites there are risks of acidified soils.

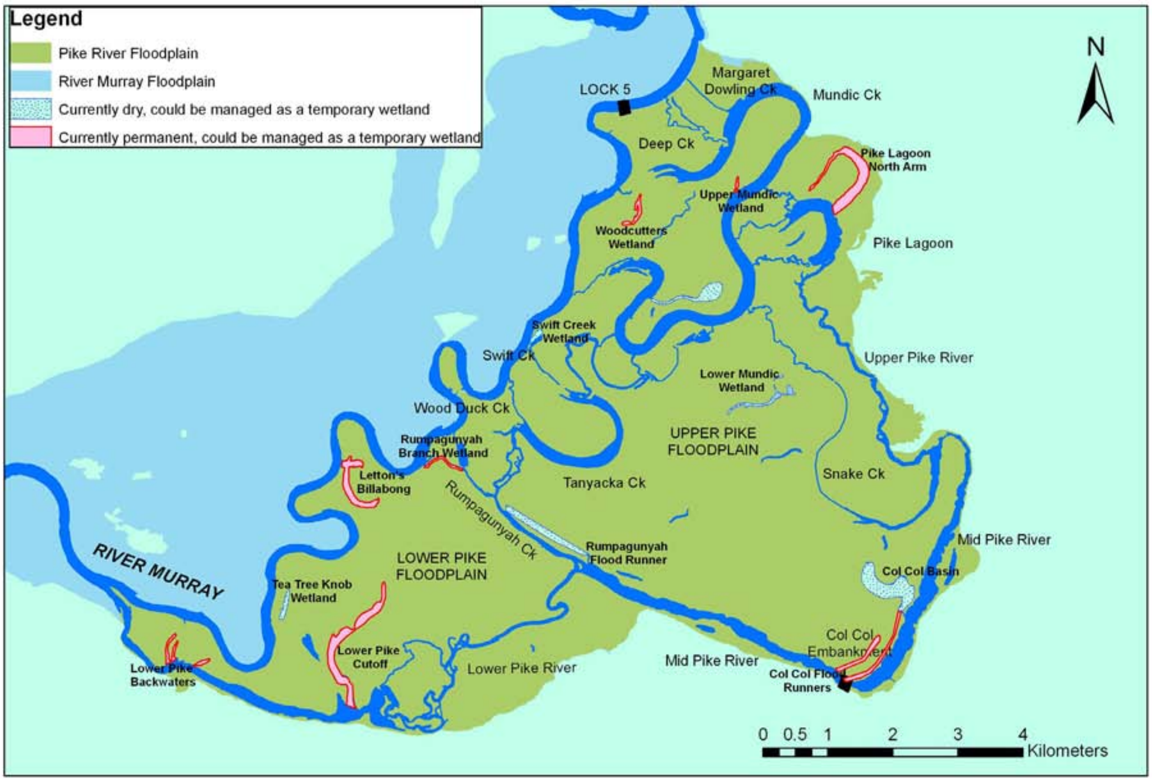

Figure 28. Permanent and temporary wetlands where water regimes could be manipulated

6.11 Pump Water to Individual Wetlands

In addition to the proposed sites for regulation there are wetland basins on the floodplain to which water could be pumped. Pumping to these sites would provide aquatic habitat and relieve drought stress in fringing vegetation. It would not be possible to release water from enclosed floodplain depressions, and water would only be lost to evaporation and seepage. This strategy may have long term risks of salt accumulation.

6.12 Improve Flow Paths

Salt accumulates in the dead-end creek on the Lower Pike Floodplain as water is drawn into the channel from Lower Pike River by evaporation. There is scope to increase the frequency of flushing flows by lowering the sill of the channel near the River Murray. It would be possible to lower the sill to a level where only minor peaks in river flow would pass through the creek and saline water would be exported.

7.1 Introduction

An effective monitoring program is central to the success of future management of the Pike River Floodplain. A monitoring program is required to:

- report the progress of the floodplain towards ecological and water management objectives;
- report how the ecosystem responds to management and identify where management is effective or can be improved;
- identify new threats and values so that management can be re-focussed on the most important issues;
- distinguish the responses of the ecosystem to local management actions from responses to regional or existing processes; and
- contribute to the broader knowledge of floodplain ecology to help guide future floodplain projects.

7.2 Scope of a Management Program

The monitoring program must address to two key considerations:

- the management objectives for the floodplain; and
- the management actions to be implemented.

Ecosystem Condition Monitoring

Management objectives relate to the promotion of conservation values and the control of threats and have been outlined in the previous sections. These should be measured with respect to the objectives, which represent a general trajectory from a current, degraded state to a future, restored state. This will require whole-of-ecosystem monitoring to provide a general report card on the ecological communities present, their extent and their health and viability.

Ecosystem condition monitoring will be long term, occur on a regular timetable and should cover the entire floodplain. It will report the condition of sites that are actively managed as well as sites where no management has been planned. It should monitor for surviving populations of plants and animals and for populations which are potentially restored.

Ecosystem monitoring can detect change over time because repeated measures provide replicates that describe ecosystem variation. Over time, as the number of measurements increases, these replicates allow real change to be distinguished from natural, random variation that occurs in the ecosystem anyway. Ideally, a monitoring program for the Pike River Floodplain should be paired with a site with a similar or identical monitoring program, such as Chowilla, to provide additional replicates and controls.

It is ***essential*** that the analysis and reporting framework for the ecosystem monitoring program is developed before data collected. Issues such as statistical power, sample independence, replication and controls will determine when, where and how data is collected. Errors in design will reduce the cost-effectiveness of monitoring and may be impossible to rectify after the program is established.

Intervention Monitoring

As management actions are designed they will include specific performance targets. Physical targets may relate to water velocity, water level fluctuation, water quality, area inundated, soil salinity, groundwater salinity. Ecological targets may relate to fish passage, fish recruitment, waterbird breeding, reed bed extent, tree recruitment and tree health. Monitoring against targets will help improve ongoing operation of structures by describing how the system responds to specific management actions. As well as reporting against targets, it will be important to measure the processes that contribute to the outcomes, so that ecosystem responses are correctly attributed to environmental triggers and opportunities.

Intervention monitoring will provide real-time guidance on the risks of management. It may report where threatening processes reach critical levels, such as high salinity, acidification or anoxia. It may report when waterbirds are nesting and a scheduled reduction in water levels should be delayed.

It is important to ensure that events which would have happened anyway, such as fish kills or fish breeding events, are not mistakenly attributed to management. Intervention monitoring should therefore include controls. Local responses should be interpreted with respect to regional environmental conditions, events and trends.

7.3 Steps to Develop a Monitoring Plan

An ecosystem condition monitoring program should be implemented as early as possible. The earlier the data is collected before management actions are implemented, the more reliably future trends can be described and the more effectively management responses can be detected. Furthermore, ecological data will help optimise the design of water management options by clarifying the location, condition and habitat requirements of ecological communities.

The steps to develop an ecosystem monitoring program are as follows.

- Agree on management objectives and make them as specific as possible.
- Identify representative and sensitive ecological and environmental indicators of progress towards or away from the objectives. This may require a multi-disciplinary input with specialists in groundwater, hydrology and a range of ecological disciplines. Conceptual models should be developed relating ecological outcomes to causal environmental factors.
- Develop cost-effective measures of the selected representative indicators.

- Design the analysis and reporting framework iteratively with the field sampling methodologies and sampling schedule.
- Reconsider how the proposed monitoring program will guide management. Refocus the proposed program if required.
- Invest in a relatively intensive initial monitoring event, with a report, review and refinement.
- Implement the ongoing monitoring program with scheduled reporting and review.

Intervention monitoring should be designed with specific regard to the design, scale and operation of the intervention. It will follow a similar process to that outlined above but cannot be planned until the options have been finalised.

8.1 Introduction

The following actions are proposed to implement this management plan. It should be recognised that this management plan is based on imperfect data and that its preparation has identified data gaps and requirements for further investigations, decision-making and planning.

It is anticipated that as management objectives are made more specific, ecological values and threats are more precisely defined and management options are scoped, this plan will be revised.

8.2 Actions

Library and Database

There have been numerous studies of floodplain hydraulics, management, ecology and land use over the past 20 years. A central library of this information will facilitate ongoing investigations and ensure that available information is not lost.

A physical and electronic library of reports and data should be created and maintained at the SA Murray-Darling Basin NRM Board. The library should include relevant datasets such as physical survey, water quality, water level, groundwater level and salinity, vegetation and tree health mapping and so on.

Protocols should identify how future datasets and reports will be identified for inclusion. Linkages to other living datasets should be established.

Comprehensive Water Management Vision

A range of large scale and small scale water management options have been identified for the Pike River Floodplain in this plan. For water management to progress, the specific objectives, scope and targets for these options should be resolved.

It is recommended that a long term and comprehensive suite of options is adopted, even if funding for some options seems unlikely at the present time. Works should be planned in a staged approach with the functions or future options factored into the design of earlier works. This will ensure that works complement each other and that costly duplication of functions or conflicts between functions is avoided.

The information and expertise to undertake this task is available in this report and in agency staff and consultants who have helped develop options. Using this knowledge, the development of a comprehensive vision would be a relatively straightforward task.

Ecosystem Condition Monitoring

A long-term monitoring program should be established to report the condition of the floodplain in relation to the ecological objectives. This program will help identify management priorities and risks and should be established before or during the design of specific management options. The program collect data before options are implemented to help evaluate ecosystem responses.

Opportunities to gain statistical power by linking a Pike River Floodplain program to existing or proposed programs elsewhere should be explored.

Design and Implement Specific Water Management Options

When an overall vision for water management is established, detailed design can begin on specific options. The designs should specify performance in terms of environmental conditions and ecological responses.

In assessing the benefits, impacts and risks of the options, it is likely that new data gaps will be identified, particularly in relation to the groundwater environment. Additional field investigations are likely to be necessary.

Intervention monitoring should be planned alongside the options.

Grazing Management

High grazing pressure is a significant ongoing and preventable stress to ecosystem viability. It is recommended that grazing by stock and native animals is reduced to sustainable levels as quickly as possible.

As a minimum, grazing should be excluded from areas to benefit from water management options.

Trial Lowering

Seasonal lowering of water levels is a component of several water management options. A trial lowering of the level in the Pike-Mundic system to explore the risks of this proposal such as exposure of acid sulphate soils and saline groundwater discharge to wetlands. The trial should be accompanied by monitoring of surface water quality, groundwater level and salinity and riparian tree health.

Acid Sulphate Soils

Long-term saturated soils are at risk of acidification. It is recommended that a survey is conducted of acid sulphate soil risks.

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Appendix A
Conservation Action Plan Worksheets