Chowilla Floodplain

Operations Plan for Chowilla Creek Regulator and ancillary structures

Version 2.3

August 2014

Government of South Australia
Department of Environment, Water and Natural Resources

Australian Government

MURRAY–DARLING BASIN AUTHORITY

Note to reviewers

This overarching document should be read in conjunction with two supporting documents:

- ***Event Plans and Hazard Mitigation strategy for operation of the Chowilla Creek Regulator and ancillary structures***
- ***Monitoring Strategy for operation of the Chowilla Creek Regulator and ancillary structures***

The template for this document has been prepared by the MDBA to provide a standard format for presentation of operational details for the Icon Site structures built to enable or enhance environmental watering events. The manual will form part of the Icon Site Environmental Management plan but should include sufficient detail for a stand-alone document.
This document is not to prescribe particular watering events, the intent is to provide assistance in planning and implementing watering events and to guide decision making leading up to and during events. It should also provide a record of previous events and any considerations to improve subsequent operations in supporting the ecological objectives and in response to any impacts of operations to third parties.

Level of detail

The level of detail will reflect the complexity of the potential operations at the site. If reasons for particular operations have origins from specific studies these should be appropriately referenced.

Version control

The document should be seen as a living document, which will evolve in response to changing site conditions and ongoing knowledge development. It will be imperative to maintain appropriate document control to enable operational decisions to be based up the latest available knowledge.

Version	Date	Prepared	Reviewed	Approved
1	1/08/2011	DFW		
1.4	11/02/14	T Wallace & J Whittle	T. Herbert	
1.5	14/02/14	T Wallace & J Whittle		
2.0		T Wallace & J Whittle	T. Herbert	

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GLOSSARY of Terms and Acronyms

ANZECC	Australian and New Zealand Environmental and Conservation Council.
Aquatic ecosystem	any water environment from small to large, from pond to ocean, in which plants and animals interact with the chemical and physical features of the environment.
Baseline condition	an environmental quality or condition that is defined at a point in time and used as a benchmark for determining a change in the environmental quality or condition. For The Living Murray the baseline condition is 2003 when the program was announced.
BOC	Basin Officials Committee: A jurisdictional committee to coordinate the management of Basin water resources between the Commonwealth, the Authority and the Basin States.
Blackwater	Water containing a high concentration of organic matter, often accompanied by an initial depletion of oxygen.
BSMS	Basin Salinity Management Strategy
CEWH	Commonwealth Environmental Water Holder
COG	Chowilla Operations Group
CMA	Catchment Management Authority
CRC	Community Reference Committee
DEWNR	Department of Environment, Water and Natural Resources (in South Australia)
Ecological Objectives	An objective is a statement of the desired condition.
Environmental Water Management Plan	A document setting out the management, control and monitoring measures to be implemented during construction and/or operation of a development, to avoid or minimise the potential environmental impacts identified during an environmental impact assessment process.
Environmental watering	Delivery of water entitlements which are legally set aside for the benefit of environmental values.
EWG	Environmental Watering Group: A jurisdictional committee that develops and implements the annual TLM Environmental Watering Plan. The EWG recommends annual TLM watering priorities and proposals to ensure consistency between icon sites.
Environmental Works and Measures Program (EWMP)	The EWMP funds infrastructure to deliver and manage water at the icon sites to achieve The Living Murray First Step environmental objectives. This infrastructure includes regulating structures, water delivery channels and fishways and focuses on achieving environmental outcomes at the six icon sites.
Fishway	A structure placed in or around a constructed barrier to allow the passage of fish.
FSL	Full Supply Level – Operating level under normal regulated conditions
Gigalitre (GL)	One thousand megalitres
Hazard	any source of potential damage, harm or adverse health effects if it is not controlled. Hazards may be biological, chemical or physical
Icon Site	One of six sites identified under The Living Murray Initiative as having iconic value to the River Murray.
Megalitre (ML)	One million litres
Murray Darling Basin Authority (MDBA)	The authority responsible for managing the Murray River system in cooperation with state authorities, with the aim of ensuring reliable water supplies for all users.

MDBA - RMO	
OAG	Operating Advisory Group – system wide advisory group consisting or representatives from the MDBA and the state jurisdictions established under The Living Murray to advise regarding multi-site environmental watering and system wide operations.
Ramsar listing	A wetland listed under the Ramsar Convention on Wetlands; an intergovernmental treaty providing the framework for national action and international cooperation for the conservation and wise use of wetlands.
Risk	defined as the consequence of exposure (occurrence) to a hazard x likelihood of exposure (occurrence).
River Murray	The Murray River, the waters and the bed and banks of its tributaries and associated water bodies.
RMOU	River Murray Operations Unit - a division of SA Water responsible for day to day operation and management of River Murray Structures Downstream of Lock 10.
River regulation	Control of water flow within a river having the aim of ensuring the health of the river as well as ensuring future water supply.
TLM	The Living Murray
Threatened species, populations and ecological communities	Species, populations and ecological communities specified in Schedules 1, 1A and 2 of the *Threatened Species Conservation Act 1995*.
Unregulated Flow	Unregulated flows are normally declared by the Murray-Darling Basin Commission when high flows are forecast to occur that are in excess of that required to meet South Australia's entitlement flow and cannot be captured and re-regulated in Murray System storages.
Water year	A period from July to June, seasonally aligned and corresponding to water allocation policy in the River Murray system.

1. Background

1.1. Chowilla floodplain and Lindsay, Mulcra and Wallpolla Islands Icon Site

The Chowilla Floodplain and Lindsay-Mulcra-Wallpolla Islands Icon Site covers more than 40,000 ha and spans three states. The site divides into two sub regions—the Chowilla floodplain (17,700 ha) in South Australia and New South Wales on the north side of the River Murray (an anabranch system straddling Lock 6) (Figure 1.1); and the Lindsay-Mulcra-Wallpolla islands in Victoria on the south side of the river (straddling Lock 7 – 10). This operational plan is focussed only on the Chowilla floodplain part of the icon site.

1.2. The Chowilla floodplain

The Chowilla Floodplain is one of the last remaining parts of the lower Murray floodplain that retains much of the area's natural character and attributes. Significantly, it contains the largest remaining area of natural river red gum (*Eucalyptus camaldulensis*) forest in the lower River Murray (MDBC 2003) and has highly diverse floodplain vegetation. The region's aquatic habitats include permanent and temporary water bodies, including over 100km of anabranch creeks. In high river flows, these creeks spread into a series of temporary wetlands, lakes and billabongs that create an area of outstanding environmental significance. As a result of the head differential created by Lock 6, between 20 to 90% of River Murray flows are now diverted through the Chowilla anabranch system under low-flow conditions, resulting in a mosaic of flowing water habitats that are now rare in the lower Murray system.

Chowilla has highly diverse terrestrial and aquatic habitats; supports populations of rare, endangered and nationally threatened species and contains heritage protected sites of cultural significance. The floodplain is also important for its recreational and economic values. It is recognised for its ecological value as part of the Ramsar Riverland Wetland of international importance (MDBA, 2012).

The Chowilla Floodplain has undergone severe decline in environmental condition due to river regulation, increasing diversions and low inflows, particularly during the period 2001-09 (known as the millennium drought (Heberger, 2011)). Flow regulation and diversions in particular have reduced the flooding frequencies and durations as well as elevating saline groundwater levels, which have significantly affected native fauna and flora.

As part of The Living Murray (TLM) First Step Decision, three broad ecological objectives were identified for maintaining the high biodiversity values of the Chowilla Floodplain and Lindsay–Wallpolla Islands icon site:

- high value wetlands maintained
- current area of river red gum maintained
- at least 20% of the original area of black box vegetation maintained.

To enable these objectives to be adequately measured, Icon Site specific Ecological Objectives and Ecological Targets have been developed (see Section 3.2).

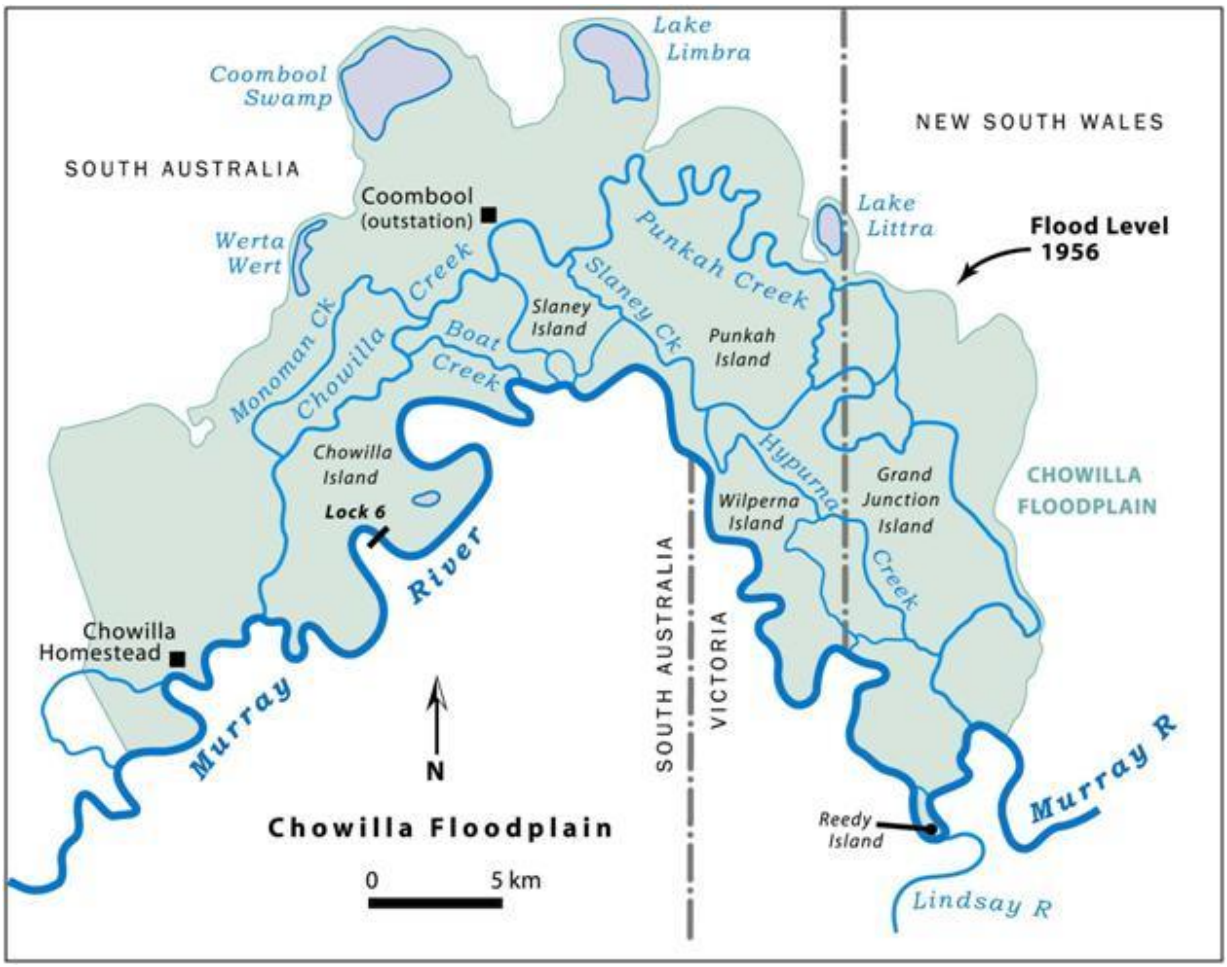

Figure 1.1: Map of Chowilla Floodplain Icon site

1.3. Environmental Works and Measures

The Murray-Darling Basin Authority's (MDBA) TLM Environmental Works and Measures Program (EWMP) provides for structural works for ecological restoration activities at Icon Sites. With funding from the EWMP a number of environmental works have been undertaken on the Chowilla floodplain. The works include:

- construction of an environmental regulator on Chowilla Creek incorporating denil and vertical slot fishways
- construction of ancillary structures:
    - Woolshed Creek South regulator
    - Woolshed Creek East regulator
    - Chowilla Island Loop channel and channel regulator
    - Chowilla Island Loop regulator
- upgrade of existing weirs on Pipeclay and Slaney Creeks to provide for more flexible operations for environmental management and incorporating combined denil and vertical slot fish passage
- Replacement of Bank E with a rock ramp fishway
- Replacement of Boat Creek bridge to remove flow restriction, improve fish passage and improve access

It is intended that these new and upgraded works will be operated in conjunction with the River Murray Locks and weirs (primarily Lock 6 but also Locks 5 and 7), providing a mechanism to enable large areas of Chowilla Floodplain to be inundated when the flows in the River Murray would otherwise be insufficient to do so naturally. A number of regulators on key wetlands within the site provide further important opportunities for flow and inundation management (see Figure 1.2). The use of these works in combination with landscape scale flow releases and other management activities will allow achievement of the Ecological Objectives.

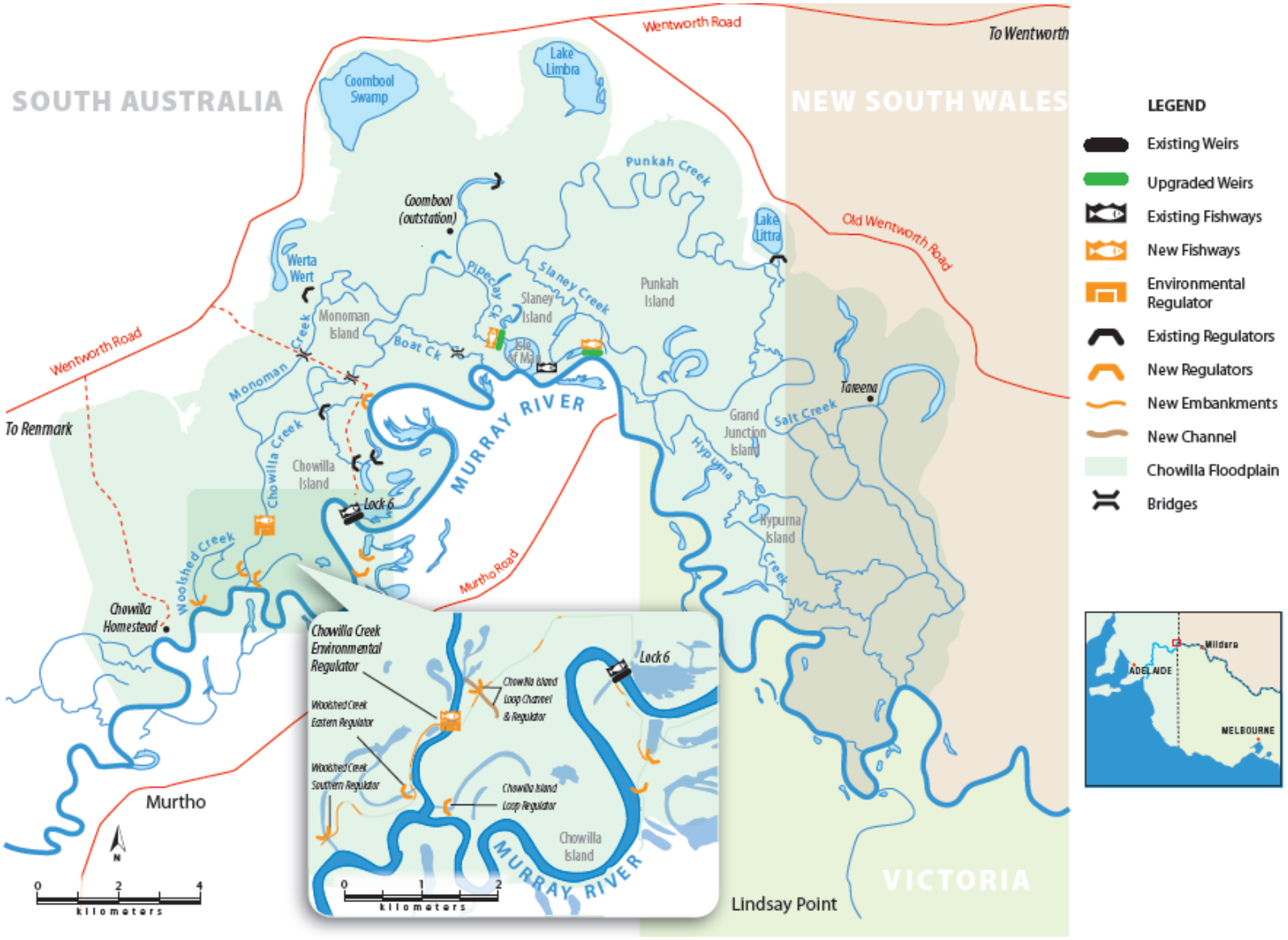

Figure 1.2: Map of Chowilla Floodplain Icon site showing location of water management structures.

1.4. About this document

1.4.1. Purpose of this document

This Operations Plan forms a Schedule to the Chowilla Environmental Water Management Plan (EWMP) (MDBA, 2012a) and is one of a number of documents which together set the framework for operations of infrastructure on the Chowilla floodplain (see Table 1.1). Table 1.2 summarises the intended audience of the Operations Plan and their respective primary requirements. The Operations Plan provides the framework for the operation of the Chowilla Floodplain TLM structures to meet key ecological objectives within the broader context of TLM, legislative requirements and governance. This includes:

- Providing direction for planning and decision making leading up to and during commissioning and subsequent operation of the new and upgraded structures on the Chowilla Floodplain in conjunction with existing infrastructure such as River Murray Locks and Weirs.
- Defining governance arrangements related to the management of flow control structures at Chowilla Icon Site.
- Summarising the physical and organisational arrangements for environmental watering activities at the site.
- An overview of hazard management and monitoring requirements (listed in 1.4.2, with full detail presented in Supporting Documents).

The Operations Plan does not prescribe particular watering events or if a watering event must occur. The information outlining that decision process for determining events is outlined in section 7 of this document.

1.4.2. Content of the Operations Plan

This Operations Plan contains information on:

- The roles and responsibilities of different Government agencies and stakeholder groups (section 2)
- The ecological objectives for the Icon Site (section 3)
- Environmental Water Requirements for the Icon Site (section 4)
- Ecological Principles for operation of the constructed infrastructure (section 5)
- The range of management options available at the Icon Site (section 6)
- The process for selecting the most appropriate management action (section 7)
- Water use and accounting (section 8)
- An overview of monitoring and hazard management requirements (section 9)
- Communication (section 10)
- Adaptive management (section 11)

Detailed event plans, conceptual models, hazard management and monitoring requirements are presented in supporting documents. They are:

- *Event Plans and Hazard Mitigation Strategy for Operation of the Chowilla Creek Regulator and ancillary structures* (MDBA, 2014a)
- *Monitoring Strategy for Operation of the Chowilla Creek Regulator and ancillary structures* (MDBA, 2014b)

Table 1.1: Chowilla Floodplain Icon Site – documents related to environmental watering and operation of infrastructure

Document	Purpose	Author / Owner
Chowilla Floodplain Environmental Water Management Plan	Prepared by the Icon Site staff in conjunction with the MDBA, the plan establishes priorities for the use of TLM water within the icon site and identifies environmental objectives, water delivery options and regimes for the site. It also outlines monitoring; communications and community and Aboriginal engagement activities associated with the icon site management.	Jointly owned by DEWNR and MDBA
Chowilla Floodplain Operations Plan for Chowilla Creek Regulator and ancillary structures (this document)	This document guides the planning and implementation of management actions at the site scale. Includes range of available management actions and information on hazard mitigation.	DEWNR
Chowilla Floodplain Event Plans and Hazard Mitigation Strategy for Operation of the Chowilla Regulator and ancillary structures	This document presents supporting information to the Chowilla Floodplain Operations Plan regarding the hydrodynamic modeling which underpins the Operational Guidelines and risk assessments for the Chowilla infrastructure and presents Event Plans for different management actions and detail regarding risk mitigation strategies.	DEWNR
Chowilla Floodplain Monitoring Strategy for Operation of the Chowilla Regulator and ancillary structures	This document presents supporting information to the Chowilla Floodplain Operations Plan which outlines the monitoring and hazard management requirements associated with delivery of environmental water at the Chowilla Floodplain Icon Site. It includes; a conceptual model for the Chowilla Floodplain; conceptual models for issues identified as critical hazards and alignment of ecological targets with monitoring objectives to optimise effort.	DEWNR
Chowilla Floodplain Communication Plan	This document will outline roles and responsibilities around communications in relation to Chowilla Operations	DEWNR
Chowilla Regulator and Associated Structures Commissioning Plan	This document outlines the specific requirements for initial operations of each of the structures and describes the requirements to test the components of the works against design assumptions and describes the requirements for surveillance during initial operations.	SA Water

1.4.3. Stakeholders

There are numerous stakeholders with key interests in the operations of the works. These include:

- The Murray-Darling Basin Authority (MDBA), including those responsible for TLM and those responsible for river operations, water accounting and the ecological outcomes of TLM water delivery.
- The South Australian Government represented by multiple agencies, primarily the Department of Environment, Water and Natural Resources and SA Water.
- The New South Wales Government represented by the Office of Water.
- The Victorian Government represented by the Mallee Catchment Management Authority (CMA) and the Department of Environment and Primary Industries.
- Landholders in NSW, Victoria and SA (government and private) (refer the EWMP (MDBA, 2012a) for more detail of different land tenures at Chowilla).
- Environmental water holders including the Australian Government (Commonwealth Environmental Water Holder (CEWH)), the MDBA TLM, and the South Australian Government.
- The scientific community.
- The community including a range of specific stakeholder groups and the wider community.
- Native Title Holders.

Table 1.2 Intended Audience for the Operations Plan

Audience	**Requirements**	**Primary Interest**		
		Ecological	**Operation**	**Hazard**
Event Managers (DEWNR; Chowilla Operations Group (COG) – see Section 2.2	Adaptive Management	✓	✓	✓
Operators (SA Water - RMOU)	Operation of structures		✓	✓
SA Land Manager for Chowilla Game Reserve (DEWNR)	Adaptive Management	✓	✓	✓
Kulcurna Land Manager (NSW Office of Water)	Adaptive Management	✓	✓	✓
Water holder / funder (TLM-MDBA; CEWH)	Accountability	✓		✓
River managers (DEWNR, SA Water, MDBA)	Safe and effective river operations	✓	✓	✓
Mallee CMA and Department of Environment and Primary Industries (Vic)	Awareness regarding likely operations Compatibility and synergy with their proposed watering operations (and vice versa)	✓	✓	✓
Community Reference Committee	Awareness of likely operation; information to enable advocacy and ensuring community support	✓	✓	✓

1.5. Revision of the Operations Plan

Knowledge continually emerges from environmental watering events at this Icon Site and other locations that can be used to improve understanding of the benefits, opportunities and hazards associated with the new infrastructure. It is expected that the level of certainty associated with information related to adjusting and optimising structure operations will increase with each event. That information needs to be reviewed, and incorporated into the Operations Plan and utilised in subsequent management actions in order to capitalise on the investments made at the Icon Site.

In order to facilitate the incorporation of emerging knowledge, the Operations Plan is considered to be a 'living document' that, once approved in the first instance, will be iteratively refined and developed over time. It is expected that the Operations Plan will be reviewed following each operation by DEWNR in consultation with relevant stakeholders for the first 10 years following the date of first approval of the Operations Plan. This ongoing revision of the Operations Plan is important as it will take a number of years before the full range of possible operation types have been implemented using the range of floodplain infrastructure to full extent. This process will enable future operational decisions to be based upon the best available knowledge.

1.6. Commissioning Operations

The wet commissioning of the structures requires a separate 'commissioning plan'. The *Chowilla Regulator and Associated Structures Commissioning Plan* is being developed through SA Water in conjunction with the structural designers and constructors and the Chowilla Design and Construction Committee.

The first commissioning operations of the Chowilla Regulator and ancillary structures will target a conservative rising of water levels through relatively low level operation of the Chowilla Regulator, the extent of which will be dependent upon the available River Murray flows and environmental water allocations and also on the capacity to raise Lock 6.

1.7. Delivery of environmental water

Delivery of water to South Australia is managed by SA Water in consultation with DEWNR under the direction of River Management Division - MDBA. The real-time management of water required by SA for all purposes (including environmental water) is coordinated by DEWNR in liaison with SA Water and the MDBA regarding the preferred pattern of delivery to SA and related matters including delivery of regulated flow (Entitlement Flow, trade, Additional Dilution Flow and environmental water) and unregulated flow.

The SA River Murray Annual Operating Plan prepared by DEWNR incorporates the annual priorities and watering actions whereby the water delivery required to support these priorities and actions is integrated with broader river operations planning to ensure management on a real-time basis and appropriate feedback to the MDBA.

1.8. Interactions with other sites

This section describes the location of other structures, systems and sites and the links between them and Chowilla Floodplain.

1.8.1. Influence of raising Lock 6 on Lindsay River

The Lindsay River diverges from the River Murray upstream from Lock 7 and converges upstream of Lock 6 in the Lock 6 weir pool. A potential impact of raising the Lock 6 weir is an increase in the backwater effect and changes in hydraulic conditions in the lower Lindsay River and Mullaroo Creek. This may cause a reduction in the hydrodynamic diversity and thus impact on fish habitat in this reach, which has a well-known Murray cod population (Mallen-Cooper et al., 2011). Modelling was conducted by Water Technology (2009) and indicates that a partial raising of Lock 7 can mitigate these potential impacts in the Lindsay River and Mullaroo Creek. Further information on this provided in section 5.4 of the *Monitoring Strategy* document.

1.8.2. Multi-site watering

The operation of the Chowilla Floodplain infrastructure may occur in conjunction with other icon sites and environmental watering activities, to achieve multiple benefits and optimise outcomes through the delivery of environmental water along the system including in association with delivery of flows through to the Lower Lakes, Coorong and Murray Mouth Icon Site. Further information on this is provided in section 5.8 of this document.

Floodplain restoration projects are underway at downstream sites in South Australia (Pike and Katarapko floodplains) and future Chowilla watering activities will need to be planned in conjunction with opportunities and hazard management for events at these sites.

2. Governance

This section outlines both the high level governance of TLM, and the governance arrangements for the operation of Chowilla Floodplain water management infrastructure.

2.1. Overview of TLM governance

TLM is a joint initiative between the Australian, South Australian, New South Wales, Victorian and Australian Capital Territory governments. It is governed by:

a) The Intergovernmental Agreement (2004) on addressing water over-allocation and achieving environmental objectives in the Murray-Darling Basin (IGA 2004);

b) The Supplementary Intergovernmental Agreement (2006) on addressing water over-allocation and achieving environmental objectives in the Murray-Darling Basin (IGA 2006);

c) Further agreement (2009) on addressing water over-allocation and achieving environmental objectives in the Murray-Darling Basin (IGA 2009).

TLM governance is undertaken through the Murray-Darling Basin Ministerial Council, the MDBA, the Basin Officials Committee (BOC), The Living Murray Committee (TLMC) and the Environmental Watering Group (EWG) (see Table 2.1). Further detail regarding governance and planning arrangements for use of TLM water is contained within the Chowilla Floodplain Icon Site Environmental Water Management Plan (EWMP) (MDBA, 2012).

Table 2.1. Summary governance arrangements for environmental water holders

	TLM Water	**Commonwealth Environmental Water**
Water Holder	Partnership; MDBA, SA, Vic, and NSW	Commonwealth Environmental Water
Planning mechanism	Annual TLM Environmental Water Plan	Annual Water Use Options via Seasonal Watering Plan
Governance	MDB Ministerial Council (with advice from BOC); MDBA (with advice from TLMC and EWG)	Commonwealth Environmental Water Holder

While the MDBA is responsible for implementing TLM (under Section 18H of the *Water Act 2007* (Cth)), the management and delivery of TLM activities at the icon sites are primarily undertaken by the relevant agencies within the jurisdictions. The Environmental Water Operations group within River Murray Operations and Major Projects branch of the SA Department of Environment, Water and Natural Resources (DEWNR) is responsible for delivering TLM program at the Chowilla Floodplain Icon site. In addition, the MDBA, other branches within DEWNR, the NSW Office of Water, SA Water, and the Commonwealth Environmental Water Holder (CEWH) play key roles which are outlined below.

Under the MDB Agreement (Schedule 1, Water Act 2007) the Assets created under TLM will be managed by the MDBA on-behalf of the Asset Controlling Governments (Commonwealth Government and the Government of South Australia, New South Wales and Victoria).

Under the MDB Agreement, the Minister for Water and the River Murray is the SA Constructing Authority. The Minister has delegated certain functions of this role to SA Water as the 'operational agent' thereby the works on the Chowilla Floodplain will be operated and maintained by SA Water. The MDBA has advised that it cannot direct the operation of the works but that it will provide a procedure under Clause 66 for the raising of Lock 6 and operation of the Chowilla Regulators and ancillary structures. This procedure will relate to the

coordination of operations between DEWNR, SA Water and MDBA River Operations and the safe operation of the structures.

DEWNR as the Icon Site Manager, will work with all relevant agencies to plan, develop and implement operation of the Chowilla regulator and associated infrastructure to deliver environmental watering events to achieve ecological outcomes for the icon site. DEWNR will direct SA Water to undertake agreed operations in accordance with this Operations Plan and the MDBA procedure under Clause 66. The agencies involved, and their roles and responsibilities are summarised in section 2.2.

The Chowilla Floodplain Environmental Water Management Plan (EWMP) details governance and planning arrangements associated with Icon Site Management and relevant agreements and legislation. The following information relates to governance arrangements around operation of the environmental water infrastructure and should be read in conjunction with the EWMP.

2.2. Roles and Responsibilities

Department of Environment, Water and Natural Resources (DEWNR)

DEWNR – River Murray Operations

DEWNR – Environmental Water Operations within the River Murray Operations and Major Projects Branch is the Icon Site Coordinator and has a key role in coordination, delivery and reporting on environmental watering at the Chowilla Floodplain Icon Site. This includes preparation of environmental watering plans and proposals to the water holders for specific operational events. DEWNR is also responsible for initiating and supervising monitoring programs with support from a range of internal and external providers. This responsibility will include convening, and coordination of, the Chowilla Operations Group (see later).

The DEWNR Icon Site Coordinator will be responsible for the coordination of environmental monitoring, reporting and provision of advice through DEWNR River Murray Operations to SA Water and MDBA River Murray Operations. The Icon Site Coordinator is also be responsible for wider community engagement and communications relating to TLM and operations events.

DEWNR – Natural Resources SAMDB – Chowilla Game Reserve Public Land Manager

DEWNR, Natural Resources SAMDB is the manager of the Chowilla Game Reserve, responsible for ongoing Game Reserve management including visitor management during operations events as well as management related to Game Reserve specific stakeholders; in particular, liaising with leasees, and licensed business operators.

The Wetlands and Floodplain Team within Natural Resources SAMDB are responsible for the management of numerous individual pool level and temporary wetlands. This team also provides monitoring and wetland planning support to the Icon Site Coordinator for the Chowilla Floodplain.

DEWNR - Strategy and Advice Group

DEWNR Strategy and Advice is responsible for overarching environmental water policy for the River Murray in SA in consultation with other State agencies involved in River Murray environmental projects. The Icon Site management team will liaise closely with this group particularly around development of environmental watering plans and reporting on environmental water use and outcomes.

DEWNR – Science, Monitoring and Knowledge (SMK)

DEWNR SMK provide support to, and deliver, some of the key monitoring programs for the Chowilla Floodplain Icon Site which underpin planning and implementation of environmental watering events. SMK may provide scientific advice during planning and event management and may also have a role in using outputs of monitoring to evaluate outcomes of the Basin Plan. This will include the transfer of monitoring data into corporate databases.

New South Wales Office of Water

The NSW Office of Water is responsible for management of the portion of the Chowilla Floodplain within NSW known as Kulcurna. The Icon Site management team will liaise closely with NSW and officers responsible for Kulcurna management particularly around development of environmental watering plans, operation of the environmental regulator, hazard management and monitoring and reporting on environmental water use and outcomes.

Murray Darling Basin Authority (MDBA)

MDBA - River Murray Operations (RMO)

The MDBA, as agent on behalf of the Joint Venture, manages and provides operating procedures for the water delivery structures (assets) within the Chowilla Floodplain Icon Site. Appropriate arrangements for onsite control of the works will be put in place by SA Water's RMOU.

MDBA River Murray Operations staff oversee and coordinate water operations along the River Murray system. They convene the Operational Advisory Group (OAG) to enable collaboration across the jurisdictions in the delivery of multi-site watering events.

MDBA – TLM Planning and Delivery

The MDBA – TLM Planning and Delivery Directorate is responsible for the coordination of the planning and delivery of environmental water to all icon sites. This is achieved in close consultation with the Environmental Watering Group (EWG), which is chaired by the MDBA and consists of the partner states and the Commonwealth Government. The EWG develops and implements TLM annual environmental watering actions.

South Australian Water Corporation (SA Water)

SA Water is the SA Minister-delegated operational agent for SA including the Chowilla Floodplain Icon Site. As such, SA Water is responsible for the detailed design and construction activities under the EWMP.

SA Water - River Murray Operations Unit (RMOU)

RMOU is responsible for the operation and maintenance of all major water delivery structures within the Chowilla Floodplain Icon Site that have been constructed under TLM on behalf of the MDBA.

This is undertaken as part of an asset agreement between the MDBA and SA Water. Under this agreement, SA Water is responsible for "accounting for the assets, recording, reporting and auditing as well as specific high level requirements in relation to construction, maintenance and operation of assets" (MDB Agreement, Clause 55). It is anticipated that SA Water may engage local contractors to undertake some operation and maintenance activities if required.

SA Water will operate the Chowilla Regulators (as well as Lock 6) under directions from DEWNR and in accordance with procedures to be provided by the MDBA under Clause 66. This procedure will relate to the coordination of operations between DEWNR, SA Water and MDBA River Operations and the safe operation of the structures.

Commonwealth Environmental Water Holder (CEWH)

The Commonwealth Government has acquired water entitlements as part of Murray-Darling Basin reforms, with the objective to return a proportion of the total available water to the environment. These entitlements have become a part of the Commonwealth environmental water holdings and are managed by the CEWH. The volume of environmental water held by the CEWH is significant and may constitute an important source of environmental water for operation of the Chowilla Floodplain environmental regulator and associated infrastructure. Where the CEWH approves the use of water from its entitlements, the necessary agreements and approvals are provided and they transfer water for use.

Chowilla Operations Group

DEWNR will convene the Chowilla Operations Group (COG), to provide advice to guide event planning and the day-to-day real-time management during an event. The COG will be chaired by the DEWNR Icon Site Manager and membership will include agency representatives with delegated responsibilities, including those involved in day-to-day management of the structures. Representatives with delegated responsibilities include SA Water RMOU, DEWNR Natural Resources SAMDB (Game Reserve Manager), NSW Office of Water, and MDBA RMO. The Group will also include key scientific advisors and other agencies may be invited as members or observers, as deemed necessary (Figure 2.1).

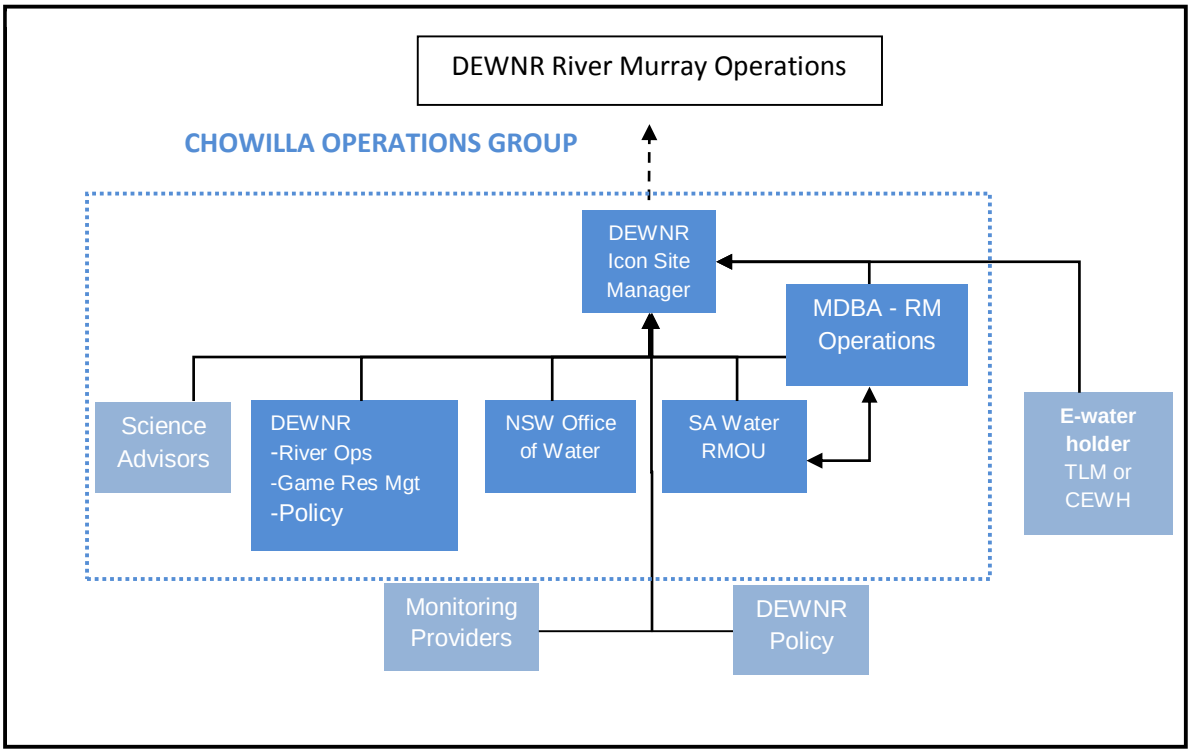

Figure 2.1: Chowilla Operations Group (COG)

The purpose of the COG is for representatives to have input into operational decision making and ensure that recommendations made to DEWNR River Murray Operations are sensible, practical and incorporate up-to date information regarding constraints, hazards and ecological opportunities.

It is anticipated that groups such as the COG will be established at each TLM Icon Site to advise on operations, and it is expected, in the longer term, that all these groups will be co-ordinated through the system-wide Operating Advisory Group (OAG) already established under TLM.
An overview of the roles and responsibilities of these stakeholders are provided in Table 2.2.

Table 2.2 Roles and responsibilities for Chowilla Floodplain operations

	Main Roles	Tasks/Responsibilities		
		Event Planning	**Event Management**	**Event Review and Reporting**
Icon Site Manager	Event Coordination Communications Monitoring	• Convene Chowilla Operations Group (COG) • Ensure planning process according to annual schedule • Review and Revise Operating Plan and Monitoring Plan with COG input • Prepare Chowilla input to SA Annual Watering Plan and environmental water proposal • Have regard to Basin Plan requirements	• Convene and coordinate weekly (or as required) meetings / teleconferences of COG. • Forward advice of COG via RM Operations • Coordinate event monitoring (ecology/environment/water use) • Coordinate Community Communications and Consultation • Keep event records	• Compile/Collate Monitoring Results • Review decision making process and outcomes • Prepare Annual Watering Report with other stakeholder input • Adaptive management – identify learnings to be applied to future events.
SA River Murray Operations (DEWNR)	Provide SA advice to MDBA - RMO Instruct Operations in accordance with MDBA Operating Procedures	• Receive advice from COG re planned event scenarios • Provide advice on SA river operations and any implications (ie potential impacts on other users) • Accounting for environmental water	• Take advice from COG • Confirm to MDBA – RMO re water / operational requirements for SA • Issue Operating Instructions in accordance with MDBA Operating Procedures	• Provide advice on any water delivery implications encountered and future considerations
River Murray Operations (MDBA)	Water Delivery Water Accounting Provide Operating Procedures	• Provide advice on basin wide river operations and any implications • Convene Operations Advisory Group (OAG)	• Coordinate delivery of flows to SA • Provide MDBA Operating Procedures for operations of Chowilla structures • Convene OAG • Provide advice on river operations and any implications • Conduct water use modelling	• Water Accounting • Provide advice on any water delivery implications encountered and future considerations including advice from OAG • Adherence to Operating Procedures
SA Water	Structure Operation & Maintenance Monitoring	• Provide advice on structural or maintenance issues and any implications • Conduct maintenance and structural pre-event monitoring • Undertake pre-event monitoring	• Operate Structures in accordance with instructions from DEWNR RMO and with MDBA Operating procedures • Monitoring of structural integrity; water levels and flows; other opportunistic recording. • Record operational actions • Provide advice on structural or maintenance issues and any implications	• Provide details on operational details; performance of structures and any issues or future considerations • Provide monitoring data • Provide details of issues associated with operational costs
Natural Resources SAMDB (DEWNR)	Land (Game Reserve) Manager and Wetlands and Floodplains Team	• Provide advice on achieving ecological objectives • Advise COG regarding site ecological values or threats and implications • Manage communications with Reserve visitors and leaseholder • Provide advice on management of individual managed wetlands within Chowilla	• Manage public access (during and after event) • Advise site ecological values or threats and any implications • Manage communications with Reserve visitors and leaseholder • Provide advice on management of individual managed wetlands within Chowilla	• Provide details of site ecological responses and any future implications • Report on comments received from Reserve visitors and leaseholder

		• Provide advice on management, objectives and coordination of wetlands outside of the Chowilla floodplain, which will also be impacted by Chowilla regulator operation. • Provide support for Icon Site monitoring,	• Provide advice on management, objectives and coordination of wetlands outside of the Chowilla floodplain, which will also be impacted by Chowilla regulator operation. • Provide support for Icon Site monitoring.	• Report on wetland scale outcomes on Chowilla Floodplain and other sites impacted by Chowilla regulator operations. • Report on monitoring outcomes
NSW Office of Water	Land Manager (Kulcurna)	• Provide advice on achieving ecological objectives • Advise COG regarding site ecological values or threats and any implications • Manage communications with Reserve visitors	• Manage public access (during and after event) • Advise site ecological values or threats and any implications • Manage communications with Reserve visitors and leaseholder	• Provide details of site ecological responses and any future implications • Report on comments received from Reserve visitors
TLM – Environmental Delivery (MDBA)	Water Availability • (If TLM water used)	• Advise on TLM watering objectives • Advise on TLM water availability • Consider risks • Coordinate activities across TLM Icon Sites • Approve use of MDBA works	• Observer on COG (if providing water) • Assist with water use modelling	• Water accounting • Assist with report compilation and review
CEWH	Water Availability • (If Commonwealth water used)	• Advise on Commonwealth watering objectives • Advise on Commonwealth water availability • Coordinate other CEWH activities	• Liaise with SA and the MDBA regarding use of water holdings (if providing water) • Observer on COG (if providing water)	• Assist with review process (if providing water)
DEWNR E-Water Policy	• Annual Environmental Water Planning and water accounting	• Coordinate SA long-term and annual environmental water planning • Administer environmental water trades • Advise on Commonwealth watering objectives	• Observer on COG	• Assist with report compilation and review • Address any additional policy implications that have emerged.
DEWNR Science, Monitoring and Knowledge (SMK)	• Support for monitoring and data management	• Monitoring; interpretation and management of data	• Monitoring; interpretation and management of data	• Monitoring; interpretation and management of data • Support reporting activities
Scientific Advisors (external and internal via SMK)	• Specialist Advice	• Assist confirming relevant ecological objectives and operation type	• Provide specialist advice on COG	• Input to adaptive management based on monitoring outcomes.
EWG	Advice	• Recommends TLM watering priorities and the implementation of events based on the TLM Annual Watering Plan	• NIL –unless site or river conditions lead to substantial change from planned event	• Review TLM Watering summaries provided by Icon Site Managers
Mallee CMA &/or Department of Sustainability and Environment (DSE)	Advice Link to broader Icon Site management Consult re impacts on Lindsay	• Observer on COG • Provide advice re links with upstream watering actions and hazard management • Advice re potential impacts at Lindsay	• Observer on COG • Provide advice re links with upstream watering actions and hazard management • Advice re potential impacts at Lindsay	• Advice on outcomes at Lindsay from a hazard / impact perspective

2.3. Governance arrangements for planning and operating environmental regulator and ancillary structures

The MDBA manages the assets in accordance with: the *Water Act 2007* (Cth); the Murray-Darling Basin Agreement (Schedule 1 to the Water Act); the MDBA's annual Corporate Plan; the Asset Agreement; and the Asset Management Plan for River Murray Operations Assets. Operation and maintenance of the assets are conducted by the MDBA River Management Division in conjunction with SA Water. SA Water is the operational agent that operates works on behalf of the Minister for Water and the River Murray who is the SA Constructing Authority. MDBA River Murray Operations staff coordinate the delivery of water (both irrigation and environmental) and manage unregulated flows throughout the River Murray System in conjunction with DEWNR River Murray Operations branch and SA Water. In addition to the documents above, the MDBA must manage river operations in accordance with the Objectives and Outcomes document, the Specific Objectives and Outcomes document and any relevant decision of the MDBMC and the Basin Officials Committee (BOC).

The Icon Site Coordinator develops annual proposals regarding potential preferred Chowilla Floodplain environmental watering activities under the range of water availability scenarios which are incorporated into the SA Annual Environmental Watering Plan and the SA River Murray Annual Operations Plan. Detail regarding ecological and other considerations underpinning decisions regarding the range of operations to be included in the proposal are provided in Section 7. This information is provided annually within a Chowilla Floodplain Icon Site environmental watering proposal to the TLM EWG.

Environmental water for the Chowilla Floodplain Icon Site may be sourced from a number of environmental water holders. These sources include TLM, CEWH and SA Environmental Water. Operations will also be implemented under unregulated flow conditions which may or may not require additional environmental water allocations.

The proposals for environmental watering will be developed in close collaboration with the range of stakeholders including land managers in SA and NSW (DEWNR and NSW Office of Water), SA Water and with scientific advice from DEWNR and other monitoring providers.

Information is also provided to the CEWH to inform their water planning commitments. If TLM water is proposed to be used, submissions are presented to, and assessed by, the EWG who then advises the MDBA on allocations of TLM water. The CEWH also has its own internal processes for prioritisation and approval of environmental water proposals.

The following steps will be undertaken once confirmation is provided by the environmental water holder(s) of the environmental water allocation and/or by MDBA RMO of appropriate unregulated River Murray flows to enable operation:

- The COG will be convened to discuss the possible events for the coming water year.
- The COG will meet on an as needs basis (potentially daily) in the lead up to and during the event to oversee implementation of the Operations Plan and make recommendations to MDBA River Murray Operations regarding environmental water delivery and the operation of the structures.
- MDBA RMO will consider the water order, and determine a course of action for flow management and water delivery.
- Instruction will be issued by DEWNR RMO to SA Water regarding the operation of the structures.
- SA Water will report back to the COG and the MDBA RMO following implementation of the instruction for operations.

- Monitoring will be undertaken as per the monitoring strategy (MDBA, 2014b)
- Any advice regarding operation of Chowilla structures or delivery of environmental water will be provided to MDBA RMO and SA Water RMOU by DEWNR.

The environmental water planning process, the pre-event planning process and the planning and decision making process during management actions including detail regarding ecological and hazard management considerations are detailed in Section 7 of this document.

2.3.1. COG event planning and management meetings

In the lead up to the water year and following confirmation of potential access to adequate flows via unregulated flows to SA and/or the approval of environmental water allocations, the COG will be convened with relevant monitoring providers and key scientific advisors to prepare in detail for the events for that water year. Detail regarding the system and site specific factors that must be taken into consideration in the pre-event period and during an event are presented in section 7 of this document.

The COG will meet in the lead up to, and during the operation event to oversee the event in the context of:

- management of the operation of structures based on the Ecological Principles and Critical Operational Limits that have been defined (Section 5 of this document), and hazard management (section 9 of this document).
- ensuring **adequate monitoring is in place** (see the *Monitoring Strategy* document) and taking into account the information about prevailing/emerging conditions.
- making recommendations to MDBA River Murray Operations (RMO) regarding environmental water delivery.

The frequency of meetings/communications will need to be high (i.e. potentially daily) during operations in order to:

- review the flow forecasts
- review and make decisions based on real-time data for critical hazards
- discuss any operational issues and capacity to respond to any emerging hazards
- discuss communication with stakeholders and the general public
- any other relevant issues

2.3.2. Communications

Effective communications between the key stakeholders will be critical to the successful implementation of environmental watering events. A Chowilla Operations Communications strategy will be used to provide clear direction for the commissioning operation and will be reviewed and updated on an ongoing basis. The DEWNR Icon Site Coordinator will have overarching responsibility for overseeing implementation of the strategy, convening the COG, ensuring all parties are aware of their roles and responsibilities, and coordination of communications with and between stakeholders, and with affected landholders and the wider community.

DEWNR Natural Resources SAMDB will have key responsibility for communications with Game Reserve visitors and the leasee regarding Chowilla operations and environmental watering events.

Further information regarding communications and engagement are included in Section 10 of this document.

3. Management and Ecological Objectives for Chowilla Floodplain

3.1. Management Objectives

3.1.1. Interim outcomes and objectives of the First Step Decision

The First Step Decision (FSD) identified a series of interim outcomes and objectives for each Icon Site. Those established for the Chowilla Floodplain (including LMW) are listed in Table 3.1. The Chowilla Floodplain and Lindsay-Wallpolla Islands Icon Site Environmental Management Plan (MDBC, 2006), outlined the vision for the Chowilla Floodplain as:

> *To maintain and restore a diverse and healthy floodplain environment that will provide for the long-term ecosystem and community needs and serve as a showcase for lower River Murray floodplain management*

Table 3.1 First Step Decision outcomes and objectives (MDBMC, 2003)

First Step Decision outcomes and objectives
Maintain high biodiversity values of the Chowilla Floodplain
• High value wetlands maintained
• Current area of River Red Gum maintained
• At least 20% of the original area of Black Box vegetation maintained

3.2. Ecological Objectives and Ecological Targets

The site-specific Ecological Objectives stated in the Chowilla Floodplain Environmental Water Management Plan (MDBA, 2012a) are presented in Table 3.2. Additional Ecological Objectives and Ecological Targets have been developed via an iterative process guided by Wallace (2011), and following recommendations of Robinson (2013a; 2013b) and Wallace *et al*., (2014) to provide a framework to support:

- decisions regarding the need for targeted management actions
- development and rationalisation of monitoring programs
- streamlined reporting of monitoring programs
- focussed assessment of outcomes of management actions

The additional Ecological Objectives and the Ecological Targets presented in Table 3.2, are consistent with the MDBA 2012a Ecological Objectives but should be considered "preliminary" as they have not been endorsed by Murray-Darling Basin Ministerial Council (MDBMC). It is intended that these will be incorporated into future versions of the Icon Site Environmental Water Management Plan. The Ecological Targets related to native and non-native fish are derived from Ecological Targets developed for the Lower River Murray channel {Wallace, 2014 #5856}. These targets are currently under review in order to be refined to be specific to the Chowilla Icon Site.

Purpose of Ecological Targets

The Ecological Targets are intended to be tested within a monitoring program that is explicitly linked to an adaptive management regime. Short-term targets have been established for achievement by 2020. This provides for the completion of the construction and initial operation of the primary and ancillary structures. Long term targets have been established for achievement by 2030. With regard to baseline condition, the period 2004-10 has been selected as it corresponds with (i) a period where the intensity of data collection increased markedly; and (ii) the period of a prolonged, intense drought. Where practicable, the targets are structured within a SMART (specific, measurable, achievable, realistic, time bound) framework. It is important to note that achieving some of the Ecological Targets will require flow and climate conditions that occur at the landscape (Murray-Darling Basin) or reach (i.e. Murray-Darling Junction to Lower Lakes) scale rather than management actions undertaken at the Icon Site scale. However, actions at the Icon Site scale may have an influence on local and regional populations. Examples include highly mobile fauna such as some guilds of fish and waterbirds.

With regard to measured (observed) condition relative to the Ecological Targets at any given time, it is essential to note that attaining stable conditions is counterproductive, and that recording condition scores that do not meet the Ecological Target in any given year is not an indication of failure. It should be expected that the measured condition and trajectory of each attribute or process will be dynamic over time and space. Position and trajectory relative to the targets is intended to be used as a decision tool to decide which management actions are most appropriate at any given time, with management actions targeted at maintaining condition of biota and abiotic processes within responsive ranges rather than at a specific target level. A hypothetical example is shown in Figure 3.1. In this example, the condition of the population of trees is poor in the first year of a 10-year period of assessment. The black circles indicate a successful outcome over the 10-year period, whereby management actions have supported an improvement in condition between years 1 and 5, such that the target is exceeded in years 5 and 6. Although the trajectory is negative between years 5 and 9, the population remains in resilient condition where there is a rapid positive response to management actions, and the target is almost met in year 10. In contrast, the red triangles indicate a 'fail' scenario, where the resistance limit(s) have been exceeded, and the decline in condition over the 10 years is likely to lead to loss of the population. Timeframes for assessment and 'fail' points will vary between assets and functions. As a rule, the timeframes need to be relevant to (i) the life cycle of the organisms (including longevity of seed banks) and/or (ii) the time scales of the biogeochemical processes involved.

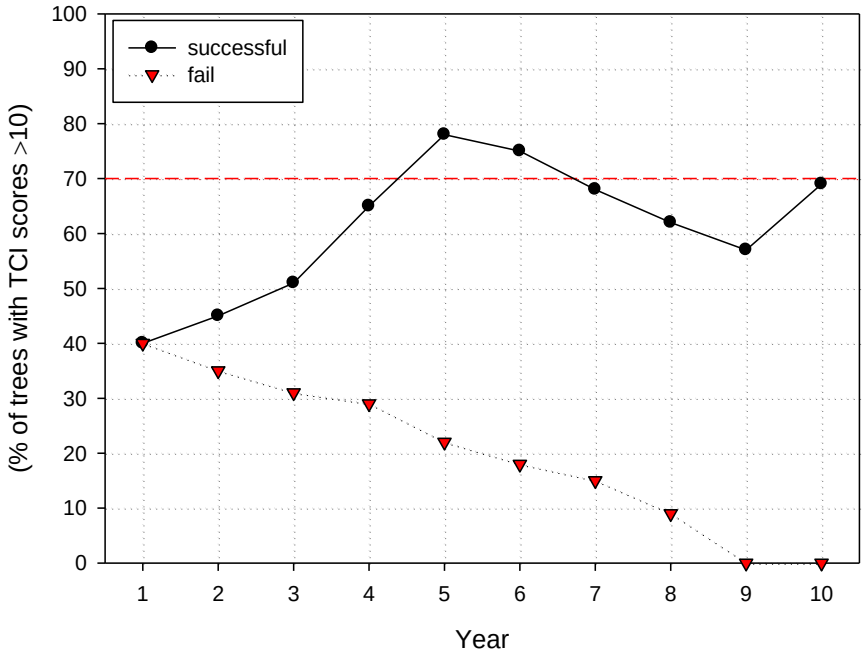

Figure 3.1. Hypothetical example of condition measured annually relative to the Ecological Target "70% of trees will have a Tree Condition Index (TCI) score ≥10" (indicated by the red broken line). The black circles indicates a successful outcome over the 10-year period. In contrast, the red triangles indicate a "fail" outcome over the 10-year period. From Wallace et al., (2014).

Table 3.2. Linkages between Icon Site specific Ecological Objectives and Ecological Targets at Chowilla Floodplain. Additional Ecological Objectives are presented in italics.
*Ecological Targets are preliminary (see accompanying text).

Group	Type	Icon Site Ecological Objective	Ecological Target*
Floodplain Trees	River red gum	Maintain viable River Red Gum populations within 70% (2,414 ha) of River Red Gum woodland	In standardised transects that span the floodplain elevation gradient and existing spatial distribution, >70% of trees will have a Tree Condition Index Score (TCI) ≥10 by 2020
			A sustainable demographic that matches the modelled profile for a viable population is established within existing communities across the floodplain elevation gradient by 2020
	Black Box	Maintain viable Black Box populations within 45% (2,075 ha) of Black Box woodland	In standardised transects that span the floodplain elevation gradient and existing spatial distribution, >70% of trees will have a Tree Condition Index Score (TCI) ≥10 by 2020
			A sustainable demographic that matches the modelled profile for a viable population is established within existing communities across the floodplain elevation gradient by 2020
	River Cooba	Maintain viable River Cooba (*Acacia stenophylla*) populations within 50% of existing River Cooba and mixed Red Gum and River Cooba woodland areas.	In standardised transects that span the floodplain elevation gradient and existing spatial distribution, >70% of trees will have a Tree Condition Index Score (TCI) ≥10 by 2020
			A sustainable demographic that matches the modelled profile for a viable population is established within existing communities across the floodplain elevation gradient by 2020
Understorey vegetation	Lignum	Maintain viable lignum populations in 40% of areas.	In standardised transects that span the floodplain elevation gradient and existing spatial distribution, ≥70% of lignum plants will have a Lignum Condition Score (LCI) ≥6 for colour by 2020
	Floodplain, aquatic and amphibious plants	Improve the abundance and diversity of grass and herblands	Flood-dependent/responsive plant species are recorded in 70% of quadrats spanning the floodplain elevation gradient at least once every 3 years
		Improve the abundance and diversity of flood-dependant understorey vegetation	Native macrophytes are recorded in 70% of quadrats spanning the elevation gradient within each of the recognised permanent and ephemeral wetlands at least once every 3 years
		Improve the abundance and diversity of submerged and emergent aquatic vegetation.	
		Maintain or improve the area and diversity of grazing sensitive plant species	No target set
	Invasive/nuisance plants	Limit the extent of invasive (increaser) species including weeds	Cumbungi distribution is maintained within ±20% of the range recorded during the period 2004-10
			The relative abundance of weed species does not increase compared to mean levels recorded during the period 2004-10

Table 3.2 continued. Linkages between Icon Site specific Ecological Objectives and Ecological Targets at Chowilla Floodplain. Additional Ecological Objectives are presented in italics.
*Ecological Targets are preliminary (see accompanying text).
Fish related ecological targets are based on work undertaken for the River Murray Channel. These targets are currently under review to refine for the Chowilla anabranch.

Group	Type	Icon Site Ecological Objective	Ecological Target* #
Fish	Native Fish	Maintain or increase the diversity and extent of distribution of native fish species	Expected[1] species occur in each mesohabitat i.e. fast flowing, slow flowing, backwaters and the Murray River main channel
		Maintain successful recruitment of small and large bodied native fish	The length-frequency distributions for foraging generalists† include size classes that demonstrate annual recruitment
			Population age structure[2] for Murray cod includes recent recruits [3], sub-adults and adults in 9 years in 10,
			Population age structure for Murray cod indicates a large recruitment[4] event 1 year in 5 as demonstrated by a cohort representing >50% of the population
			Abundance of Murray cod, as measured by CPUE[5], increases by ≥ 50% over a 10 year period
			Population age structure for golden perch and silver Perch includes YOY with juveniles and adults in 9 years in 10
			Population age structure for golden perch and silver perch indicates a large recruitment event 2 years in 5 as demonstrated by separate cohorts each representing >30% of the population
			Abundance of golden perch and silver perch, as measured by CPUE, increases by ≥ 30% over a 5 year period
			Population age structure for freshwater catfish includes YOY, with juveniles and adults in 9 years in 10.
			Population age structure for freshwater catfish indicates a large recruitment event 2 years in 5 as demonstrated by separate cohorts each representing >30% of the population
			Abundance, of freshwater catfish, as measured by CPUE, increases by ≥ 30% over a 5 year period
			Unrestricted lateral access to and from key off-channel (i.e. wetland) habitats is provided for native fish once every three years by 2020
	Introduced Fish	*Restrict the abundance and biomass of introduced fish species*	*The relative abundance and biomass of carp does not increase in the absence of increases in abundance and biomass of flow-dependent native species.*
			Flow events do not result in new cohorts of carp entering the population in the absence of new cohorts of large bodied native fish

[1]Expected species are those that historically occurred in high abundance (i.e. Silver perch and Freshwater catfish) that would not be considered beyond their extant range (i.e. Trout cod), only vagrant (i.e. Spangled perch) in the lower River Murray, or not expected to occur in that habitat (i.e. mature Murray cod in temporary wetlands)
[2] Population age structure is inferred from length-frequency distributions and validated by otoliths where appropriate
[3] "Recent recruits" = fish that are < 2 years old
[4] "Recruitment" = survival and growth of the larvae and juveniles to YOY.
[5] CPUE is "catch per unit effort" resulting from formal fish surveys using standardised techniques (e.g. boat mounted electrofishing, fyke nets)
†Foraging generalists include Australian smelt, bony herring, Murray rainbowfish, un-specked hardyhead, carp gudgeon spp., flathead gudgeon spp.

Table 3.2 continued. Linkages between Icon Site specific Ecological Objectives and Ecological Targets at Chowilla Floodplain. Additional Ecological Objectives are presented in italics.
*Ecological Targets are preliminary (see accompanying text).

Group	Type	Icon Site Ecological Objective	Ecological Target*
Birds	Habitat	Create conditions conducive to successful breeding of colonial waterbirds in a minimum of three temporary wetland sites at a frequency of not less than one in three years	A habitat mosaic comprising shallow water, open water, mud flat and littoral zones is provided simultaneously at a minimum of three large wetlands at least once every three years
			Minimum inundation periods required for successful breeding by a range of water bird species are provided during 80% of flood events
	Abundance and Diversity	Maintain or improve the diversity and abundance of key bird species	Attempted breeding (nesting) by >500 pairs of colonial waterbirds more than three times in any ten year period
			Attempted breeding (nesting) by >10 pairs of at least five species of colonial water birds other than Australian White Ibis, Nankeen Night-Heron and Cattle Egret in any five year period
			Each of the bird species known to historically utilise Chowilla will be recorded at ≥ 3 sites in any three year period
	Threatened Species	Maintain the current abundance and distribution of Regent Parrots	Abundance and distribution of threatened birds is maintained at or above levels recorded during 2004-10
		Maintain the current abundance and distribution of the Bush Stone-curlew (*Burhinus grallarius*)	
Frogs	Riparian species	Maintain sustainable communities of the eight riparian frog species recorded at Chowilla	Each of eight riparian frog species known to occur at Chowilla will be recorded at ≥ 3 sites in any three year period
	Threatened species	Improve the distribution and abundance of the nationally listed Southern Bell Frog at Chowilla	
Mammals and Reptiles	Grazing pressure	*Reduce grazing pressure to sustainable levels*	*Reduce grazing animal numbers to DEH recommended densities*
	Habitat	*Re-establish habitat condition to sustain high value fauna communities*	*Maintain breeding populations of the 17 mammals recorded in surveys undertaken prior to 1990*
			Maintain the 5 listed reptile species recorded in surveys undertaken prior to 1990
Soil condition and groundwater	Groundwater	*Establish groundwater and soil conditions conducive to improving vegetation condition*	*Establish and maintain freshwater lenses in order to improve condition of overlying vegetation communities*
	Soil condition	*Avoid fringe degradation due to soil salinisation in areas where ground water levels fluctuate in the absence of inundation*	*Maintain soil water availability, measured as soil water potential at soil depth 20-50cm, greater than -1.5 MPa in order to sustain the recruitment of long-lived vegetation*
			Reduce soil salinity (EC 1:5) to below 5,000 µScm^{-1} to prevent shifts in understorey plant communities to salt tolerant functional groups
			Maintain soil sodicity below the exchangeable sodium percent (ESP) value of 15 (highly sodic)

Table 3.2 continued. Linkages between Icon Site specific Ecological Objectives and Ecological Targets at Chowilla Floodplain. Additional Ecological Objectives are presented in italics.
*Ecological Targets are preliminary (see accompanying text).

Group	Type	Icon Site Ecological Objective	Ecological Target*
Water Quality	Downstream salinity impacts	*Avoid unacceptable salinity impacts to downstream users*	The levels of salinity should not exceed the following values 95% of the time (section 9.14(5c) of the Basin Plan): o River Murray at Lock 6† = 580 EC o River Murray at Morgan = 800 EC o River Murray at Murray Bridge = 830 EC o Lower Lakes at Milang = 1,000 EC †At Chowilla, the target of salinity to be <580 EC is taken to be measured in the River Murray downstream of Chowilla Creek (Station No. A4260704)
	Biogeochemical processes	*Maintain water quality within ranges that support aquatic biota and normal biogeochemical processes*	Total Phosphorus <100 μgL^{-1}
			Total Nitrogen < 1000 μgL^{-1}
			pH = 6.5-9.0
			<10 mm^3L^{-1} total biovolume of all cyanobacteria
			Thermal stratification is not allowed to persist for more than 5 days in the anabranch creeks or adjacent reach of river channel
			Turbidity during base flows = <40 NTU for water from Murray system, <76 for water from Darling system
			Maintain dissolved oxygen above 50% saturation* (4 mg O_2L^{-1}) throughout water column at all times
Ecosystem processes	Connectivity	*Provide processes for the mobilisation of carbon and nutrients from the floodplain to the river in order to reduce the reliance of in-stream foodwebs on autochthonous productivity*	During September-March, open water productivity measurements reflect a temporary shift from near zero or autotrophic dominance (positive Net Daily Metabolism) towards heterotrophic conditions (negative Net Daily Metabolism)
			Increase the abundance and diversity of invertebrate food resources for higher order organisms
			Provide unrestricted lateral exchange between the channel and the off-channel (i.e. wetland) habitats during >90% of inundation events
	Hydrology	*Maintain the flow mosaic characteristic of the Chowilla Anabranch system*	Maintain flows >0.18 ms^{-1} in 75% of core fish habitat at all times
	Variability	*Establish a flow regime with distinct variability in components of the flood pulse*	Successive events do not repeat the preceding hydrograph with respect to (i) magnitude, (ii) duration and (iii) timing
	Geomorphology and channel stability	*Maintain sedimentation and erosion processes within normal ranges*	Mass bank failures are restricted to <2% of stream length

4. Environmental Water Requirements for Chowilla Floodplain

Environmental Water Requirements (EWRs) specific to the Icon Site are presented in the Chowilla Floodplain Environmental Water Management Plan (2012). Each of the respective EWRs are presented, relative to the vegetation focused site-specific ecological objectives, in Table 4.1. The EWRs are 'guidelines' for average return intervals, magnitude and duration of inundation. The EWRs were developed using results from the WINDS modelling (CSIRO, 2004) combined with consideration of the hydrological indicators developed during the MDBC MFAT (Murray Flow Assessment Tool) modelling and flow regime requirements as described in Roberts and Marsden (2000).

Table 4.1. Environmental Water Requirements for Chowilla Floodplain site specific ecological objectives. Adapted from Chowilla Floodplain Environmental Water Management Plan (MDBA, 2012a).

Ecological Objectives relative to specific flow bands							In-river flow band (ML/day)	Attributes inundated	Frequency	Days in 100 years inundation required	Area of floodplain inundated (ha)
					High value wetlands (incorporates frogs, fish and water birds)		1,000 - 5,000	Permanent Creeks and Wetlands	100 in 100 years	100%	472 ha permanently inundated
Maintain viable River Red Gum populations within 70% of River Red Gum woodland							5,000 - 40,000	River red gum forest, herbland	61 in 100 years (1 in 1-2 years)	15%	≤1,000
	Maintain viable River Cooba populations within 50% of existing River Cooba and mixed Red Gum and River Cooba woodland areas.	Improve the abundance and diversity of flood dependent understory vegetation	Maintain viable lignum populations in 40% of existing areas.	Improve the abundance and diversity of grass and herblands			40,000 - 50,000	River red gum forest, ti tree, herbland, lignum, cooba	53 in 100 years (1 in 2 years)	13%	≤1,800
						Maintain viable Black Box populations within 45% of Black Box woodland	50,000 - 60,000	River red gum woodland, black box, cooba, ti tree, grassland, lignum, chenopod, herbland	45 in 100 years (1 in 2-3 years)	11%	≤4,400
							60,000 - 70,000	River red gum woodland, black box, cooba, grassland, lignum, chenopod, herbland	32 in 100 years (1 in 3 years)	8%	≤5,700
							70,000 - 80,000	Black box, lignum, chenopod, samphire, herbland	28 in 100 years (1 in 4 years)	7%	≤9,400
							80,000 - 90,000	Black box	24 in 100 years (1 in 4-6 years)	6%	≤13,500
							90,000 - 140,000	Black box	12 in 100 years (1 in 8 years)	3%	>13,500

5. Ecological principles for operation of the Chowilla Regulator and ancillary structures

Conceptual models of the expected responses to managed inundation of the Chowilla Floodplain utilising the Chowilla Regulator and the ancillary structures are presented in the Monitoring Strategy for Chowilla Creek Regulator and ancillary structures (MDBA, 2014b). The conceptual models presented in that document highlight the complexity of the key processes required in order to achieve the desired outcomes at the higher trophic levels. It is critical to note that management for one objective will directly or indirectly affect the ability to achieve other objectives. Hence, achieving successful managed inundations will not be as simple as "just add water". Therefore, a set of ten Ecological Principles have been established to guide management actions. These are:

1. Managed inundations are not a substitute for natural floods
2. The scale of management actions will be adaptively managed so as to maintain conditions within the Basin Plan and other statutory water quality targets
3. Management will strive for a balance between maximising benefit and minimising the likelihood of identified hazards causing harm
4. Flow regime, history and components of pulses will be used in planning management actions
5. Management actions will be synchronised to river hydrology
6. Maintaining water exchange is a key priority
7. The source of water used in management actions will be taken into account
8. Outcomes from multi-site watering will be taken into account
9. Operating regimes will be flexible and responsive to emerging conditions
10. Management shall strive for a resilient, sustainable ecosystem

Detail on each of the Ecological Principles is presented in the following sub-sections. Recognising the capacity for flexibility in operations, and that no event will unfold exactly as described in the Event Plans due to the complexities of environmental watering and the range of factors both within and outside of the boundaries of the Icon Site, a set of Critical Operational Limits that encapsulate these principles were identified to develop the Event Plans (Event Plans are presented in sections 6-9 of the *Event Plans and Hazard Mitigation Strategy* document). These Critical Operational Limits are

1. Maintain flows >0.18 ms^{-1} in 75% of core fish habitat at all times
2. Maintain minimum daily water exchange ≥20%
3. Limit the maximum rate of rise† (averaged over 3 consecutive days) to 0.1 $mday^{-1}$
4. Limit the maximum rate of drawdown (averaged over 3 consecutive days) to ≤0.1 $mday^{-1}$ whilst surface water levels are out of channel and to ≤0.05 $mday^{-1}$ when surface water levels are within channel
5. Maintain minimum flow of 1,000 $MLday^{-1}$ over Lock 6

5.1 Managed inundations are not a substitute for natural floods

Large scale releases from storages to enhance or maintain periods of unregulated flow may be used to support or achieve the Basin Plan management outcomes for *wet* and *very wet* water resource availability allocations (see MDBA, 2012b for information on Resource Availability Scenarios). In the lower River Murray,

a large flow where the effects of in-stream structures have largely been nullified, either by direct removal of weirs or by water levels exceeding the crest height of structures is the closest approximation to a natural flood (Wallace et al., 2011). Conversely, management actions that rely on constructed infrastructure for desynchronised delivery of water to floodplains (inundation during periods of low river discharge) are consistent with the management outcomes for Basin Plan management outcomes for *dry* and *moderate* resource availability scenarios. However, it is critical to note that the use of constructed infrastructure cannot replicate all the functions that occur when a river is flooding. Hence sole reliance on site specific management actions will lead to a failure to achieve many of the management objectives for the floodplain and the wider region.

5.2 The scale of management actions will be adaptively managed so as to maintain conditions within the Basin Plan and other statutory water quality targets

Chapter 9 of the Basin Plan (Commonwealth of Australia, 2012) establishes the Water Quality and Salinity Management Plan (WQSMP) for the water resources of the Murray-Darling Basin. As part of the implementation of the WQSMP all river operators and holders of environmental water are required to have regard to 'Targets for managing water flows' (section 9.14 of the Basin Plan) when making decisions relating to flow management and the use of environmental water]. The targets relevant to management actions at the Chowilla Floodplain Icon Site are:

1. To maintain dissolved oxygen at a target value of at least 50% saturation (section 9.14(5a) of the Basin Plan)
2. The water quality targets for water used for recreational purposes are that the values for cyanobacteria cell counts or biovolume meet the guideline values set out in Chapter 6 of the Guidelines for Managing Risks in Recreational Water (NHMRC, 2008) (section 9.18 of the Basin Plan)
3. The levels of salinity should not exceed the following values 95% of the time (section 9.14(5c) of the Basin Plan):
    - River Murray at Lock 6 = 580 EC
    - River Murray at Morgan = 800 EC
    - River Murray at Murray Bridge = 830 EC
    - Lower Lakes at Milang = 1,000 EC

In the context of point 3, "time" is defined as the current water accounting period and the previous four water accounting periods, i.e. a rolling five year average (section 9.14 (6) (b)). Information on hazard mitigation is provided in the *Events Plans and Hazard Mitigation Strategy* document. Information on monitoring these targets is provided in the *Monitoring Strategy* document.

There are also obligations under the South Australian Environment Protection (Water Quality) Policy (2003) that must be taken into account. This includes targets and guidelines for parameters including nutrients, organic carbon, dissolved oxygen, salinity, turbidity and pH. Detail is provided in section 3.3 of the *Monitoring Strategy* document.

5.3 Management will strive for a balance between maximising benefit and minimising the likelihood of identified hazards causing harm

The most appropriate management action at any time will vary with a range of factors including but not limited to; antecedent conditions, availability of water, and condition of attributes and functions relative to the specified Ecological Objectives. Achieving a balance between maximising positive outcomes and avoiding negative outcomes is the central tenant by which all actions will be planned and managed. This must include a balanced view of both in-stream and floodplain functions and attributes in order to maintain the ecological character of the Icon Site. One of the key tools that will be used in this process is adaptive monitoring and management, whereby the scale of achieved benefits and the effectiveness of hazard mitigation approaches will be assessed during and following each management action in order to progressively refine and subsequently apply our understanding of the response of the ecosystem to management interventions.

While we currently lack sufficient ecological knowledge to accurately predict how the floodplain will respond to the use of constructed infrastructure to deliver environmental water allocations, it is evident that some responses will be very rapid. Other responses may not be revealed/detected until many events have occurred (cumulative impacts), or will only eventuate under some circumstances. Failure to observe an outcome during an event where it was predicted, does not eliminate it as a hazard or benefit of the management action.

5.4 Flow regime, history and components of pulses will be used in planning management actions

The terms 'flow' and 'flow regime' are used with varying definitions throughout the published literature. Puckridge et al., (1998) and Walker et al., (1995) reformulated parts of the Flood Pulse Concept (Junk et al., 1989) to make it more applicable to the Murray. The following definitions are adopted here:

- flow regime: a long-term, statistical generalization of the hydrograph
- flow history: the hydrological sequence before any point in time
- flow pulse: defined not in terms of a threshold (e.g. overbank flow or flood), but as a rise and fall in discharge (or stage) at scales of space and time appropriate to the observer's frame of reference

All three components are ecologically significant. For the purpose of event planning, flow history and the flow pulse are perhaps the most important. Antecedent conditions will have a substantial bearing on the prevailing condition of ecological attributes and functions. The characteristic of the flow pulse generated by the planned management action(s) will determine which Ecological Objectives benefit and hence which of the Ecological Targets will either (i) be met, or (ii) substantive progress towards the target will be achieved . Hence, variability in magnitude, frequency, timing, duration, and sequence must be provided to allow for different ecological processes to occur without biasing outcomes to groups advantaged by, or adapted to particular types of events.

5.5 Management actions will be synchronised to river hydrology

Minimising the disconnection between river hydrology and inundation of the floodplain is a priority. This implies selecting management actions that minimise the difference between flow to SA (QSA) and surface water elevation within the anabranch such that small-scale management actions are undertaken during periods of low flow, and large-scale management actions are undertaken during periods of high flow. This is anticipated to improve responses from processes that rely on outcomes from upstream flooding and/or biota that utilise behavioural adaptations to flow that rely on landscape scale cues. The timing, magnitude, duration and rate of fall characteristics of the managed hydrograph should, where practicable mimic the modelled natural hydrograph.

5.6 Maintaining water velocity and exchange is a key priority

Poor rates of water exchange generate a higher likelihood of very poor water quality and a decline in the quality of in-stream habitats that define the ecological character of the anabranch. Maintaining velocities >0.18 ms^{-1} in the core fish habitats (see Figure 5.1) and minimum daily water exchange ≥20% have been identified as key ecological principles and Critical Operational Limits that will be used to guide management actions. Maintaining the velocity target and the daily exchange target can be managed by regulating the following parameters in combination:

- the gradient between Lock 6 and the main control structures (Chowilla Regulator, Woolshed Creek and Chowilla Island Loop)
- the volume of water flowing into the impounded area (e.g. Pipeclay, Slaney, Boat, Swifty's Creeks)
- the volume of water flowing out of the impounded area *via* the main control structures
- the volume of water within the impounded area

A range of operating conditions (QSA, structure height and inflow: outflow configurations) that maintain the Critical Operational Limits have been modelled and the results are presented in section 4 of the *Event Plans and Hazard Mitigation Strategy* document. Validating (i) that the hydrodynamic model results are fit for purpose, and (ii) the assumptions underpinning the values defined in the Critical Operational Limits are valid need to be a priority during the first operations (see section 3.3 of the *Event Plans and Hazard Mitigation Strategy* document).

5.7 The source of water used in management actions will be taken into account

The catchment and/or storage from which water is being sourced is likely to influence ecological outcomes. Conditions within upstream storages can range from functioning as a sink or source of nutrients (and other resources such as zooplankton), with associated changes in speciation of chemicals leading to changes in phytoplankton community structure at downstream sites (Baldwin et al., 2010). This can lead to flow-on effects on primary productivity and food webs downstream (see Burford et al., 2011). Furthermore, the microfauna of water from the Darling and Murray Rivers are markedly different and the composition of microfauna varies between storages with short (e.g. Lake Mulwala) and long (e.g. Hume Dam) retention times (see Brookes et al., 2009). Water from the Darling River typically has higher nutrient loads than water from the upper Murray (Baker et al., 2000). Aldridge et al., (2012) demonstrated that during low flows,

inputs of nutrients can be higher from Lake Victoria than from flows delivered from the mid- and upper Murray.

Flood waters from the Darling River can reduce the euphotic depth in the lower River Murray to less than 0.2 m (Mackay et al., 1988) such that in-channel flows comprised of high turbidity water have the potential to limit the growth of aquatic plants (Brookes et al., 2009). It is of note that in the 1980s, water in the Lower Murray was made up by disproportionate contributions from the Darling, via Lake Victoria, and the water was highly turbid. When this management practice stopped, turbidity decreased and dramatic differences in distribution and diversity of littoral plants were observed between the two periods (Walker et al., 1994; Blanch et al., 1999; Blanch et al., 2000).

Water sourced from floods in the Darling River or catchments in the middle Murray is preferred to water that has been stored in Lake Victoria (Stuart & Mallen-Cooper, 2011). Re-regulating water sourced from high flows and upstream flooding via Lake Victoria is not desirable from an ecological perspective as the lake is likely to act as a sink for resources and propagules that may drive outcomes in the Lower River Murray (Mallen-Cooper et al., 2011). The magnitude of impacts is a knowledge gap that requires attention. The COG may request, where feasible, that the bulk of water delivered to the Icon Site to enable managed inundations is not routed via Lake Victoria.

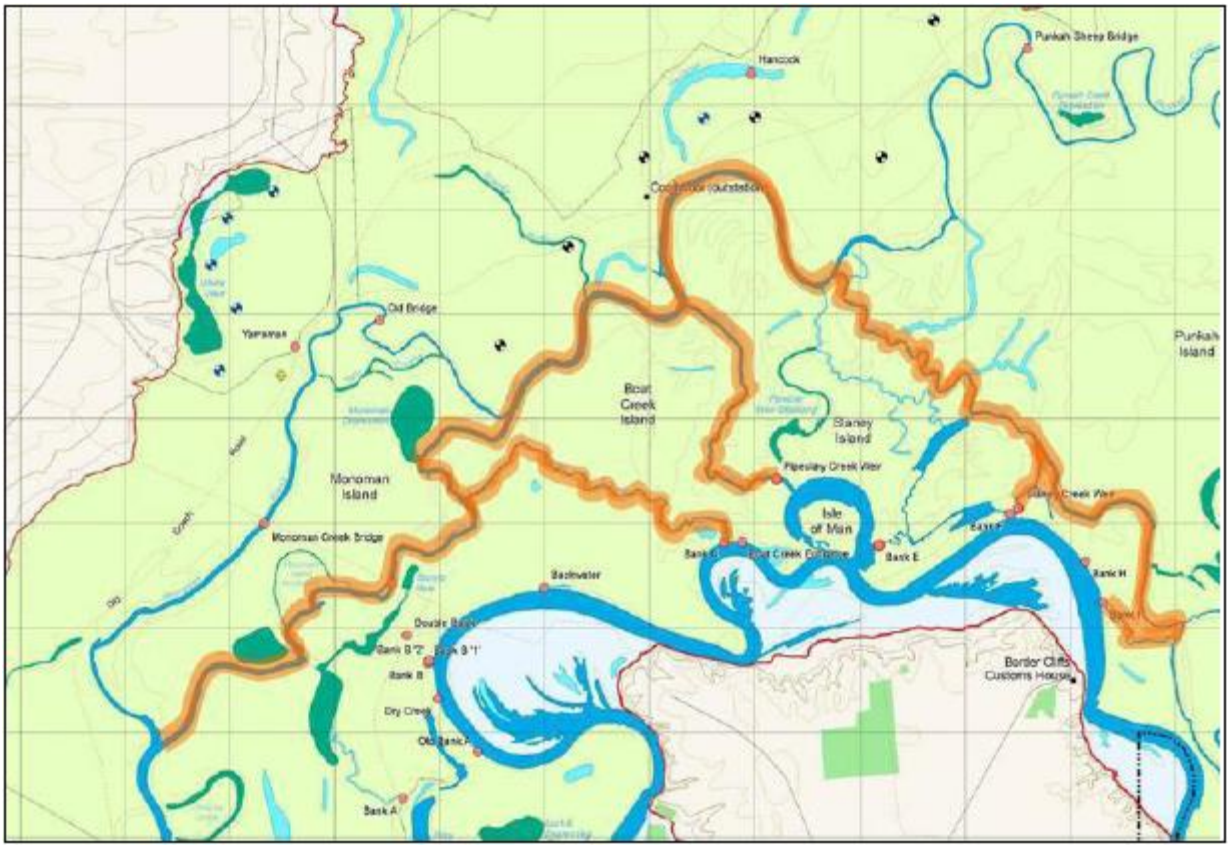

Figure 5.1. Map of Chowilla Anabranch with "core fish habitat" highlighted in orange. From Water Technology (2010).

5.8 Outcomes from multi-site watering will be taken into account

Water released from an upstream storage as an environmental water allocation and diverted into an individual site during periods of in-channel flow, may have restricted ecological outcomes as the productivity gains from upstream flooding are not available to be transported into the managed site. The "missing pieces" are likely to include food resources, plant and invertebrate propagules dispersed from upstream sites, increased carbon and nutrient concentrations and other chemical cues resulting from inundation of floodplain soils and plant material, eggs and larvae of fish and other organisms spawned at upstream sites.

At the landscape (Murray-Darling Basin) scale, synchronising management actions at the Icon Site to periods of high (unregulated) flow that generated bank full or extensive out of channel flows in upstream reaches is considered likely to deliver an increased scale of ecological benefit (see also section 5.5) and a reduced demand on the volume of environmental water required to enable management action(s) at Chowilla Floodplain.

At the reach scale (i.e. Murray-Darling Junction to Lower Lakes), synchronising management actions at the Icon Site to management actions occurring upstream (i.e. flow pulses out of the Darling River, return flows of environmental water from the Greater Darling Anabranch, return flows from environmental watering activities at Lindsay-Mulcra-Wallpolla Islands) or to management actions occurring downstream (i.e. delivery of water to enable water level management and/or barrage releases at the Coorong, Lower Lakes and Murray Mouth Icon Site), is likely to reduce demand on the volume of environmental water required to enable the management action(s).

The potential influence from environmental watering actions undertaken at an individual Icon Site on water quality or other ecological processes and attributes beyond the sub-reach (weir pool) scale is currently a major knowledge gap. It is considered likely that resources (carbon, nutrients) and propagules from upstream site scale actions will enhance the outcomes of management actions at downstream locations (see section 5.7). However, the longitudinal extent of the influence resulting from return flows following managed inundation of relatively small sections of floodplain in a river that may be resource (i.e. carbon and nutrient) limited is uncertain. Conversely, the impact of cumulative watering actions on water quality parameters such as dissolved oxygen and salinity must also be taken into account. For example, a managed inundation that utilises water that is already low in dissolved oxygen will incur a higher likelihood of triggering an hypoxic/anoxic blackwater event.
At the sub-reach (weir pool) scale, synchronising management actions such as opening/closing regulators at wetlands managed by DEWNR outside of the Icon Site may also benefit from synchronising management actions to periods of elevated flow where (i) the concentration of nutrients and propagules, or (ii) the variation in water level and inundation extent that can be achieved relative to normal pool level, may be increased.

5.9 Operating regimes will be flexible and responsive to emerging conditions

The Operations Plan must remain flexible and responsive to changing flow and environmental conditions, and be influenced by formal monitoring programs and incidental observations. Failure to detect, interpret and respond in an appropriate time frame to emerging conditions is likely to have two main outcomes:

1. ability to maximise outcomes will be compromised
2. the likelihood of incurring long-term or irreversible damage is increased

During the commissioning and early operations, uncertainty of how biota and biogeochemical processes will respond to the management action will be greatest. This will be the period where it is most important to validate (i) the hydrodynamic modelling that has been used to determine the structure height and inflow:outflow configurations required, and (ii) the conceptual models regarding how the river-floodplain-anabranch complex will respond. This knowledge will be essential to underpin Operations planning and where necessary to amend proposed range and timing of operations. Hence, it is during this period that monitoring requirements will be highest. Monitoring requirements are likely to decrease over time as understanding of how the ecosystem responds to different management actions increases. If monitoring resources are scarce, actions that may incur higher likelihood of hazards being triggered shall not be undertaken as the ability to detect and subsequently respond to those hazards is compromised.

5.10 Management shall strive for a resilient, sustainable ecosystem

The key foci of management actions must be to reinstate resilience and ensure the floodplain is a sustainable ecosystem. 'Resilience' (i) has multiple attributes, but incorporates latitude, resistance, and precariousness (Walker *et al*. 2004), and (ii) can be either created or destroyed (Colloff & Baldwin, 2010). A floodplain that is always either wetting or drying has a large degree of *latitude* (the system can change but retain the same character) and *resistance* (a large disturbance is required to change its character). Long drying of floodplains reduces *resistance* and places them in a *precarious* position (close to a threshold that could change its character). Very long drying may cause a catastrophic transition to an alternate state (Scheffer *et al*., 2001; Scheffer & Carpenter, 2003) such as a shift in dominant vegetation from forest/woodlands to salt tolerant perennial understory vegetation. Once such a shift occurs, simply restoring the flow regime is unlikely to induce a switch back to the pre-existing condition. Therefore management actions shall be targeted at maintaining condition of biota and abiotic processes within responsive ranges such that (i) the floodplain can withstand extended periods of climate derived droughts; (ii) there is a large positive response to the next unregulated flood; and (iii) long-term or irreversible damage is avoided.

6. Description of management actions available with the constructed infrastructure.

With the existing, new and upgraded structure types and their spatial configuration (Figure 1.2), there is a wide range of management actions available including:

1. no-action required at the site scale
2. delivery of water to individual wetlands (pumping and/or gravity)
3. weir pool manipulation
4. pulse flows *via* Pipeclay and Slaney weirs
5. in-channel rise (using the regulator)
6. managed inundations (using the regulator)
    a. low floodplain
    b. mid-flooplain
    c. maximum-floodplain
7. manage hydrograph recession (using the regulator)

A matrix table summarising the types of management actions that are available within different flow bands is presented in Table 6.1. A brief description of each of these options is presented in the following sub-sections. Detail, including example hydrographs for each management action is provided in the supporting document *Event Plans and Hazard Mitigation Strategy* document. The decision process for selecting, and shifting between operation types is presented in section 11 of that document.

Table 6.1. Matrix of management options that are available pending flow conditions. Cells shaded green and yellow denote that the hydrodynamic modelling predicts the operation allows for maintenance of the Critical Operational Limits. Cells shaded yellow denote that those operations may not provide sufficient contingency for (i) processes that occur outside of the anabranch, (ii) controlling identified hazards (e.g. hypoxic blackwater, harmful algal blooms) that may be triggered during management actions, or (iii) unanticipated outcomes. Unshaded cells indicate option is not available due to (i) Critical Operational Limits not being met or (ii) other river operations constraints. Cells shaded purple indicate predicted flow will/may exceed inundation extent that would be created by management action.

Flow (QSA)	Management options potentially available at given flow band									
4,000 - 5,500 MLday^{-1}	No action	Delivery of water to individual wetlands	Weir pool lowering	Weir pool raising	Pulse flows via Pipeclay and Slaney	in-channel rise	Low floodplain	Mid- floodplain	Max- floodplain	Manage hydrograph recession
7,000 MLday^{-1}	No action	Delivery of water to individual wetlands	Weir pool lowering	Weir pool raising	Pulse flows via Pipeclay and Slaney	in-channel rise	Low floodplain	Mid- floodplain	Max- floodplain	Manage hydrograph recession
8,000-9,000 MLday^{-1}	No action	Delivery of water to individual wetlands	Weir pool lowering	Weir pool raising	Pulse flows via Pipeclay and Slaney	in-channel rise	Low floodplain	Mid- floodplain	Max- floodplain	Manage hydrograph recession
10,000 MLday^{-1}	No action	Delivery of water to individual wetlands	Weir pool lowering	Weir pool raising	Pulse flows via Pipeclay and Slaney	in-channel rise	Low floodplain	Mid- floodplain	Max- floodplain	Manage hydrograph recession
15,000 MLday^{-1}	No action	Delivery of water to individual wetlands	Weir pool lowering	Weir pool raising	Pulse flows via Pipeclay and Slaney	in-channel rise	Low floodplain	Mid- floodplain	Max- floodplain	Manage hydrograph recession
20,000 MLday^{-1}	No action	Delivery of water to individual wetlands	Weir pool lowering	Weir pool raising	Pulse flows via Pipeclay and Slaney	in-channel rise	Low floodplain	Mid- floodplain	Max- floodplain	Manage hydrograph recession
30,000 MLday^{-1}	No action	Delivery of water to individual wetlands	Weir pool lowering	Weir pool raising	Pulse flows via Pipeclay and Slaney	in-channel rise	Low floodplain	Mid- floodplain	Max- floodplain	Manage hydrograph recession
40,000 MLday^{-1}	No action	Delivery of water to individual wetlands	Weir pool lowering	Weir pool raising	Pulse flows via Pipeclay and Slaney	in-channel rise	Low floodplain	Mid- floodplain	Max- floodplain	Manage hydrograph recession
50,000 MLday^{-1}	No action	Delivery of water to individual wetlands	Weir pool lowering	Weir pool raising	Pulse flows via Pipeclay and Slaney	in-channel rise	Low floodplain	Mid- floodplain	Max- floodplain	Manage hydrograph recession
Flood operations >50,000 MLday^{-1}	No action	Delivery of water to individual wetlands	Weir pool lowering	Weir pool raising	Pulse flows via Pipeclay and Slaney	in-channel rise	Low floodplain	Mid- floodplain	Max- floodplain	Manage hydrograph recession

6.1. No-action required at the site scale

It is important to recognise that a decision not to take any action at the Icon Site is a legitimate choice. Conditions under which this decision may be made include:

- ecological targets are met
- if trajectory relative to the Ecological Targets is strong/stable
- a management action would incur a high likelihood of negative processes

6.2. Delivery of water to individual wetlands (pumping and/or gravity)

6.2.1. Gravity based delivery of water into discrete sites

For sites with a commence-to-flow level at or below the normal weir pool height, the opening of regulators can be used to deliver environmental water. In some cases, very small increases in channel water level associated with flow spikes or weir pool raising may greatly increase the spatial area that can be inundated via this method (Wallace et al., 2011).

6.2.2. Pumping water to wetlands

For wetlands and sections of floodplain that are above the normal operating height of Locks 5 and 6, where it is not possible to deliver water via gravity, water can be delivered using pumps. A key advantage of this approach is that relatively small volumes of water can be utilised to inundate targeted sections of the floodplain during low flow periods when inundation would otherwise not be possible due to low water availability (Wallace et al., 2011). Pumping water into individual wetlands has been highly successful in achieving a limited set of objectives. However, there are a number of critical limitations that must be taken into account; (i) pumping can be costly and the distance water can be efficiently pumped is limited; (ii) very few ecological requirements that depend on connectivity will be met from pumping; (ii) delivering water to wetlands via pumps and then drying them through evaporation provides extremely low connectivity to the river and provides no short-term benefit to the river channel (iv) repeated ponding and evaporation of water has the potential to accumulate salt in the upper soil profile (Wallace et al., 2011).

6.3. Weir pool manipulation

The Riverine Recovery Project (RRP) in SA includes work to support the implementation of weir pool manipulation to raise and lower water levels along the River Murray channel to achieve ecological benefits by generating in-channel water level variability; and enhanced near floodplain inundation and enhance flowing habitat through the Chowilla creek system.

Manipulating water levels by raising or lowering the weir heights to reinstate water level variability may lead to:

- ecological improvement in river health (Cheshire and Ye 2008)
- increased exchange between near bank groundwater and surface water in order to lower the near bank groundwater salinity and/or create freshwater lens and thereby improve soil moisture availability for riparian vegetation.

- benefits for many plant species, promoting diversity by restoring a wider range of water regimes (see Bunn & Arthington, 2002)
- positive outcomes for understorey vegetation (Siebentritt et al., 2004) and riparian trees (Souter et al., 2013).

Specific goals of weir pool manipulation as a management action are outlined in the SA Murray Weir Manipulation Strategy (Cooling et al., 2010). The influence of weirs and weir pool manipulation as a management strategy on riverine hydrology is discussed in Wallace et al., (2014).

The raising of the Lock 6 weir pool presents a management option to generate benefits for the Chowilla floodplain both independently or in association with pulsing flows via Pipeclay and Slaney weirs. Raising of Lock 6 is an important action to be undertaken in conjunction with operation of the Chowilla regulator to generate floodplain inundation (see 6.6 to 6.7 below). With raising Lock 6, concurrent raising of Lock 7 may be required in order to maintain the velocity matrix in the Mullaroo Creek and Lindsay River upstream in Victoria. This is discussed in detail in *Monitoring Strategy* document (sections 5.3 and 5.4). Raising of Lock 5 may be required to generate the minimum depth required in the vertical slot fishway on the Chowilla Regulator (see section 2.2 in the *Event Plans and Hazard Mitigation Strategy* document).

Weir pool raisings conducted at low (i.e. entitlement) flows will result in a proliferation of slow flowing habitats in the weir pool. Consequently, operations that require large increases in the height of Lock 6 to maximise inundation extent and maintain hydraulic complexity within the anabranch needs to take into account prevailing and forecast flow to minimise impacts on the river channel.

6.4. Pulse flow via Pipeclay and Slaney Weir

The upgraded weirs on Pipeclay and Slaney Creeks will allow for increased flexibility in operations including ability to manipulate inflows and increase the diversity of the velocity matrix and hence the available flow habitats via (i) seasonal manipulation inflow and (ii) reinstating a relationship between inflows and flow in the river (QSA). The focus of management will shift between periods of low, moderate and high flow. Detail on this management action is provided in section 5 of the *Event Plans and Hazard Mitigation* document

6.5. In-channel rise

"In-channel rise" describes conditions where Chowilla Regulator is raised to a minimum of 17.25 mAHD (0.85 m rise) and a maximum of 18.0 mAHD (1.6 m rise). For this management action, Lock 6 does not need to be manipulated. The primary operational objective is, during periods of low water availability, to provide a rise in surface water levels at the Chowilla Regulator equivalent to that which would be generated at QSA = 35,000 (±5,000) $MLday^{-1}$ (see Figure 6.1). This action is most applicable during periods of QSA ≤10,000 $MLday^{-1}$. Detail on this management action is provided in section 6 of the *Event Plans and Hazard Mitigation* document.

6.6. Low floodplain inundation

"Low floodplain inundation" describes conditions where Lock 6 has been raised above standard operating height, and Chowilla Regulator is raised to a minimum of 18.0 mAHD (1.6 m rise) and a maximum of 18.75 mAHD (2.35 m rise). The primary operational objective is during periods of low water availability, to provide

a rise in surface water levels at the Chowilla Regulator equivalent to that which would be generated at QSA ca. = 50,000 (±5,000) MLday^{-1} (see Figure 6.1). This action is most applicable during periods of QSA ca. 10,000 MLday^{-1}. Detail on this management action is provided in section 7 of the *Event Plans and Hazard Mitigation* document.

6.7. Mid-floodplain inundation

"Mid- floodplain inundation" describes conditions where Lock 6 has been raised above standard operating height, and Chowilla Regulator is raised to a minimum of 18.75 mAHD (2.35 m rise) and a maximum of 19.4 mAHD (3.0 m rise). The primary operational objective is during periods of moderate water availability, to provide a rise in surface water levels at the Chowilla Regulator equivalent to that which would be generated at QSA ca. = 75,000 (±5,000) MLday^{-1} (see Figure 6.1). This action is most applicable during periods of QSA ca. 15,000-25,000 MLday^{-1}. Detail on this management action is provided in section 8 of the *Event Plans and Hazard Mitigation* document.

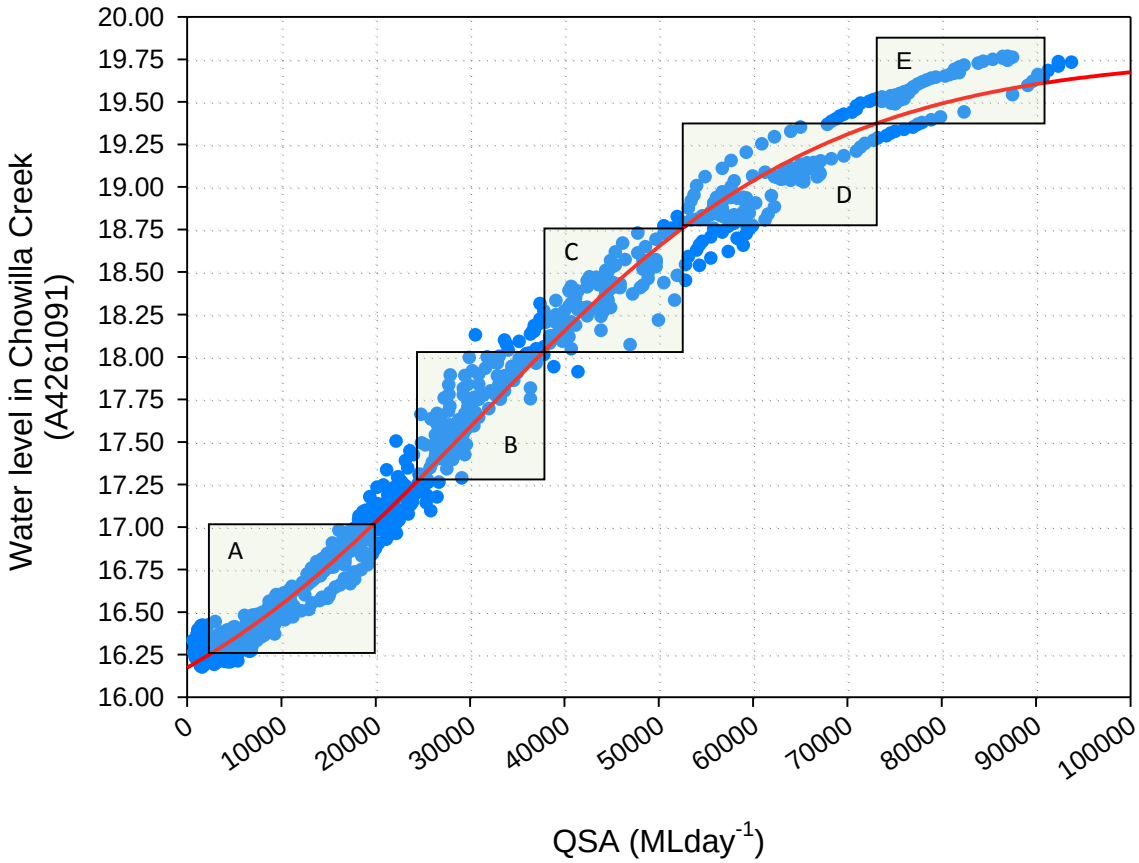

Figure 6.1. Water levels recorded in Chowilla Creek downstream of Monoman Creek (Station A4261091) relative to QSA (Station A4261001) during the period 1st June 2006 - 19th February 2013**.** Red regression line is for a 3-parameter sigmoidal curve for flows in the range 767-93,872 MLday^{-1} f= 15.474+4.303/(1+exp(-(x-30649.2)/18700.4)), P = <0.0001, r^2 = 0.99148). Shaded boxes represent surface water levels at Chowilla Regulator that can be targeted by the range of management actions [A] = weir pool manipulations and pulse flows, [B] in-channel rise, [C] low floodplain inundation, [D] mid-floodplain inundation, [E] max-floodplain inundation.

6.8. Maximum-floodplain inundation

"Max- floodplain inundation" describes conditions where Lock 6 has been raised above standard operating height, and Chowilla Regulator is raised to a minimum of 19.4 mAHD (3.0 m rise) and a maximum of 19.8 mAHD (3.4 m rise). The primary operational objective is during periods of moderate water availability, provide a rise in surface water levels at the Chowilla Regulator equivalent to that which would be generated at QSA ca. = 90,000 (±5,000) MLday^{-1} (see Figure 6.1). This action is most applicable during periods of QSA ca. 30,000-50,000 MLday^{-1}. Detail is provided in section 9 of the *Event Plans and Hazard Mitigation* document.

6.9. Managed recession

At flows greater than 50,000 MLday^{-1} river operations are in "flood" operations mode. Under these conditions, the structures may need to be deactivated (i.e. stop logs removed) to avoid damage to the structures. Under these conditions, managing the recession of the hydrograph may be possible, pending access to the structures. The limit at which flows will have inundated access tracks and precluded ability to access structures in order to manage recession is deemed to be approximately 60,000 MLday^{-1}.

The Chowilla Regulator, the ancillary structures including structures on individual wetlands, may be used to extend the period of inundation resulting from unmanaged floods. The primary use of this management action is to ensure flood duration is sufficient for achieving ecological outcomes. A key example is ensuring that the breeding cycle of waterbirds is not disrupted by short, or fast recession floods. Catching the recession of a flood may provide a mechanism to minimise the likelihood of a hypoxic blackwater event during managed inundations, as the release of carbon and nutrients and the associated stimulation of heterotrophic activity will have already occurred in those areas that have already been inundated.

6.10 Expected occurrence of flows

The expected occurrence of flows of different magnitude that correspond to the range of management actions under 3 contrasting water availability scenarios (Pre TLM Water and Works, with TLM Water and Works, and Basin Plan with 2,800 GL) are presented in Tables 6.3 - 6.5 respectively. The data indicates that under the 'with TLM Water and Works' scenario (Table 6.3) flows of 30,000 MLday^{-1} persisting for >60 days could be expected to occur 47 times in 114 years. Under the 'with Basin Plan 2800' scenario (Table 6.4), this increases to in 67 times in 114.

Table 6.2. The expected occurrence (number of times flow metric is met within 114 years) of flows of different magnitude that correspond to the range of management actions under "Pre TLM Water and Works" conditions (MSM-Bigmod Run 5893000). Assumes minimum 7 days between events.

Duration (days)	**QSA (MLday^{-1})**				
	≥10,000	≥20,000	≥30,000	≥40,000	≥50,000
≥30	109	74	59	44	34
≥60	80	52	46	31	22
≥90	62	47	34	24	12
≥120	51	36	25	14	5

Table 6.3. The expected occurrence (number of times flow metric is met within 114 years) of flows of different magnitude that correspond to the range of management actions under "With TLM Water and Works (MSM-Bigmod Run 5894000)" conditions. Assumes minimum 7 days between events.

Duration (days)	QSA ($MLday^{-1}$)				
	≥10,000	≥20,000	≥30,000	≥40,000	≥50,000
≥30	136	77	56	48	35
≥60	77	54	47	31	22
≥90	61	48	38	25	17
≥120	51	37	27	16	7

Table 6.4. The expected occurrence (number of times flow metric is met within 114 years) of flows of different magnitude that correspond to the range of management actions under "Basin Plan 2800 (MSM-Bigmod Run 5895000)" conditions. Assumes minimum 7 days between events.

Duration (days)	QSA ($MLday^{-1}$)				
	≥10,000	≥20,000	≥30,000	≥40,000	≥50,000
≥30	125	103	83	61	50
≥60	100	89	67	48	36
≥90	93	76	52	35	25
≥120	86	59	39	26	14

7. Environmental water planning process

7.1. Annual watering proposal process

The following steps are to be used in the pre-event planning process for the development and submission of watering proposals. The process is summarised in Figure 7.1.

1. **Review antecedent flow conditions**

Environmental Water Requirements (EWR's) for the site are presented in section 4. The flow history from recent years should be compared to the EWR's to determine what types of flow events have not occurred, and hence what types of management action(s) may be appropriate for the coming year. However, in addition to the EWR's, the condition of the various ecological attributes and processes must be taken into account when determining if management action is required, rather than a "tick-a-box" exercise of having met, or not having met the respective EWR's. Within this, it is critical to note that condition of the Icon Site relative to the ecological targets carries a higher weighting in the decision process.

2. **Review of prevailing condition of the Icon Site relative to the ecological targets**

The data from the Condition Monitoring program represents the core data to be used in this process. However, relevant data from Intervention Monitoring programs may also be included to inform the decision process. When considering position relative to the Ecological Targets (Table 3.3) at any given time, it is essential to note that attaining stable conditions is counterproductive, and that recording condition scores that do not meet the Ecological Target in any given year is not an indication of failure (see section 3.2 of this document). Thresholds for management action at the icon Site relative to selected Ecological Targets are presented in Table 7.1.

Thresholds for management action for highly mobile fauna, particularly waterbirds have not been provided, as animals from these guilds may be responding to processes at the global, national, or landscape (Murray-Darling Basin) scale rather than the regional (reach) or local (sub-reach) scale. Furthermore, waterbirds require habitat to occur within wetlands to achieve any targets that would be set for them. Hence for these guilds, the focus is on providing the water to generate and maintain the supporting habitat, rather than providing water for specific species that might utilise the habitat once it is generated.

It is reasonable to anticipate that there will be occasions when the thresholds for management action (Table 7.1) will not be met, indicating that management action may not be required (see Figure 7.1). However, a precautionary approach would suggest that undertaking management actions when water is available, and building resilience such that the system can withstand dry periods when water availability is low should be considered. This is consistent with shifting the emphasis from damage avoidance to improving resilience (see sub-section 7.1.4) as water availability improves and highlights the Ecological Principle that Management shall strive for a resilient, sustainable ecosystem (see section 5.10).

3. **Climate and storage conditions**

The prevailing resource availability conditions and climate (predicted rainfall) will influence the amount of environmental water that may be available to undertake management actions, and hence will constrain the operations that can be implemented in any year. Therefore, the watering proposal submitted will present a range of possible actions. The action that would be implemented will depend on actual flow conditions, water availability (e.g. extreme dry, dry, moderate, wet) and environmental conditions.

The Living Murray uses a scenario planning framework to preview the potential watering activities which may occur during the year, considering water availability and icon site water requirements. This scenario planning provides a level of adaptability to changing conditions and provides a transparent process for allocating environmental water. The framework defines objectives for five different climatic scenarios: extreme dry, dry, median and wet/very wet (Table 7.2), providing guidance on how TLM water is likely to be managed under different climatic conditions (MDBA, 2013).

4. **Identify the range of operations that would be implemented pending flow conditions and water availability**

The most appropriate action at any given time, will vary accordingly with a range of factors including but not limited to (i) condition of the Icon Site relative to the ecological targets (iii) projected water availability and (iii) multi-site watering demand/opportunities. At the Icon Site, as water resource availability increases, the emphasis will shift from damage avoidance $\rightarrow$ capacity for recovery $\rightarrow$ maintaining health and resilience $\rightarrow$ improving health and resilience. Conditions under which options that incur a higher likelihood of potential negative outcomes might be selected are outlined in Section 7.2.

5. **Develop and submit environmental water proposal**

Proposals for environmental water based on a range of potential water resource availability scenarios and presenting the range of associated desirable operations will be made leading into the water year and will be incorporated into the SA Annual Environmental Watering Plan. A framework for The Living Murray planning and implementation process is presented in MDBA (2013). It is reasonable to anticipate that in most circumstances, there will be a requirement for the MDBA to prioritise between watering actions and sites. The ranking criteria used by the MDBA to prioritise environmental watering actions based on environmental benefit is presented in Table 7.3. Additional detail is provided in MDBA (2013). If the proposal is a high priority, proceed to the "Pre-event" planning process (Section 7.3). The environmental water proposal and other relevant information will also be provided to the CEWH to inform the development of their water use planning including consideration of provision of CEWH water in support of Chowilla operations.

Table 7.1. Thresholds for management action at the icon Site utilising condition relative to the stated Ecological Targets.

Ecological Target	Thresholds for Management Action	Justification
In standardised transects that span the floodplain elevation gradient and existing spatial distribution, >70% of trees will have a Tree Condition Index Score (TCI) ≥10 by 2020	Within the area that can be influenced by management action(s), more than 10% of established viable† river red gums with DBH > 10 cm receive TCI scores in the poor condition (5-6) category or below	A TCI score of 10 or above represents a tree in "good" condition. TCI scores between 5 and 6, and between 7 and 9 are considered to represent trees in "poor" and "moderate" condition respectively. In comparison, a TCI score of 4 or below are considered to have a "sparse" crown and be in "very poor" condition. Trees with TCI scores ≥ 7are expected to respond positively to watering and increase to the next condition class. The strength of the response decreases as TCI scores decrease.
	Within the area that can be influenced by management action(s), more than 10% of established viable† black box trees with DBH > 10 cm receive TCI scores in the poor condition (5-6) category or below	
A sustainable demographic that matches the modelled profile for a viable population is established within existing communities across the floodplain elevation gradient by 2020	Within the area that can be influenced by management action(s), the population demographic for river red gum and/or black box does not match the modelled profile	Assessments of population demographics within Chowilla and at other regionally relevant areas demonstrate that there is insufficient recruitment to sustain the existing forest and woodland communities
	Within the area that can be influenced by management action(s), the average number of viable young trees (>3 m high but < 10 cm DBH) and or saplings (0.25 – 3 m high) in the standardised quadrats is <10	Per the Standardised Tree Condition Method: • < 10 seedling/saplings = scarce • 10-50 seedlings/saplings per quadrat = common • > 50 seedlings/saplings = abundant
	Within the area that can be influenced by management action(s), the average abundance score for seedlings (< 0.25 m high) in standardised transects is > 50	Regeneration is greatly enhanced by follow-up flooding and/or above average rain fall
In standardised transects that span the floodplain elevation gradient and existing spatial distribution, ≥70% of lignum plants will have a Lignum Condition Score (LCI) ≥6 for colour by 202	Within the area that can be influenced by management action(s), more than 10% of established viable$^{\delta}$ plants receive LCI scores ≤2	An LCI score = 2 for colour by 2020 is equivalent to ≥75% of crown is yellow-brown or not viable
Flood-dependent/responsive plant species are recorded in 70% of quadrats spanning the floodplain elevation gradient at least once every 3 years	Within the area that can be influenced by management action(s), the target has not been met in the preceding 5-year period	Seed banks are relatively long lived. Therefore, failure to meet the target does not automatically imply seed-banks will be approaching a tipping point. However, understory vegetation plays an important habitat role and resources for a range of species and contributes to maintaining soil condition and structure.
Native macrophytes are recorded in 70% of quadrats spanning the elevation gradient within each of the recognised permanent and ephemeral wetlands at least once every 3 years	Within the area that can be influenced by management action(s), the target has not been met in the preceding 5-year period	Seed banks are relatively long lived. Therefore, failure to meet the target does not automatically imply seed-banks will be approaching a tipping point. However, understory vegetation plays an important habitat role and resources for a range of species and contributes to maintaining soil condition and structure.
Maintain dissolved oxygen above 50% saturation* (4 mg/L) throughout water column at all times	Within the area that can be influenced by management action(s), the red gum forest areas that generate high organic loading have not been inundated in the last 3 years	The likelihood of generating a hypoxic blackwater event is directly related to carbon loading and temperature. Carbon load increases with every non-flood year,. with the magnitude of risk considered to increase markedly after 4 non-flood years

Table 7.1. (continued) Thresholds for management action at the icon Site utilising condition relative to the stated Ecological Targets.

Ecological Target	Thresholds for Management Action	Justification
Establish and maintain freshwater lenses in order to improve condition of overlying vegetation communities by 2020	Data from piezometers indicates that freshwater lenses generated in preceding inundations have been exhausted during the dry phase such that without action the salinity of groundwater underlying areas of established trees will exceed the identified salinity tolerances of the tree species in those areas; river red gum = 30,000 μScm^{-1} black box = 55,000 μScm^{-1}	Freshwater lenses improve/maintain soil moisture availability in the unsaturated zone for floodplain vegetation. Vertical recharge occurs through direct infiltration of floodwater, and horizontal recharge occurs in wetlands, backwaters, the river and its anabranches and tributaries when the surface water level exceeds the head at the groundwater interface
Reduce soil salinity (EC 1:5) to below 5,000 μScm^{-1} to prevent shifts in understorey plant communities to salt tolerant functional groups	Median soil salinity (EC 1:5) within any soil monitoring site exceeds 5,000 μScm^{-1}	Preliminary data (2012) from Chowilla indicate that median values for soil EC1:5 were 1,965 μScm^{-1} (range = 129 to 5325) at Kulkurna (Figure 8A) and 1,177 μScm^{-1} (range = 137-4774) at Werta Wert.
Each of eight riparian frog species known to occur at Chowilla will be recorded at ≥ 3 sites in any three year period	Target has not been met in the preceding 5-year period	Existing amphibian populations can be negatively impacted by circumstances which reduce the magnitude, timing and duration of inundation of floodplain wetlands and hence reduce the available breeding habitat in a given year. Providing breeding opportunities is critical to maintaining population in the long term.

Table. 7.2. Proposed ecological watering objectives under different climatic conditions. From MDBA (2013).

Condition	Extreme dry	Dry	Median	Wet/very wet
Overarching objective	Avoid catastrophic loss/maintain capacity for potential recovery	Improved capacity for recovery	Protect ecological health	Improved health and resilience
Ecological Watering Objectives	Avoid irretrievable loss of key environmental assets	Ensure priority river reaches and wetlands have maintained their basic functions	Ecological health of priority river reaches and wetlands have been protected or improved	Improve the health and resilience of aquatic ecosystems
Management Objectives	Avoid critical loss of species, communities and ecosystems	Maintain river functioning with reduced reproductive capacity	Enable growth, reproduction and small-scale recruitment for a diverse range of flora and fauna	Enable growth, reproduction and large-scale recruitment for a diverse range of flora and fauna
	Maintain key refuges	Maintain key functions of high priority wetlands	Promote low-lying floodplain-river connectivity	Promote higher floodplain-river connectivity
	Avoid irretrievable damage or catastrophic events	Manage within dry-spell tolerances	Support median flow and floodplain functional processes	Support high flow river and floodplain functional process
		Support connectivity between sites		
Management Actions	Water refugia and sites supporting species and communities	Water refugia and sites supporting threatened species and communities	Prolong flood/high-flow duration at key sites and reaches of priority assets	Increase flood/high-flow duration and extent across priority assets
	Undertake emergency watering at specific sites of priority assets	Provide low flow and freshes in sites and reaches of priority assets	Contribute to the full-range of in-channel flows	Contribute to the full range of flows incl. over-bank
	Use carryover volumes to maintain critical needs	Use carryover volumes to maintain critical needs	Provide carry over to accrue water for large watering events	Use carryover to provide optimal seasonal flow patterns in subsequent years

Table 7.3. Ranking criteria for TLM watering actions. Additional detail on how scores are applied to each criteria are presented in MDBA (2013).

Ranking Criterion	Description
Amount of benefit for the volume of water	An assessment of the predicted contribution to key site values and /or icon site management objectives; the area of target community of icon site watered; the scale of outcomes (system, icon site or localised); and the time period over which the outcomes of the watering can be sustained.
Risk of not applying water	An assessment of ecological risks of not watering. This includes the previous history, desired watering frequency, resilience period and protection of previous investment.
Certainty/likelihood of benefit	An assessment of the certainty of getting the predicted outcomes; including the extent of evidence in terms of scientific underpinning into the development of conceptual models and the previous success of the watering at the site.
Environmental risks associated with watering	An assessment of any risks associated with the delivery of water and the confidence in the associated mitigation strategies.
Cost	An estimate of the overall costs of delivering the watering action (per ML) including delivery, pumping and associated infrastructure costs

7.2. Conditions under which options that incur a higher likelihood of negative outcomes might be selected

7.2.1. Decision criteria

It is important to note that failure to meet Environmental Water Requirements (Table 4.1) is not justification for implementing an action that incurs a higher likelihood of negative outcomes. Operations should take advantage of higher flows during median and wet/very wet climatic conditions to build resilience and therefore limit the frequency of management actions undertaken during sub-optimal flow conditions. However, on occasion, there may be circumstances where such management actions may be considered for implementation. Under such circumstances, the Objectives and Actions would be aligned with the Extreme dry scenario in which the Watering Objective is to "Avoid irretrievable loss of key environmental assets" (see Table 7.2). The following three criteria must be addressed if implementing an action that may incur a higher likelihood of negative outcomes is being considered.

Criteria 1. Condition of attributes

Such an action could be considered where Condition Monitoring data indicates that the condition of selected attributes is substantially below and trending away from the relevant ecological targets. Thresholds for management action under these circumstances are presented in Table 7.4. Condition relative to the ecological targets for water birds and frogs are not included as justification for implementing a management action that incurs a higher likelihood of negative outcomes, as it is considered that small scale benefits can be attained by pumping water to refuge sites (key wetlands). In addition, condition relative to the ecological targets for native fish are not included, as they are one of the guilds that is most likely to be disadvantaged by management actions that incur a higher likelihood of negative outcomes.

Table 7.4. Thresholds for determining if selecting a management action that may incur high likelihood of negative outcomes is justified.

Ecological Target	Thresholds for Management Action that may incur high likelihood of negative outcomes	Justification
In standardised transects that span the floodplain elevation gradient and existing spatial distribution, >70% of trees will have a Tree Condition Index Score (TCI) ≥10 by 2020	Within the area that can be influenced by management action(s), more than 10% of established viable† river red gums with DBH > 10 cm have TCI scores ≤4	A TCI score of 4 = crown extent and density ca. 11-20%. Data from environmental watering at Chowilla indicates that ~92% of trees with <50% crown will respond to the application of environmental water. Once the crown is depleted to <10%, only ~68% of trees will respond. Hence actions should be implemented prior to high likelihood of loss of mature trees. Due to the wide spread die-back experienced during the Millennium drought, further losses are not considered acceptable. Trees with minimal TCI scores will have a slow response and need multiple, back-to-back watering to stabilise condition and rebuild resilience. Persistence of woodland/forest areas as a functioning habitat requires trees to be in good to moderate condition
	Within the area that can be influenced by management action(s), more than 10% of established viable† black box with DBH > 10 cm have TCI scores ≤4	
A sustainable demographic that matches the modelled profile for a viable population is established within existing communities across the floodplain elevation gradient	Within the area that can be influenced by management action(s), the median condition of young trees (>3 m high but < 10 cm DBH) is very poor (TCI ≤4)	Assessments of population demographics within Chowilla and at other regionally relevant areas demonstrate that there is insufficient recruitment to sustain the existing forest and woodland communities. Due to the wide spread die-back experienced during the drought, ensuring young trees survive and recruit into the population should be a priority.
In standardised transects that span the floodplain elevation gradient and existing spatial distribution, ≥70% of lignum plants will have a Lignum Condition Score (LCI) ≥6 for colour by 202	Within the area that can be influenced by management action(s), the more than 25% of established viable$^{\delta}$ plants receive LCI scores ≤1	An LCI score = 1 for colour by 2020 is equivalent to ≥95% of crown is yellow-brown. Rootstock is presumed to be viable. Plant will recover to moderate scores if watered. However, response may be from new growth rather than improvement in condition of above ground biomass. Hence habitat values is compromised. If not watered, likelihood of recovery decreases.
Flood-dependent/responsive plant species are recorded in 70% of quadrats spanning the floodplain elevation gradient at least once every 3 years	Within the area that can be influenced by management action(s), the target has not been met in the preceding 7-year period	Brock (2011) demonstrated that viable seed for more than 70 % of the species originally present in wetland soil cores survived drought conditions for longer than 5 years . Therefore, failure to meet the target does not automatically imply seed-banks will be approaching a tipping point. However, understory vegetation plays an important habitat role and resources for a range of species and contributes to maintaining soil condition and structure.
Native macrophytes are recorded in 70% of quadrats spanning the elevation gradient within each of the recognised permanent and ephemeral wetlands at least once every 3 years	Within the area that can be influenced by management action(s), the target has not been met in the preceding 7-year period	Brock (2011) demonstrated that viable seed for more than 70 % of the species originally present in wetland soil cores survived drought conditions for longer than 5 years . Therefore, failure to meet the target does not automatically imply seed-banks will be approaching a tipping point. However, understory vegetation plays an important habitat role and resources for a range of species and contributes to maintaining soil condition and structure.

Criteria 2. Risk of not taking management action to apply water

The condition data is the key decision criteria for considering an action that may incur a higher likelihood of negative outcomes, but there should be either:

- strong consensus on conceptual understanding, or
- direct and/or indirect observational or scientific supporting data

that the risk of not applying water is considered to be either Medium (high risk of loss of a local population of a species, but limited scope for recovery) or High (catastrophic risk to a species or key habitat component or site value that would have a long recovery time) (see Table 7.5).

Table. 7.5. Risk of not applying water. From MDBA (2013).

Risk class	Criteria
High	catastrophic risk to a species or key habitat component or site value that would have a long recovery time
	high loss of previous watering investment (ecological, volume or $)
	site is reaching end of resilience period
Medium	high risk of loss of a local population of a species, but limited scope for recovery (i.e. poor recolonisers) or long recovery time
	loss of key habitat components that have a short recovery time
	moderate loss associated with previous watering investment
	may not be able to fully deliver minimum regime
Low	risk of loss of a local population (of a common species) but scope for recovery within short term
	minor loss associated with previous watering investment
	may not be able to fully deliver optimum watering regime

Criteria 3. Management will strive for a balance between taking action to prevent damage to one suite of functions and attributes and those actions inducing damage to another suite

Even under circumstance where there is a need to accept a higher likelihood of negative outcomes, the balance between avoiding long-term or irreversible damage to floodplain functions and attributes, and potentially causing damage to in-stream functions and attributes remains the central tenant by which actions will be planned and managed. Furthermore, as outlined in section 5.2 of this document, all river operators and holders of environmental water are required to have regard to 'Targets for managing water flows' (section 9.14 of the Basin Plan) when making decisions about flow management and use of environmental water. There are also obligations under the South Australian Environment Protection (Water Quality) Policy (2003) that must be taken into account.

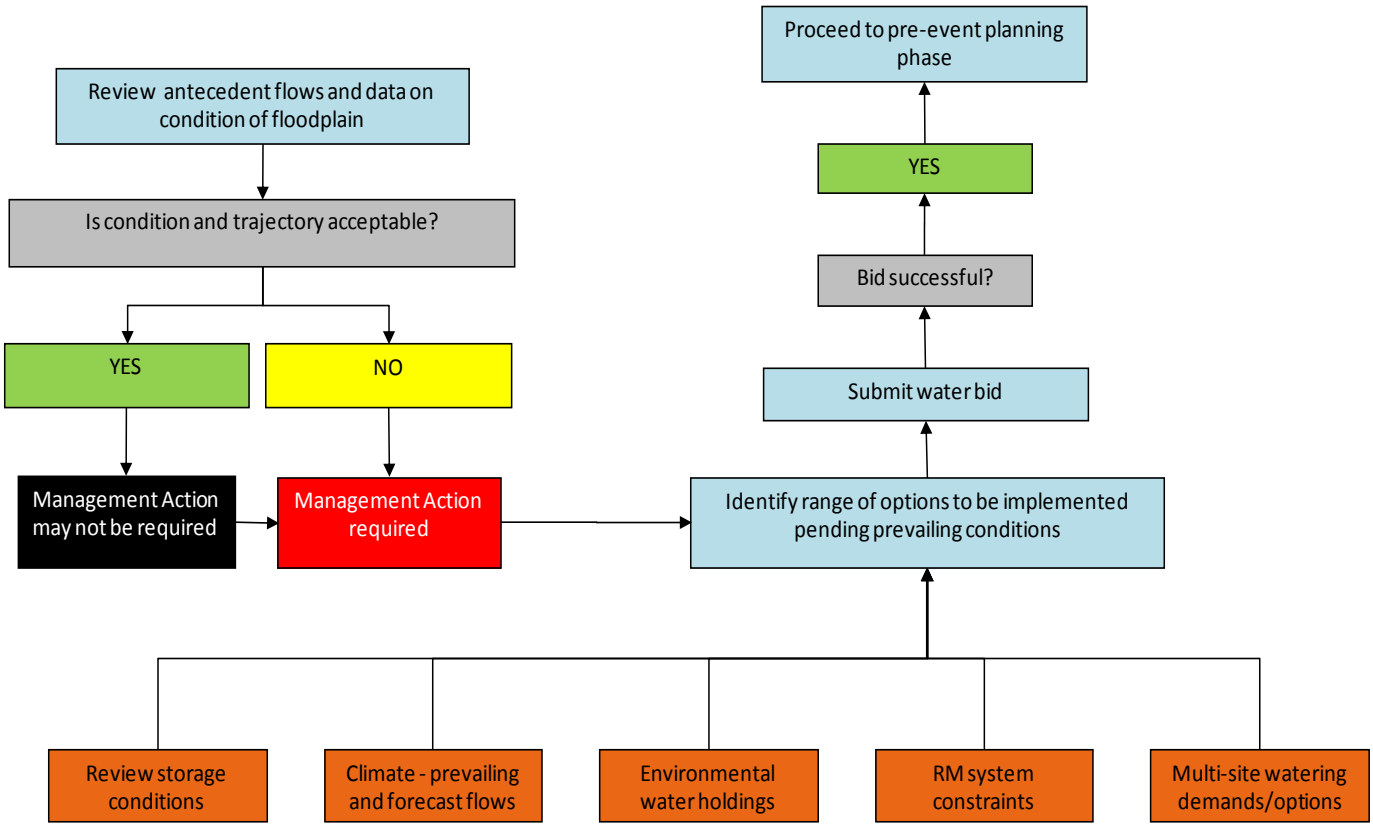

Figure 7.1. Decision matrix for annual water year planning of management actions at the Chowilla Floodplain

7.3. Pre-event planning process

The pre-event planning process for operations at Chowilla will be led by DEWNR in conjunction with the range of other agencies. The following steps are to be used in the pre-event period to confirm the most appropriate operation and prepare for its implementation. The process is summarised in Figure 7.2.

Step 1. River Murray system considerations

Prevailing flows

Prevailing flows and the volume of available environmental water, directly influence the most appropriate types of management action (see Table 6.1 and Table 7.2).

The source of water

The catchment and/or storage that water is being sourced from will influence ecological outcomes (see section 5.7 of this document).

Outcomes from multi-site watering

Positive and negative outcomes of multi-site watering need to be taken into account (see section 5.8 of this document).

System constraints

Channel capacity, outlet capacity, storage operational rules and demands for environmental water at other sites all influence which management actions are achievable.

Review of these factors will occur on an ongoing basis throughout the pre-event process and concurrently with the following steps.

Step 2. Consider site specific factors

Condition of the Icon Site relative to the ecological targets

The condition of the various ecological attributes and processes must be taken into account when determining if management action is required. The process for this is outlined in section 7.1.

Water quality impact of management action

A number of targets are identified under the Basin Plan, which all Basin States must have regard to when managing River Murray flows and making decisions about the use of environmental water (see section 5.2 of this document). There are also obligations under the South Australian Environment Protection (Water Quality) Policy (2003) that must be taken into account. Information on monitoring these parameters is provided in section 3.3 of the *Monitoring Strategy* document

Ability of management action to contribute towards Ecological Targets

The ability of a given action to contribute towards achieving the objectives and targets for the site needs to be taken into account. A summary of the ability of different actions to contribute towards ecological targets is presented in Table 7.6. This demonstrates that if the management objective is "Maintain sustainable communities of the eight riparian frog species recorded at Chowilla" a maximum achievable elevation managed inundation is not required. Options such as a low elevation managed inundation would be appropriate. Conversely, if the targeted objective is “Maintain viable Black Box populations within 45% of Black Box woodland", a low elevation managed inundation would not be appropriate, as the respective areas of the floodplain would not be inundated. In this instance, a maximum achievable elevation inundation would be required.

The influence of season needs to be taken into account. Undertaking management actions during winter-early spring provides a means of limiting the likelihood of (i) water quality hazards associated with high water temperature and (ii) spawning response from non-native fish. However, water availability may be low at this time. Furthermore, temperature and day length has implications for most biotic groups through metabolic (animal energetics), endocrine (e.g. circadian rhythm), behavioural traits (Bunn & Arthington, 2002), and life history adaptations (Lytle & Poff, 2004). Thermal regime and day length also affect biogeochemical rates, shaping ecological patterns and processes in riverine ecosystems (Lytle & Poff, 2004; Arthington et al., 2010). During winter, rates of biogeochemical processes that drive primary productivity and growth rates of plants will be very slow due to low water and soil temperatures and short day-length.

Monitoring and operating resources

Due to differences in the spatial scale (in-stream, wetland, floodplain) and the level of anticipated benefit and hazard with different management actions, the requirements for monitoring will vary significantly between actions. The magnitude of resources required to implement management actions increase with the scale of the proposed action. In the planning process it must be recognised that changes to infrastructure will be required at a large number of locations, in a short period of time. For example, raising Lock 6 may require Lock 7 to be raised to maintain the velocity matrix in the Mullaroo Creek and Lindsay River (Victoria).

Responding to changing conditions such as declining dissolved oxygen by increasing flow through the anabranch must be implemented rapidly to manage emerging hazards.

Balancing anticipated benefits and risks

There is a set of ten ecological principles (see section 5) for operation of the Chowilla Regulator and ancillary structures that inform the planning process. Those principles and the hazards, consequences, and potential mitigation strategies for those hazards must be taken into account during the pre-event planning and operations phase. Detail is provided in the *Event Plans and Hazard Mitigation* document. .

7.3.1. Record of Pre-event planning

A fundamental component of adaptive management is the maintenance of transparent records of actions and outcomes. Records of the information used to inform the decision processes for pre-event planning need to be retained. DEWNR will facilitate the collection and storage of relevant records which include:

- Prevailing condition of floodplain
- Antecedent flow conditions (i.e. EWR's met/not met)
- Environmental Water availability
- Objectives for the planned event(s) and consideration of management of hazards and benefits
- Compliance and Hazard Monitoring to be implemented and details of service providers
- How regard was had to Basin Flow targets for managing water flows
- Knowledge generation research (hypotheses testing) to be implemented and details of service providers
- Licensing and/or approvals required and/or submitted
- Log of all Communications activities

Table 7.6. Relationship matrix between management action and ability to contribute to meeting Ecological objectives. ✓indicates that the management action is likely to have a substantial impact, ⌖indicates that the action is only likely to influence the respective component in limited (i.e. specifically targeted) locations, ✗ indicates that action is not likely to contribute towards achieving the respective ecological objective.

Ecological objectives	Pulse flows via Pipeclay and Slaney weir	In-channel rise	Low - elevation managed inundation	Moderate elevation managed inundation	Maximum achievable managed inundation	Managed recession	Gravity based delivery to sites	Pumping water to wetlands
Maintain viable river red gum populations within 70% (2,414 ha) of river red gum woodland	✗	✓	✓	✓	✓	⌖	⌖	⌖
Maintain viable black box populations within 45% (2,075 ha) of black box woodland	✗	✗	⌖	⌖	⌖	✗	✗	✗
Maintain viable river cooba (*Acacia stenophylla*) populations within 50% of existing river cooba and mixed red gum and river cooba woodland areas.	✗	⌖	✓	✓	✓	⌖	⌖	⌖
Maintain viable lignum populations in 40% of existing areas.	✗	✗	✓	✓	✓	⌖	⌖	⌖
Improve the abundance and diversity of grass and herblands	✗	✗	✓	✓	✓	⌖	⌖	⌖
Improve the abundance and diversity of flood dependant understorey vegetation	✗	✗	✓	✓	✓	⌖	⌖	⌖
Improve the abundance and diversity of submerged and emergent aquatic vegetation.	⌖	⌖	✓	✓	✓	⌖	⌖	⌖
Maintain or improve the area and diversity of grazing sensitive plant species	⌖	⌖	⌖	⌖	⌖	⌖	⌖	⌖
Limit the extent of invasive (increaser) species including weeds	⌖	⌖	⌖	⌖	⌖	⌖	⌖	⌖
Maintain or increase the diversity and extent of distribution of native fish species	⌖	⌖	⌖	⌖	⌖	✗	✗	✗
Maintain successful recruitment of small and large bodied native fish	⌖	⌖	⌖	⌖	⌖	✗	✗	✗
Maintain sustainable communities of the eight riparian frog species recorded at Chowilla	⌖	⌖	✓	✓	✓	⌖	⌖	⌖
Improve the distribution and abundance of the nationally listed Southern Bell Frog at Chowilla	⌖	⌖	✓	✓	✓	⌖	⌖	⌖
Create conditions conducive to successful breeding of colonial waterbirds in a minimum of three temporary wetland sites at a frequency of not less than one in three years	✗	✗	⌖	✓	✓	⌖	⌖	⌖
Maintain or improve the diversity and abundance of key bird species	✗	✗	⌖	✓	✓	⌖	⌖	⌖
Maintain the current abundance and distribution of Regent Parrots	✗	⌖	⌖	⌖	⌖	⌖	⌖	⌖
Maintain the current abundance and distribution of the Bush Stone-curlew (*Burhinus grallarius*)	✗	⌖	⌖	⌖	⌖	⌖	⌖	⌖
Restrict the abundance and biomass of introduced fish species	✗	✗	✗	✗	✗	✗	✗	✗
Re-establish habitat condition to sustain high value fauna communities	✗	⌖	✓	✓	✓	⌖	⌖	⌖
Establish groundwater and soil conditions conducive to improving vegetation condition	✗	⌖	✓	✓	✓	⌖	⌖	⌖
Avoid fringe degradation due to soil salinisation in areas where ground water levels fluctuate in the absence of inundation	⌖	⌖	⌖	⌖	⌖	⌖	⌖	⌖
Avoid unacceptable salinity impacts to downstream users	⌖	⌖	⌖	⌖	⌖	⌖	⌖	⌖
Maintain water quality within ranges that support aquatic biota and normal biogeochemical processes	⌖	⌖	⌖	⌖	⌖	⌖	✗	✗
Provide processes for the mobilisation of carbon and nutrients from the floodplain to the river in order to reduce the reliance of in-stream foodwebs on autochthonous productivity	✗	✗	⌖	✓	✓	⌖	✗	✗
Maintain the flow mosaic characteristic of the Chowilla Anabranch system	✓	✓	✓	✓	⌖	✗	✗	✗
Establish a flow regime with distinct variability in components of the flood pulse	✓	✓	✓	✓	✓	✓	✗	✗
Maintain sedimentation and erosion processes within normal ranges	⌖	⌖	⌖	⌖	⌖	⌖	⌖	⌖

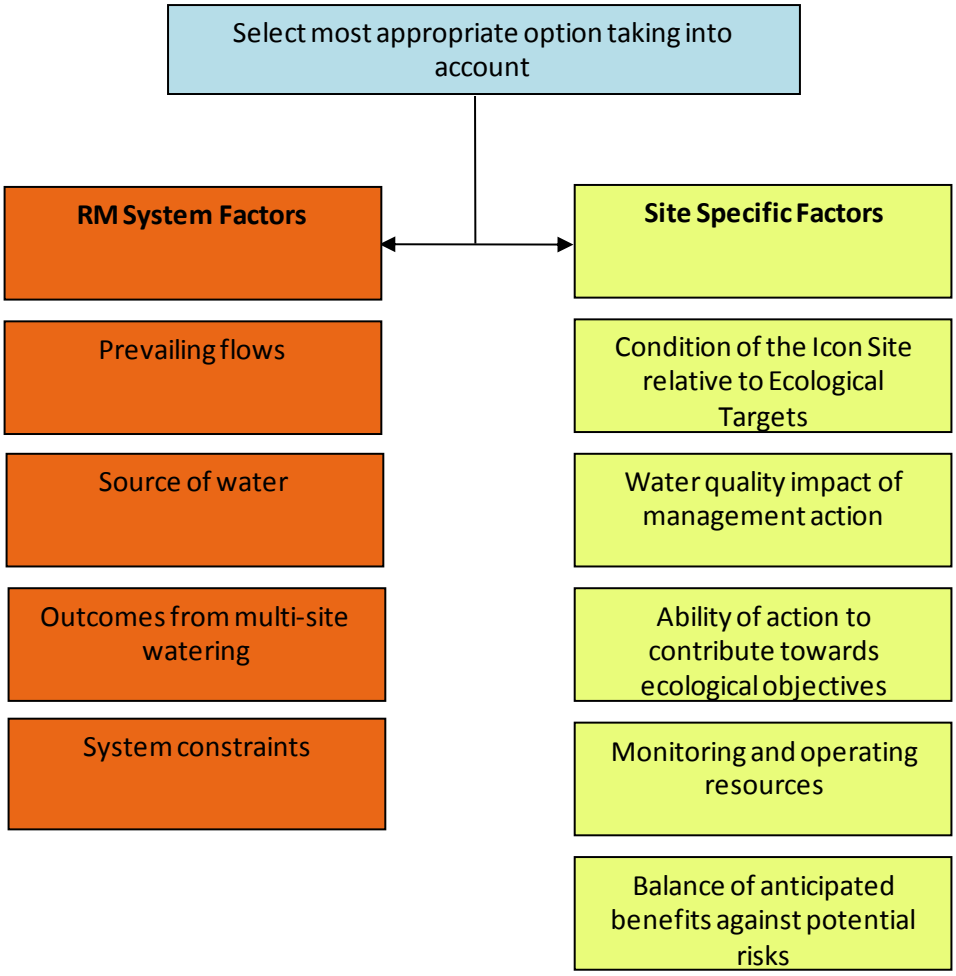

Figure 7.2: Decision matrix for pre-event planning for management actions at the Chowilla Floodplain. The range of options available once the River Murray (RM) system factors and Site Specific Factors have been taken into account are outlined in Table 5.2

7.4. Planning and decision making process during management actions

The following steps are to be used during the implementation of management actions. The process is summarised in Figure 7.3.

Step 1. Chowilla Operations Group (COG) determine the most appropriate management action given current and forecast conditions and provide advice to DEWNR RMO who instruction to SA Water RMOU:

The most appropriate management action is selected. This will by necessity require a revisitation of some of the steps outlined in sections 7.1, 7.2 and 7.3 to ensure the decision made is based on the most up-to-date information possible.

Step 2. Monitoring Plans are implemented:

Agreed minimum monitoring programs are implemented. The "minimum" monitoring refers to the basic level of monitoring without which it is inadvisable to proceed with the event. Monitoring requirements are outlined in section 7 of the *Monitoring Strategy* document. Sufficient lead time must be provided to ensure equipment is in place and any baseline data required is obtained prior to commencing management action.

Step 3. MDBA and SA Water River Murray Operations Unit (RMOU) commence environmental water delivery arrangements:

Delivery of environmental water is commenced to generate and/or maintain hydrograph required to enable chosen management action.

Step 4. Field data required to inform operations:

The DEWNR Icon Site Manager in conjunction with the MDBA will be responsible for coordinating the reporting of all necessary field data back to the COG for its consideration.

Management of hazards:

Detail on the hazards that have been identified in relation to management actions at the Icon Site is provided in the *Event Plans and Hazard Mitigation Strategy* document. Some of the identified hazards have the potential to develop over very rapid time scales, have consequences that may generate long-term or irreversible damage if triggered and unmanaged, and can be monitored or detected, and responded to and hence managed, in real time. Successful management of these hazards will require that many of the variables and indicators are monitored with on-line systems in order to be able to access, review and interpret the data in time for changes to be made to the management action during the event to mitigate outcomes.

MDBA operational forecasts:

These provide a forecast of flow conditions for four (4) weeks in advance of the current date. Ongoing review and utilisation of operational forecasts must be established to determine the most appropriate management action. It is critical to acknowledge and allow for operations to be flexible to account for changing circumstances. A forecast of decreasing flows may require a change to a lower tier management

option to manage potential hazards. Conversely, a forecast of increasing flows will increase the range of operation types that are available. However, a forecast for flows greater than 50,000 MLday^{-1} will induce a shift to flood operations. Under these conditions, the structures will be deactivated (i.e. stop logs removed) to avoid damage to the structures. Consideration should be given to opportunities to manage the recession of the hydrograph, if access to the structures is possible.

Data from formal monitoring programs and incidental observations:
Receiving, interpreting and acting on data and observations will be critical to understanding processes and maintaining safe operations.

Step 5. Frequent, regular meetings of the Chowilla Operations Group

Frequent, regular meetings of the Chowilla Operations Group (COG) will be essential. The frequency of meetings/communications will need to be high (i.e. potentially daily) during operations in order to:

- review the flow forecasts
- review and make decisions based on data for critical hazards
- discuss any operational issues
- discuss communication with stakeholders and the general public
- any other relevant issues

The following is provided as an example of the need for frequent meetings and the ability to rapidly respond to emerging issues in a timely manner. Based on the existing information on rates of de-oxygenation (Wallace, 2008; Wallace & Lenon, 2010) from the Icon Site, it is possible for the concentration of oxygen in the water within the impounded area to decline from normal oxygen concentrations (ca. 8 mgO_2L^{-1}) to the trigger level for stress for native fish (4 mgO_2L^{-1}) within 2 ½ days, and to the level where fish deaths may be expected (~2 mgO_2L^{-1}) within an additional 1 ½ days. In order to be effective, the adaptive management process needs to be able to undertake the following process:

- receive data from the field
- interpret and act on that information including making a recommendation for actions to control the hazard
- SA Water operations staff alter operations following direction from DEWNR based upon the recommendation(s) from the COG (e.g. increase the height of Lock 6 and decrease the height of the regulatory structures)
- review response to changed operation

Any delay in this process can be expected to have potentially serious impacts on the ecology of the anabranch complex, and the ability to meet the management and ecological objectives for the site. Mallen-Cooper et al., (2011) propose that one of the largest hazards associated with the operation of the Chowilla Regulator is that the monitoring implemented is insufficient to detect critical changes within a time frame allowing remedial action to be taken.

Operational guidelines for shifting between operation types in response to changes in flow such as an increase or decrease in QSA are presented in section 11 of the *Event Plans and Risk Mitigation* document.

Step 6. Icon Site Manager informs the MDBA Operational Advisory Group

The Icon Site Manager is a member of the Operational Advisory Group (OAG) established by the MDBA for environmental watering. The Icon Site Manager reports to the OAG on issues pertaining to the site. MDBA River Murray Operations may alter the delivery arrangements based on OAG advice and in consultation with icon site managers and environmental water holders.

Step 7. Complete Management Action

Following the process outlined above return Lock 6, the Chowilla Regulator and ancillary structures to routine operational mode. Ensure data records are completed and implement review phase. Information regarding the adaptive management phase is presented in section 7.6 of this document.

7.4.1. Record of Event

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

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

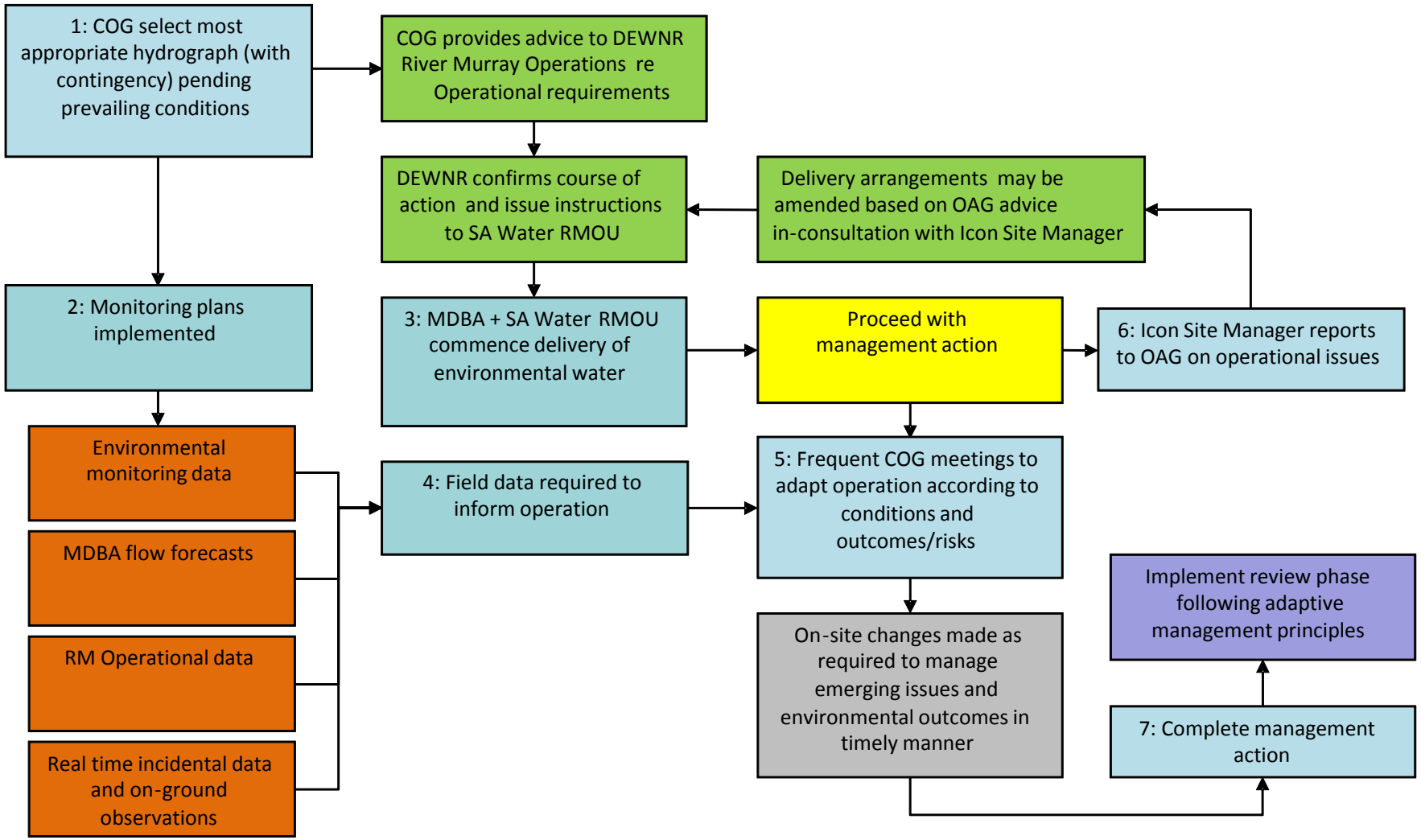

Figure 7.3: Decision matrix for event management at the Chowilla Floodplain. Numbered steps are explained in the preceding text

7.4.2. Post-event recording

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

- Monitoring summaries
    - Compliance and hazard management
    - Knowledge generation/hypotheses testing
    - Evaluation of progress towards/achievement of event specific objectives
- Recommendations for future events from:
    - Operations staff
    - Monitoring teams – identification of ecological benefits to inform adaptive management cycle.
- Resources utilised (personnel and equipment)
- Feedback from stakeholders, landowners and community

7.5. Review Phase and the Adaptive Management Cycle

Periodic review of the data from the decision making process, operational records and the monitoring program, and interpretation of that data with regard to the conceptual model and ecological objectives and targets and subsequent review and modification is essential to the adaptive management process. Detail is provided in section 11.

8. Water Use

There are a range of potential management actions using constructed infrastructure on the Chowilla Floodplain including the operation of the Chowilla regulator to different levels. Before the Chowilla regulator can be raised, thresholds for flow to SA need to be met in order to:

- maintain suitable hydraulic conditions to maintain key fish habitat
- ensure sufficient flows through the anabranch to mitigate against potential water quality issues, and
- maintain flows over Lock 6.

These critical operational limits are defined in section 5 of this document. If unregulated flows are at inadequate levels to achieve low risk operations then calling on environmental water allocations to enable flows to be boosted will be necessary.

One of the key issues around calculation of water use associated with Chowilla regulator operation is the accuracy of measurement and how to measure water use where overbank flow occurs. Physical limitations means that it becomes impractical to measure the overbank flows from the River into the icon site. The ability to measure water use at a site decreases as the volume of water available to water the site increases.

Work undertaken by MDBA provides the tools for modelling estimated water use. The following information has been extracted from a Draft Report "Operational Model Development, Chowilla Floodplain" January 2014 (MDBA Technical Report No 2014/06).

A hydrological model of the Chowilla floodplain has been developed in the MDBA hydrological model, MSM Bigmod. The model has been developed and calibrated from outputs of numerous runs of the existing detailed Chowilla MIKEFLOOD hydrodynamic model (Water Technology, 2009). The MSM Bigmod Chowilla model is capable of simulating the operation of the Chowilla regulator and associated works and estimates the on-site water use by comparing the evaporation, seepage and water retention associated with operational scenarios against a model run without the regulator operation (a 'no TLM scenario').

The MSM Bigmod model was constructed of the key hydrological components including:

- Lock 6 weir pool;
- Chowilla anabranch system;
- Chowilla regulator and floodplain;
- Chowilla wetlands (Lake Littra, Gumflat, Lake Limbra, Coombool Swamp and Werta Wert wetland);
- Woolshed Creek; and
- Floodplain retention.

Structures that have been included in the MSM Bigmod model are:

- the Chowilla regulator and Lock 6, allowing manipulation of the upstream water level during an operational scenario;
- Pipeclay and Slaney Creeks, allowing manipulation of flows into these creeks;
- Woolshed Creek to allow manipulation of outflow from this creek back to the River Murray;
- Werta Wert wetland to retain water in the wetland following a watering event.

Model outputs from the MIKEFLOOD and the MSM Bigmod models have been compared with reasonable alignment. The Chowilla hydrological model in MSM Bigmod will be further developed and refined using field data collected during Chowilla operation watering events.

An Excel spreadsheet model has been developed to run the Chowilla MSM Bigmod model and analyse the water use associated with Chowilla regulator operating scenarios. This model allows direct input of flow to SA, proposed operating levels of Lock 6 and Chowilla regulator, and discharge through Pipeclay, Slaney and Woolshed Creeks.

The model is run twice, the first time for the 'no TLM' scenario (no operations) and secondly for the proposed operation, and provides daily output from both model runs for viewing and analysis. Water-use is estimated based on the difference between the 'no TLM' model run and the operating scenario, i.e. the additional water-use associated with the proposed operation including increased evaporation and seepage due to increased inundation area and retention of water on the floodplain during and following the operation. Seepage has been assumed to be 5 mm/day over the inundation area (this can be refined as field data is collected). The water-use estimation includes additional water-use associated with changed operation of the Lock 6 weir pool and Chowilla floodplain (including wetlands) and the water retained on the floodplain following drawdown.

The MSM Bigmod model has the advantage of taking seconds to run a scenario in comparison to several days for the hydrodynamic model and will be incorporated into the MDBA system model. The model will be maintained by MDBA and will continue to be refined and improved as field data becomes available during environmental waterings.

Four initial potential operational scenarios have been modelled to determine total water use (water consumed plus water retained on the floodplain) associated with the scenario as well as the volumes required for the initial filling of the floodplain storage and the raising of Lock 6. A further five commissioning scenarios were modelled with increased flow into Pipeclay and Slaney Creeks. Results for these scenarios are presented in Table 8.1.

Table 8.1 Summary of Bigmod output for the preliminary Chowilla commissioning scenarios

	Peak Water Level (mAHD)					
Preliminary Scenario	**Chowilla Regulator**	**Lock 6**	**Approx. Water Consumption (ML)** ***(evaporation plus seepage)***	**Retained on floodplain (ML)**	**Filling Volume (ML)** ***(Returned post operation)***	**Total (ML)** ***(Consumption plus retained plus filling)***
1	18.1	19.25	3,074	358	9,650	13,082
2	18.7	19.67	5,158	3,247	18,800	27,205
3	19.4	19.87	16,211	6,589	32,000	54,800
4	19.8	19.87	24,024	8,981	51,600	84,605
1 a	18.1	19.25	2,072	358	8,400	10,830
2 a	18.5	19.25	2,360	2,290	11,800	16,450
3 a	18.7	19.25	3,445	3,255	14,300	21,000
4 a	19.0	19.45	10,965	4,670	20,000	35,635
5 a	19.0	19.45	11,050	4,670	20,000	35,720

Further work to refine the model will be ongoing as data from actual operations becomes available.

Requirements for additional flow to SA (to maintain flow velocities important for the maintenance of critical fish habitat and management of water quality) associated with the modelled scenarios have also been assessed by comparing the required flow to SA with the outlook from multi-history model run. A water balance approach has been used to provide an estimate of the additional flow requirement at the SA border (above entitlement flow) for the identified scenarios. Estimates of total water-use and peak daily additional flow for the revised scenarios are shown in Table 8.2. Unregulated flow over the SA Border would reduce the additional flow water requirement for operating the Chowilla floodplain works.

Table 8.2 Summary of water-use for revised commissioning scenarios

Revised Scenario	**Approx. water requirement (GL)** ***(Consumption plus retained plus filling plus additional flow)***	**Peak daily additional flow (ML/d)**
1 a	153	2,800
2 a	149	3,300
3 a	160	4,500
4 a	352	5,300
5 a	348	5,300

The Chowilla hydrological model in Bigmod will be further developed and refined using field data collected during Chowilla operation watering events.

8.1. Water Accounting

A number of water accounting principles will be followed during the operation of the Chowilla regulator:

- Water use will be determined on a 'net use' basis using models to determine the usage associated with a watering action;
- Return flows will not be re-credited on a licence for use further downstream. South Australia's approach to managing water allocations for River Murray water access entitlement holders is that allocations are provided on the basis of South Australia's share in the Murray-Darling Basin Authority controlled storages through the MDBA's Water Availability Assessment;
- Water use is only accounted when environmental water allocations from The Living Murray or Commonwealth Environmental Water Holder are delivered (no accounting during unregulated conditions only); and
- Operations will be undertaken consistently with the historical approach to management of unregulated flow to South Australia.

A hydrological model of the Chowilla floodplain works including the Lock 6 weir pool has been developed in the MDBA hydrological model, Bigmod and this model has been previously documented. Estimated water-use will be based on the difference between the modelled water-use with and without the operation of the Chowilla regulator. The additional water, required to cover the estimated usage component, would be ordered at the South Australian border, but may not be required if an unregulated flow event occurred.

During regulated conditions, the delivery of environmental water for the use of the Chowilla regulator and ancillary structures will be accounted as a total flow delivered to the site above the estimated normal baseflow in Chowilla Creek. The environmental water will be accounted as the additional flow required to operate the Chowilla structures compared to the flow that would have occurred without operation of the Chowilla regulator. From a water use accounting perspective, the operation must take into account any volumes of environmental water traded to South Australia specifically for operating the Chowilla regulator, to assist with the transparency of reporting on environmental water trade and use. The environmental water use will be calculated using the Chowilla hydrological model. This model will be prepared and maintained consistent with applied procedures for other MDBA models. Once real-time data is obtained from MDBA river operations, there will be an ongoing refinement process involving verification and calibration/re-calibration as required.

Environmental water use at Chowilla will be accounted during a period of operation (when delivery of environmental water commences and ceases, including losses) under a range of flow conditions using estimates prepared through using the MDBA's hydrological model. The MDBA will be responsible for running the model to determine net water use and provide regular updates for water accounting purposes to assist South Australia with its reporting obligations to Commonwealth agencies.

During unregulated flow events where no regulated water (i.e. environmental entitlements) is added, it is proposed that no accounting will occur as would be the case during any period when the structures are not being operated. This principle is currently followed for floodplain inundation in South Australia. If the structures are used to manage the recession of a natural high flow by holding up water on the Chowilla floodplain (above the normal water level of 16.43m AHD) in Chowilla Creek, then accounting of water use against an environmental entitlement (if provided) should occur if regulated environmental water is added after a period of unregulated flow ceases. This process will also require an estimate of use to be calculated. This would occur when stop logs have been reinstated specifically for the purpose of holding water behind the regulator and associated ancillary structures.

Water Accounting – method and measurement of use

Accounting for water use allowing for the operation of the Chowilla regulator and ancillary structures will occur when environmental water is delivered to the site. It will remain a MDBA responsibility to ensure that the ordered volume is delivered to South Australia.

In this context, a water order will be deemed to be the volume ordered by South Australia, which will be in addition to the trade adjusted Entitlement Flow volume. The water order will need to be sufficient to include the additional flow requirement to facilitate operations of the structures (through flows) and the water used within Chowilla (seepage and evaporation). The operation will need to be undertaken in a manner that does not affect the physical delivery and accounting for South Australia's Entitlement Flow. Any changes to rating tables due to the delivery of environmental water will need to be managed in accordance with the Specific Objective and Outcome for adjusting flow to South Australia.

The additional required flow would be measured as part of the total flow to SA (QSA) and the on-site water-use modelled to estimate the water requirement and measured during the event to verify and correct the modelled estimates.

The justification for this approach is, a similar method has recently been used for accounting of water-use at Mulcra Island – additional flow in the River Murray was not required for operating the Mulcra Island works and the on-site water-use was modelled based on incremental evaporation and seepage (the difference between the water-use with and without the operation of the works) and water retained on the floodplain following the commissioning event.

With the operation of the regulator and associated works, there will be a change in the water balance between the QSA and Lock 5 flow. This results from any or all of the following:

- Water required needed to fill the Chowilla regulator pool and raise the Lock 6 weir pool level height;
- Water subsequently returned from the lowering of these pools to normal levels;
- Additional evapotranspiration and seepage due to increased inundation extent;
- Additional River Murray flow to maintain appropriate velocities in the Chowilla anabranch system for water quality management and critical native fish habitat; and
- Additional River Murray flow required to mitigate potential downstream impacts.

Raising water levels (at Lock 6) may impact on the measurement of flow to SA (GS426200 and Mullaroo Creek offtake). This will need to be investigated separately by the MDBA (with recommendations provided to the WLWG) and an agreed way forward will need to be determined. It is also recommended that frequent gauging's occur during any watering operation and that the Chowilla Operations Group and MDBA be notified immediately of any issues or discrepancies. The operations may require a complete review of all flow measuring locations and technologies within the Lock 6 and 7 weir pools. Any review will also need to be considered in the context of developing a Specific Objective and Outcome for adjusting the flow to South Australia in response to rating table changes. This process is currently underway.

Raising the downstream water levels (at the Chowilla regulator and Lock 6) may also reduce the velocity through Mullaroo Creek and have result in a discharge relationship shift and impact rating tables in the region.

A previous study indicated raising the Lock 7 weir pool by approximately 200mm would be sufficient to restore velocity for maintenance of critical native fish habitat in the Mullaroo Creek (Water Technology, 2007). The additional water-use associated with raising the Lock 7 weir pool would be modelled and included in the water-use estimate for operating the Chowilla regulator.

It is proposed that hydrological modelling is used to provide an estimate of the additional losses, resulting from operating the Chowilla floodplain works and the modelling estimates verified and corrected during and following the operation by direct measurement at key sites.

Key sites for measurement of actual flow during operation of the Chowilla regulator include:

- *Flow to South Australia as:*
    (1) When River Murray level at GS426200A < 5.8 m:
        Flow to SA = GS426200 **plus** Mullaroo Creek Offtake GS414211A **minus** Lindsay River Allowance.
    (2) When River Murray level at GS426200A > 5.8 m:
        Flow at GS426200A.
- Water level (upstream and downstream) at the key structures including:
    - Chowilla regulator;
    - Pipeclay Creek regulator;
    - Slaney's Creek regulator;
    - Woolshed east and south regulators;
    - Wetland water levels when water is retained by closing individual wetland regulators; and
    - Locks 6 and 7.
- Flow (as required) to verify the modelled flow downstream of the key structures based on the measured upstream and downstream water level.

9. Hazard and risk mitigation and monitoring requirements

9.1 Hazard and risks

A **hazard** is any source of potential damage, harm or adverse health effects if it is not controlled. Hazards may be biological, chemical or physical. **Risk** is defined as the consequence of exposure (occurrence) X likelihood of exposure (occurrence). A simple way of describing the hazard management process is the SAFER (http://www.safework.sa.gov.au) approach:

- See it (identifying hazards)
- Assess it (risk assessment)
- Fix it (risk control/mitigation)
- Evaluate it (monitoring/evaluation)
- Review it (review during event to determine if control has been effective and post event adaptive management to determine if operational rules need to be altered)

9.2 Assessments

Numerous assessments have been undertaken in order to identify and understand likely outcomes, and enable planning for the minimisation and management of hazards associated with the operation of the Chowilla Regulator and associated infrastructure. The scope and citation details of each assessment are outlined in Appendix A of the *Event Plans and Hazard Mitigation Strategy* document. A collation of identified hazards, potential impacts, mitigation options, monitoring needs and management responses has been undertaken in order to present the data in a consistent format. Tables providing detailed summaries on the findings of each issue are presented in Appendix A of the *Event Plans and Hazard Mitigation Strategy* document. The hazards identified in those reports have been categorised into eight different groups according to the affected component. These are listed in Table 9.1.

9.3 Critical hazards

Some of the hazards that have been identified have the potential to develop over very rapid time scales, and hence can be defined as "critical hazards". This incorporates issues that exist either from an hydrological and/or management of water quality perspective. There are Commonwealth and State based statutory obligations not to contravene water quality criteria that must also be taken into account. Detail on those obligations is provided in section 3.3 of the *Monitoring Strategy* document, and section 10.2 of the *Event Plans and Hazard Mitigation Strategy* document. There are additional hazards that if triggered may also have significant, long-term consequences. Although many of these may be predicted and pre-emptively managed via the selection of the most appropriate management action given prevailing conditions, they cannot be adaptively managed in real time as their occurrence or impacts may not be detected until after the event, or cumulative occurrences may be required before the effect can be detected. Although those issues are regarded as significant and they need to be monitored, managed and accounted for, they are not defined here as critical hazards. Issues that are considered to represent a critical hazard are:

- Reduced hydraulic complexity (e.g. habitat diversity)
    - in the Chowilla anabranch, in the River Murray channel, and the Lindsay River/Mullaroo Creek
- disconnection between season, river hydrology and managed inundation
- water quality; parameters with:
    - ecological ramifications (e.g. hypoxic conditions associated with blackwater events)
    - human health and river amenity values (e.g. cyanobacteria)
    - socio-economic impacts (e.g. salinity)
- rates of rise and fall in water level

9.4 Hazard Mitigation Tools

The key hazard mitigation tools are encapsulated within the Critical Operational Limits, the Ecological Principles (Section 5), the operating conditions outlined in the event plans (sections 6-9 of the *Event Plans and Hazard Mitigation Strategy* document) and the actions briefly outlined below.

- Managing the relative height of the structures and inflow:outflow ratio's to maintain water exchange and the velocity matrix throughout the anabranch. Given that the primary inflow pathways (Pipeclay and Slaney Weirs) will be fully open for all scenarios with QSA ≥5,500 $MLday^{-1}$ and Chowilla Regulator ≥18.0 mAHD, this will require one or more of the following actions:
    - increase inflow into the anabranch by increasing the height of Lock 6
    - increasing inflow into the anabranch by increasing QSA
    - increasing outflow through primary (Chowilla Regulator) and ancillary structures (Woolshed Creek inlet [East] and outlet [South] and Chowilla Island Loop)
- Linking the scale of management actions to prevailing hydrology and ambient water quality to ensure:
    - prevailing flow is sufficient to maintain the velocity target within the core fish habitat
    - the inflow is sufficient relative to the area inundated (hence volume impounded) to maintain the minimum daily exchange
    - salinity targets in the river channel are not exceeded
    - dilution flows are sufficient to manage quality of return flows
- Closing regulators on individual wetlands if required in order to
    - achieve minimum inundation periods for waterbirds to complete breeding cycles
    - prevent water with high loads of problematic cyanobacteria or other pollutants from creating unacceptable impacts on the anabranch creeks and river channel
- Controlling the rate of fall in water levels at the Chowilla Regulator in order to:
    - prevent geomorphic impacts (e.g. bank slumping)
    - prevent impacts on biota sensitive to rapid decreases in water level
    - prevent water with high loads of problematic cyanobacteria or other pollutants from creating unacceptable impacts on the river channel
    - ensure salinity targets in the river channel are not exceeded

Additional information is presented in section 5 of the *Monitoring Strategy* document.

9.5. Monitoring Requirements

Successful management of potential hazards will require that many of the variables and indicators are monitored with on-line systems in order to be able to access, review and interpret the data before extreme events occur. In this context, it is essential that the adaptive management process is able to receive, interpret and act on that information as it becomes available in order to take effective action during management actions to maximise outcomes and minimise negative (undesirable) outcomes (Boulton, 1999).

The monitoring requirements for management actions at the Chowilla Floodplain Icon Site has been classified using the following framework:

1. Data that is currently collected within the existing Condition Monitoring Program
2. Data that has been collected within existing or pre-existing Intervention Monitoring Programs
3. Data that is required to determine if management action is warranted
4. Targeted monitoring that is required during management action to inform management of structures and potential downstream impacts
5. Critical hazard management
6. Minimum monitoring requirement for synchronised event (QSA = 20,000 MLday^{-1} commencing mid-spring)

Detail on monitoring requirements is presented in the *Event Plans and Hazard Mitigation Strategy* and the *Monitoring Strategy* documents.

9.6. Critical hazard mitigation and management matrix

The critical hazards, mitigation tool and monitoring requirements are consolidated into a management matrix in Table 10.2 of the *Event Plans and Hazard Mitigation Strategy* document. Detail on individual hazards including a description of the hazard and its potential impacts is presented in section 5 of the *Monitoring Strategy* document.

Table 9.1. Hazards identified from the existing assessments, grouped according to the affected component and the key drivers of the hazards.

Hazard group	Driver of hazard
Hydrology	Drawdown of impounded area is too fast
	Period of inundation is too short to achieve ecological objectives
	High flow velocity causes channel bed and floodplain scour
	Desynchronisation of river flows with inundation period
	Aseasonal flooding resulting from timing of inundation either due to (i) availability of water for operations, or (ii) attempts to minimise the likelihood of triggering other hazards
	Reduction of hydrodynamic diversity and fast flowing habitats during regulator operations
	High reliance on hydrodynamic model for scenario testing
	High proportion of QSA is directed into anabranch
	Sedimentation within anabranch creeks and/or deposition of sediments on floodplain
Native Fish	Decrease in availability of preferred habitat for large bodied native fish
	Reduced quality/availability of spawning sites and nursery habitats for Murray cod
	Alteration of hydrological cues for native fish
	Native fish are trapped in wetlands if wetland regulators are closed on flood recession
	Restricted fish passage during operations
Non-native fish	Temporary increase in lentic habitats that provide habitat suitable for carp spawning and recruitment
	Increased interactions between carp and freshwater catfish
Invasive plants	Increased abundance/distribution of exotic plants
	Skewed age classes and diversity/abundance of native species (e.g. red gum invasion into other vegetation communities)
Increased predation	High abundance of predatory exotic fish
Water quality	Pulse of carbon and nutrients from inundated soil and natural organic material generates hypoxic blackwater event
	High concentration of nutrients and/or harmful/nuisance algal bloom from impounded area drains to the river
	Deep, slow moving water immediately upstream of regulator when in operation - increased likelihood of stratification
	Nutrients released from inundated soils and plant material are utilised by non-desirable phytoplankton groups and harmful/nuisance algal bloom(s) develops in wetlands that become isolated during drawdown
Groundwater-surface water interactions	Salt wash off from upper soil profile leads to increased surface water salinity
	Mobilisation/entrainment of salt from dead storage areas leads to increased surface water salinity
	Groundwater discharge from floodplain aquifers leads to increased surface water salinity
	Development of groundwater mounds beneath inundated areas lead to a rise in groundwater levels beneath the floodplain
	Fringe degradation in areas where depth to groundwater varies with Chowilla Regulator operations in the absence of inundation
	Shallow depth to saline groundwater combined with evapotranspiration causes soil salt content to increase
Operations	Reduced ability to detect negative outcomes and achieve benefits due to operations designed primarily to minimise the likelihood of triggering hazards
	Inability to alter structures to maintain water quality in timely manner
	Insufficient resources for monitoring
	Political pressure to utilise infrastructure despite insufficient resources

10. Communications

A Communications and Engagement plan specific to the Chowilla Floodplain site is in place and a specific Communications Plan for Chowilla Operations has been developed. The Communications Plan identifies key stakeholders, key messages and how they will be delivered. Any media engagement with regard to TLM environmental watering actions must be in accordance with The Living Murray Communication Protocol and other water holder requirements. Overarching communications and consultation documents developed through The Living Murray program provide overarching key messages and activities relevant to the Chowilla floodplain works and environmental watering actions.

10.1 Community Consultation

The DEWNR Chowilla Floodplain Icon Site management team have an ongoing commitment to maintaining strong relationships within the local community. A vital tool in the consultation process is structured engagement with the community through engagement with key stakeholders groups. It is acknowledged that the completion and operation of significant environmental works at Chowilla will be of great interest to many groups and individuals across the community. Communications and engagement activities build on existing support for the program.

10.1.1 Community Reference Committee

The Chowilla Floodplain Icon Site Community Reference Committee (CRC) has been meeting regularly since 2004 and has played an extremely significant role over that time contributing community perspectives and providing valuable advice to the Icon Site program and links through member's networks into the wider community. The role of the CRC will continue with members providing input regarding community perceptions about the Chowilla TLM program and advice regarding how consultation and engagement with the wider community should occur. The important role of the CRC will continue as environmental watering actions using the new and upgraded infrastructure come into operation.

10.1.2 Aboriginal engagement

DEWNR Icon Site management staff are working closely with the First Peoples of the River Murray and Mallee Region to ensure that the Aboriginal community is provided an opportunity for input into water management, and a chance to raise and identify their cultural links to the floodplain and ensure cultural heritage and values are considered and incorporated by the Icon Site manager, and support the distribution of information out into the Aboriginal communities.

10.1.3 Communication with Community around watering events

DEWNR Icon Site management staff will lead communication activities for upcoming and ongoing watering events. Key messages will be provided about the scale, timing, ecological objectives and hazard management for any event.

DEWNR Natural Resources SAMDB as managers of the Chowilla Game Reserve will be responsible for communicating with its stakeholders; the lessee and with visitors regarding any impacts on visitor experience such as road closures, access restrictions to areas of the park and other related issues.

10.2 Key Stakeholder and Internal Communication

The Communications Plan for Chowilla Operations includes more specific detail and clarification about the roles and responsibilities for communication between agencies directly involved in implementing the Operations Plan and communications with other external key stakeholders including leasees, and neighbouring landholders. This will include confirming processes and responsibilities for necessary notifications to the community and to stakeholders regarding operational events. Communication of monitoring data will be required when thresholds are reached that require a response from other agencies (eg. Health Department and SA Water in the case of cyanobacterial events). The Communications will also include detail regarding mechanisms for managing enquiries and any complaints and positive feedback relating to the environmental watering process and events.

11. Adaptive Management

Periodic review of the data from the decision making process, operational records and the monitoring program, and interpretation of that data with regard to the conceptual model and ecological objectives and targets and subsequent review and modification is essential to the adaptive management process. Without this process, changes in management actions (e.g. the way structures are operated and environmental flows are delivered) cannot be efficiently implemented in order to achieve improved management outcomes. Regular, systematic reviews will ensure that:

- composition and role of COG is appropriate and effective
- the decision matrix is effective and improved as appropriate
- the ecological objectives and targets defined for the Icon Site are realistic and attainable
- the monitoring program provides the information required for (i) reporting against the ecological objectives and targets (ii) hazard mitigation and Basin Plan Schedule 12, and is modified/updated as appropriate via a structured process to rectify any gaps or redundancies
- management actions are based on the latest information and ecological understanding of the system, and how it responds to various interventions and natural events
- the management actions implemented are successful in terms of meeting the ecological objectives
- deleterious impacts or incidental environmental benefits from management actions are reported upon and accounted for in future management actions
- trigger points are established so that particular outcomes from monitoring trigger corrective action or further investigation
- Stakeholder and community feedback is considered and addressed.

A detailed framework will provide a systematic basis for adaptive management of Chowilla operations and will include answering a series of questions including the following:

- Was the action delivered as anticipated?
- Were thresholds for management complied with?
- Did the action achieve the stated objectives? If not why not?
- Where unanticipated / additional objectives achieved?
- Do objectives or targets need to be updated? If so how?
- Do conceptual models need to be updated? If so how?
- Do actions required to meet the objectives require refinement?
- Were hazard mitigation measures successful?
- Did unanticipated hazards emerge?

The outcomes of these annual systematic reviews will inform updates of this Operations Plan.

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