South Australian River Murray Water Resource Plan Area Risk Assessment

DEW Technical report 2018/05

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Department for Environment and Water

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Foreword

The Department for Environment and Water (DEW) is responsible for the management of South Australia's natural resources, ranging from policy leadership to on-ground delivery in consultation with government, industry and communities.

High-quality science and effective monitoring provide the foundation for the successful management of our environment and natural resources. This is achieved through undertaking appropriate research, investigations, assessments, monitoring and evaluation.

DEW's strong partnerships with educational and research institutions, industries, government agencies, natural resources management boards, and the community ensures that there is continual capacity-building across the sector, and that the best skills and expertise are used to inform decision-making.

John Schutz
CHIEF EXECUTIVE
DEPARTMENT FOR ENVIRONMENT AND WATER

Acknowledgements

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Participating organisations included DEW, the Environment Protection Authority (SA), Department of Primary Industries and Regions SA (PIRSA), SA Water, Natural Resources SA Murray–Darling Basin and SA Health. We thank Andrew Solomon, Kumar Savadamuthu, Kane Aldridge, Steve Kotz, Gerry Davies, Liz Barnett, Tracey Steggles, Andrew Beal, Joel Vandepeer, Rebecca Quin, Lyz Risby, Matt Gibbs, Michelle Denny, Michelle Bald, Glen Scholz, Kirsty Bevan, Theresa Heneker, Ashley Kingsborough, Tony Herbert, Richard Brown, Jarrod Eaton, Peter Goonan, Ben Smith, Peta Brettig, Rebecca Turner, Jan Whittle, James Fuller, Danny De Pierro, Christopher Wright, Diane Favier, Dan Jordan, Adam West, Patricia von Baumgarten, Stephen Madigan, Adam Watt, Lissa Arcoverde, Daniel Wohling, Marilyn Wilkins, Tumi Bjornsson, Justine Smith, Katelyn Ryan, Sarah Imgraben and Colin Cichon.

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Abbreviations and acronyms

Actual Title	Abbreviation
Australian Height Datum	AHD
critical human water needs	CHWN
Department of Environment and Heritage	DEH
Department for Environment and Water	DEW
Department of Environment, Water and Natural Resources	DEWNR
Eastern Mount Lofty Ranges	EMLR
Environment Protection Authority (South Australia)	EPA
Environment Protection and Biodiversity Act 1999	EPBC Act
gigalitres	GL
Lower Murray Reclaimed Irrigation Area	LMRIA
long-term environmental watering plan	LTWP
metres with respect to Australian Height Datum	mAHD
Murray–Darling Basin Authority	MDBA
natural resources management	NRM
Natural Resources Management Act 2004 (SA)	NRM Act
priority environmental asset	PEA
Department of Primary Industries and Regions (South Australia)	PIRSA
South Australia	SA
South Australian Murray–Darling Basin Natural Resources Management Board	SAMDB NRM Board
sustainable diversion limit	SDL
The Living Murray program	TLM
water allocation plan	WAP
water-dependent ecosystems	WDEs
water resource plan	WRP
Western Mount Lofty Ranges	WMLR

Executive Summary

The South Australian River Murray Water Resource Plan Area Risk Assessment ('the risk assessment') is the first step in developing the South Australian River Murray Water Resource Plan (WRP). The risk assessment identifies and assesses risks to the condition or continued availability of Basin water resources. The risk assessment will inform the development of the WRP to ensure the WRP measures are fit for purpose and commensurate with risk levels.

The risk assessment applied South Australia's risk management framework for water planning and management (DEWNR 2012), which in turn draws on the Australia/New Zealand Risk Management standard (AS/NZS ISO 31000:2009). The risk assessment method was designed to be a participatory process within the South Australian government to maximise confidence in, and ownership of, outcomes. Engagement with representatives from the South Australian Department for Environment and Water (DEW) (science, policy and regional natural resource management), the Environment Protection Authority of South Australia (EPA), the Department of Primary Industries and Regions SA (PIRSA), and SA Water occurred throughout the process.

The risk assessment considered risks to water-dependent ecosystems, economic use, critical human water needs and connected water resources. Sources of risk identified include climate extremes, future water demand, infrastructure operations, land use, management of connected water resources and point source pollution. The assessment examined risk pathways associated with potential changes in water quality, water availability or water regime over the 10-year timeframe of the WRP.

The risk assessment considered the effectiveness and implementation of the full range of risk controls (i.e. policy, planning and investment programs designed to manage risk) that are anticipated to operate in the South Australian River Murray over the timeframe of the WRP. The risk assessment assumed full and on-time implementation of the Basin Plan over this period.

A total of 59 risk statements were assessed through a series of workshops. These workshops engaged relevant technical, policy and regional expertise from multiple South Australian government agencies. The final risk profile consists of 10 medium and 49 low risks. No risks were evaluated as high according to the agreed risk criteria.

The lack of high risk can be attributed to the South Australian River Murray being a highly regulated system characterised by appropriate management and a high level of compliance with regulation and policies. It is also assumed that the Basin Plan and associated investment programs will play a significant role in managing future risks, albeit with some uncertainty regarding the effectiveness of implementation.

Out of the 10 medium risks identified, six are caused by management of connected water resources and the remaining four are caused by climate extremes. In general, these medium risk pathways were characterised by uncertainty regarding risk sources, as there is a level of uncertainty regarding the management of upstream connected water resources and there is an inherent inability to influence the likelihood of climate extremes.

Uncertainties regarding implementation of the Basin Plan contribute significantly to risk in many cases. These uncertainties relate to:

- the effectiveness of measures to address policy and physical constraints affecting the delivery of environmental water
- the extent to which the environmental equivalence test for sustainable diversion limit (SDL) adjustment reflects the outcomes achieved through on-ground projects
- the potential for long-term environmental water plans for the River Murray upstream of South Australia to create demands for environmental water that could compete with the achievement of environmental outcomes in South Australia
- the limited progress of interstate connected WRP development at the time of the risk assessment.

Changes in take, land use change, point source pollution, infrastructure operations and invasive organisms were not identified as sources of high or medium risks. The risk evaluation process determined that for these risk sources, the controls currently in place were adequate in minimising the risks.

1 Introduction

The Murray–Darling Basin, located in south-eastern Australia, covers an area of over one million square kilometres and contains one of Australia's most important river systems (the Murray–Darling). The river system not only provides important resources for irrigated agriculture, industries and communities across the four Basin States (New South Wales, Queensland, Victoria, South Australia) and the Australian Capital Territory, but it also supports a variety of ecological processes that support internationally and nationally listed threatened and endangered species. Due to the importance of the water resources of the Murray–Darling Basin, a coordinated approach to water management across the Basin States has been adopted through the development and implementation of the *Basin Plan 2012* (Basin Plan).

One key component of the Basin Plan is the requirement for Basin States to develop water resource plans (WRPs) for identified WRP areas. In total, 36 WRP areas are identified under the Basin Plan, with three of these occurring within South Australia (Figure 1):

- South Australian River Murray
- Eastern Mount Lofty Ranges (EMLR)
- SA Murray Region.

The purpose of a WRP is to set out the management and planning arrangements for Basin water resources taking into consideration connected resources. Under the Basin Plan (Chapter 10), WRPs must set limits on the quantities of surface water and groundwater that can be taken for consumptive purposes and establish rules to ensure environmental and water quality objectives are met.

The first step in developing a WRP is the identification and assessment of risks to the condition or continued availability of Basin water resources (as stated in Chapter 4 of the Basin Plan). This risk identification and assessment process can then be used to develop fit-for-purpose, cost-effective strategies or measures to address the risks.

The risk assessment presented in this report is aimed at addressing the requirements of Chapter 10 of the Basin Plan for the WRP area identified as the South Australian River Murray. This corresponds to the surface water WRP area denoted as SW6 (Basin Plan section 3.05) and the corresponding sustainable diversion limit (SDL) resource unit SS11. The South Australian River Murray WRP area is a surface water WRP area only and does not include any groundwater resources. Groundwater beneath the River Murray is included in the SA Murray Region WRP area.

This risk assessment recognises that failure to implement the Basin Plan in full and on time, both in South Australia and in upstream states, could adversely affect the risk profile in the South Australian River Murray. The timetable for Basin Plan implementation extends to 2024 for some measures. This means that the full extent of both Basin Plan implementation and effectiveness in achieving outcomes was not known at the time of risk assessment. However, this assessment assumes that the Basin Plan will be implemented on time and in full, while uncertainty remains regarding the manner in which some elements of the Basin Plan will be implemented.

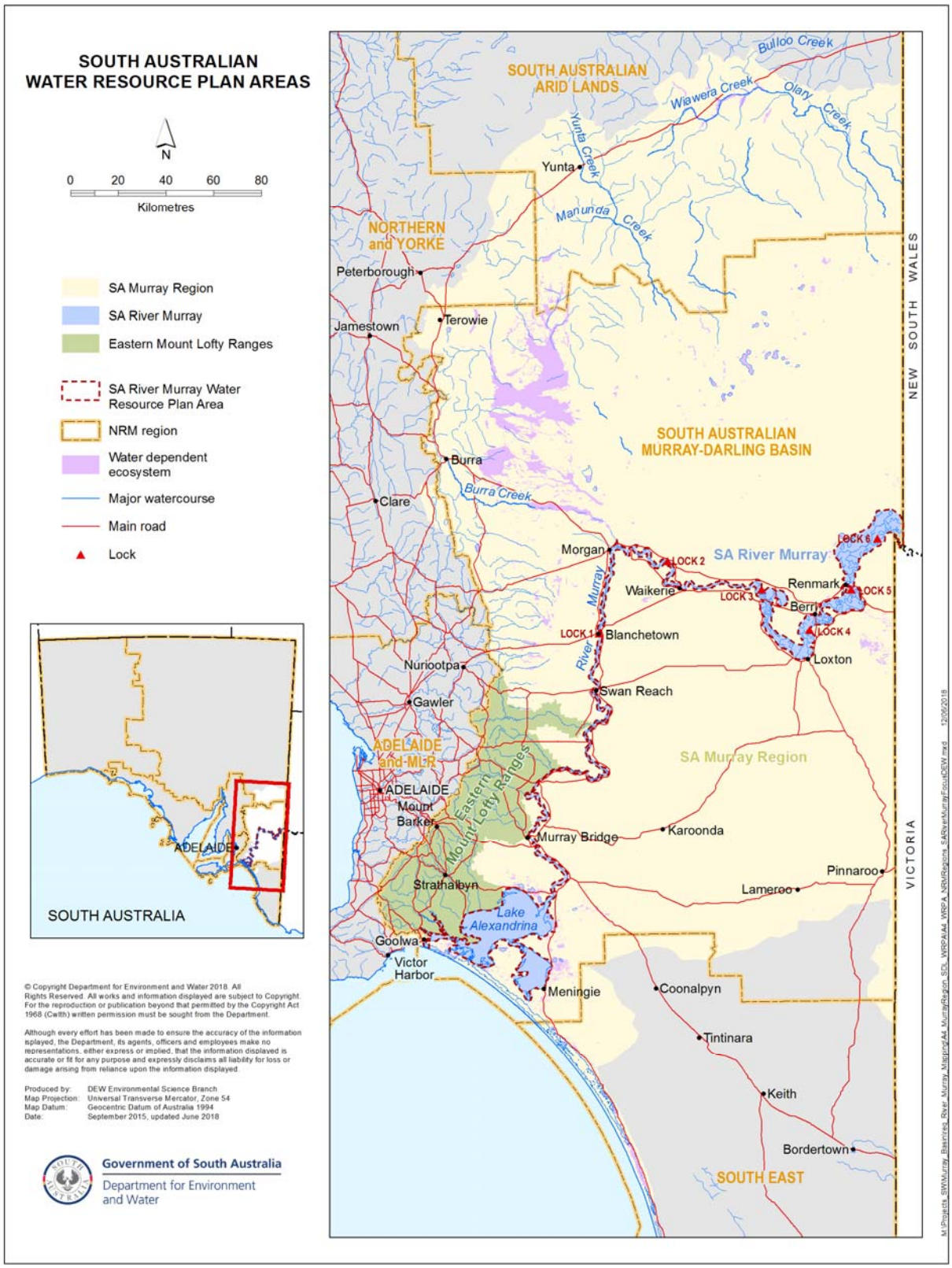

Figure 1. South Australia's WRP areas as identified by the Basin Plan

2 Background

2.1 South Australian River Murray Water Resource Plan area

The South Australian River Murray Water Resource Plan (WRP) area, as identified in the Basin Plan (Figure 1) includes the River Murray and its floodplain (defined by the 1956 flood extent), from the SA/NSW/Victoria border to the barrages. The area includes Lakes Alexandrina and Albert (the Lower Lakes) and the confluences of Currency Creek and the Finniss, Angas and Bremer rivers.

The South Australian River Murray WRP area, which includes only surface water, does not include:

- the Coorong or Murray Mouth which, for the purposes of the Basin Plan, are included in the SA Murray Region WRP area
- groundwater resources below the river and the Lower Lakes, which are also part of the SA Murray Region WRP area (Basin Plan Schedules 2 and 4).

The South Australian River Murray WRP area is consistent with the River Murray Prescribed Watercourse under South Australia's *Natural Resources Management Act 2004* (NRM Act) and lies entirely within the South Australian Murray–Darling Basin natural resources management (NRM) region. Being a prescribed watercourse, the River Murray water allocation plan (WAP) is the key state statutory instrument that outlines how the water resource will be managed to meet the requirements of the NRM Act.

The River Murray in South Australia is located at the end of the Murray–Darling Basin system and is the largest river in the state. South Australia diverts approximately 7 per cent of the Basin's total extracted surface water resources (SAMDB NRM Board 2017a). The River Murray Prescribed Watercourse area is part of a region that is home to some 66,000 people (Australian Bureau of Statistics 2007–2011), which equates to approximately 4 per cent of South Australia's population. The River Murray supplies water for irrigation, industries, urban and town water use and supports high-value ecological communities, including nationally and internationally important wetlands. The River is also important for a range of social and cultural needs. The main economic driver for communities along the river is primary production followed by value-adding manufacturing. The region contributes at least $2.2 billion to South Australia's estimated $15 billion gross food and wine production. Tourism is a major industry in the region, which contributes $200 million annually to the Murraylands and Riverland (Regional Development Australia 2014).

The provision of water for public supply represents a significant licensed use of water from the River Murray Prescribed Watercourse. SA Water can divert a maximum of 650 gigalitres (GL) over any consecutive five-year period to provide water to metropolitan Adelaide and associated country areas via three pipelines (the Swan Reach–Paskeville pipeline, Mannum–Adelaide pipeline and Murray Bridge–Onkaparinga pipeline). A further entitlement of 50 GL per annum is held by SA Water to supply urban water to other country towns, which is largely delivered via the Morgan–Whyalla pipeline, Tailem Bend–Keith pipeline and direct Riverland town water treatment plants.

The reservoirs of the Mount Lofty Ranges catchment are the primary preferred source of water to metropolitan Adelaide. However, like the River Murray system, annual inflows to the Mount Lofty storages are highly variable. Annual diversions from the River Murray to supplement the provision of water to Adelaide are therefore also highly variable (between 10 per cent and 90 per cent). Over the last five years, 54 per cent of South Australia's urban water needs were supplied from the River Murray, ranging from 36 per cent during wet years in the Mount Lofty Ranges and 83.5 per cent

during dry years (SA Water annual reports). On average, the River Murray provides 45 per cent of metropolitan Adelaide's water.

The hydrology of many wetlands along the River Murray was permanently changed in the 1920s and 1930s with the installation of weirs along the river. As a result of the weirs, water levels are no longer as variable and wetlands have gone from being seasonally to permanently inundated. This altered hydrology has changed the dynamics and the ecology of the affected wetlands.

The South Australian River Murray WRP area includes three Ramsar-listed wetlands of international importance. These include: part of the Coorong, Lower Lakes and Murray Mouth Ramsar Site; the Riverland Ramsar Site (which includes Chowilla); and the Banrock Station Wetland Complex.

Wetlands play a critical ecological role and perform functions such as: water purification; flood mitigation; providing vital refuge, nursery and habitat areas for many species; and replenishing the groundwater. They are important culturally, socially and to economies along the river.

Water is held on licence for the management of icon sites along the River Murray through The Living Murray program (TLM). TLM arose recognising that to achieve a healthy, functioning river system, water that was previously taken out for consumptive purposes would need to be returned to the environment. TLM was set up by the Commonwealth and Basin States in 2002 as a long-term river restoration program. The South Australian icon sites are: the Chowilla Floodplain; the Lower Lakes, Coorong and Murray Mouth; and the River Murray Channel (Murray–Darling Basin Authority 2011).

Allocations are also held by the Commonwealth of Australia and the South Australian Minister for Water and the River Murray for environmental watering purposes. The delivery of water arising from these allocations is coordinated through state and Basin-wide environmental watering plans to deliver on agreed outcomes. This process includes annual identification of state priorities which informs the Basin-wide annual watering priorities. These agreed Basin priorities guide the delivery of environmental water by the Commonwealth Environmental Water Holder, TLM and state environmental water holdings with input from the Southern Connected Basin Environmental Watering Committee, which aims to maximise environmental outcomes for sites by coordinating environmental watering across state borders.

2.2 Sub-areas for risk assessment

The South Australian River Murray WRP area is large and diverse. To promote consistent identification and analysis of risk, the risk assessment considered smaller spatial extents having similar physical and management characteristics. These sub-areas were defined based on alignment with the South Australian long-term environmental watering plan (LTWP) for the River Murray (DEWNR 2015). The sub-area boundaries took into consideration inherent characteristics including climatic, geomorphic and ecological, as well as river operation and management.

In total, three sub-areas were defined (Table 1):

- The Upper Murray – the River Murray channel upstream of Lock 1 (at Blanchetown) to the NSW/Victoria state border; this sub-area includes the floodplain (to the 1956 flood level)
- The Lower Murray – the River Murray channel downstream of Lock 1 to Wellington
- The Lower Lakes – Lake Alexandrina and Lake Albert to the barrages and includes the confluences with Currency Creek and the Finniss, Angas and Bremer rivers.

These sub-areas are described further in the sections below.

The Coorong and Murray Mouth, while connected to the Lower Lakes and included as part of the LTWP for the River Murray, is not included in the South Australian River Murray WRP area (as defined by the Basin Plan (section 3.05)). This critical asset is included in the SA Murray Region WRP area. Risks to the Coorong and Murray Mouth are addressed by the risk assessment for that WRP (DEWNR 2017).

2.2.1 Upper Murray

The Upper Murray sub-area covers the River Murray Prescribed Watercourse from the SA/NSW/Victoria border down to, and including, Lock 1. The River Murray channel within this sub-area is a highly modified system and heavily regulated. A series of six locks and weirs within the sub-area are used to regulate downstream river flows. They are used to manage water levels to deliver water for consumptive use and allow river vessels to navigate the weirs via the locks.

An offtake at Morgan supplies water to the population centres of the mid north and upper Spencer Gulf via SA Water's Morgan–Whyalla double pipeline. The towns along the River Murray in this sub-area, such as Renmark, Berri, Loxton, Barmera and Waikerie, all rely on the River Murray for town water supply.

The water resources of the River Murray support extensive irrigated agriculture in the region around the channel and floodplains of the River Murray known as the Riverland. Significant horticultural crops include grapes (table and wine), citrus, stone fruit, vegetables and nuts. Primary production supports a range of processing and packaging industries, with the Riverland being the state's largest producer of wine grapes (Regional Development Australia 2014).

The Upper Murray sub-area contains two Ramsar-listed wetlands of international importance: the Banrock Station Wetland Complex and the Riverland Ramsar site. The Banrock Station Wetland Complex was listed as a Ramsar wetland of international importance in 2002 (Butcher et al. 2009). The Riverland Ramsar site, first listed in 1987, is contained entirely in the Riverland Biosphere Reserve. It is located on the River Murray floodplain between the town of Renmark and the SA/NSW/Victoria border (Newall et al. 2009).

The Upper Murray sub-area is an area with significant saline groundwater inflows to the River Murray. The impact of these inflows on the floodplain and the river channel are managed through a series of salt interception schemes that intercept saline groundwater before it reaches the River and divert it into a series of disposal basins. The area around this sub-area is characterised by low rainfall (200–300 mm per year) (SAMDB NRM Board 2014).

2.2.2 Lower Murray

The Lower Murray sub-area comprises a 210 km stretch of river from Lock 1, located at Blanchetown, to the township of Wellington where the River Murray flows into Lake Alexandrina and Lake Albert. The sub-area contains areas of floodplains having high ecological value that support state and nationally listed threatened and endangered species.

There are no locks or weirs controlling water level within this stretch of the river. Water levels in the Lower Murray are primarily linked to the water levels in the Lower Lakes, which are controlled through releases over Lock 1 and through the barrages to the sea, although daily water level changes of 30 cm may occur under the influence of south-westerly winds (Webster et al. 1997).

The Lower Murray supports potable water supply to over 1.2 million people including in the Adelaide metropolitan area, Barossa Valley, Adelaide Hills, Fleurieu Peninsula and the upper South East of South Australia. This water is pumped through four pipelines owned by SA Water. These are the Swan Reach to Stockwell, Mannum to Adelaide, Murray Bridge to Onkaparinga and Tailem Bend to Keith pipelines. For the smaller towns, River Murray water is the only source of water, while during prolonged dry

periods in the Mount Lofty Ranges, as much as 90 per cent of the total water supply for this population may be pumped from the river.

The SA Water infrastructure supplied by the Lower Murray supports significant industrial and commercial activity in the Adelaide region and the upper South East. River Murray water is also used for irrigation of wine grapes in the Barossa Valley.

The Lower Murray Reclaimed Irrigation Area (LMRIA) is approximately 5,200 hectares of flood-irrigated agricultural land protected by a levee bank system on the former floodplain of the River Murray in South Australia (Leyden et al. 2012). The LMRIA is located between the townships of Mannum and Wellington and comprises 24 individual irrigation areas. Historically, dairy farming was the predominant land use; however, following the Millennium Drought, it is increasingly used for beef cattle, fodder production and lifestyle farming.

The irrigation bays are typically 1.0–1.5 m below the normal river pool level (+0.75 mAHD (metres with respect to Australian Height Datum)), enabling gravity-fed flood irrigation. The excess runoff from irrigation, as well as highland groundwater seepages, are returned to the River Murray via a drainage network and pumping system (Mosley et al. 2009).

The LMRIA is recognised as a significant point source pollution risk in the WRP area. During periods of low inflows between 2007 and 2009, water levels within the Lower Murray River (below Lock 1) fell, lowering the groundwater table and exposing acid sulfate soils underlying pastures to oxygen. This caused significant drying, cracking and slumping. When water levels in the river rose together with groundwater levels, and irrigation recommenced in the area (2010–11), sulfuric acid was mobilised and transported to the drains (Leyden et al. 2012). Acid water along with elevated metals is a characteristic of the drainage returning into the River Murray.

The groundwater inflows into the Lower Murray are less saline and there are no salt interception schemes. There are some small inflows from the Eastern Mount Lofty Ranges (EMLR) through ephemeral tributaries such as the Marne River and Saunders Creek (SAMDB NRM Board 2010).

2.2.3 Lake Alexandrina and Lake Albert (Lower Lakes)

The Lower Lakes include Lake Alexandrina (approximately 65,000 hectares) and Lake Albert (approximately 23,000 hectares) which together represent the largest freshwater reservoir in South Australia. Lake Albert is situated to the south-east of Lake Alexandrina, to which it is connected by a narrow channel near Point Malcolm (Phillips and Muller 2006). For the purposes of this assessment, the sub-area covers the area of the lakes between Wellington and the barrages.

Lake Alexandrina and Lake Albert are shallow, with mean depths of 2.8 m and 1.7 m respectively (DEWNR 2014). Lake Albert is generally more saline but less turbid than Lake Alexandrina (WAP 2009). Surface water inflows are dominated by the River Murray, which flows into the north of Lake Alexandrina near the township of Wellington. There are also minor inflows from the tributary streams draining the southern catchments of the EMLR along the edge of Lake Alexandrina. Freshwater in Lake Alexandrina maintains inundation of wetlands in the lower reaches of tributaries to the EMLR, which include Currency Creek, and the Finniss, Angas and Bremer rivers.

Lake Alexandrina is the primary source of inflows to Lake Albert, although there are minor additional inflows from local rainfall and groundwater discharge (Phillips and Muller, 2006). As Lake Albert has no through-flow connection to the Coorong, it represents a local, inland terminus of the River Murray system (Phillips and Muller 2006).

The Lower Lakes together with the Coorong are a declared wetland of international importance under the Ramsar Convention. The Lower Lakes are physically separated from the Coorong (and Murray Mouth) through a series of islands, channels and five barrages (DEWNR 2015). The barrages were

constructed in the 1930s to prevent ingress of saline water to the Lower Lakes and to regulate lake water levels. Since 2002, five fishways have been incorporated into two barrages and associated channels to allow fish movement between the freshwater and saline environments (DEWNR 2015).

Water quality and levels in Lake Alexandrina and Lake Albert are highly dependent on flows into the lakes from the River Murray and out through the Goolwa and Tauwitchere barrages. Wind is a significant factor affecting transfer of water between the lakes and the Coorong. During low flows, the barrages can be closed to create a barrier to prevent seawater from entering the freshwater lakes. Sufficient flows through the barrages are required to flush salt and other pollutants to maintain water quality in the lakes as well as provide adequate flows to the Coorong when possible.

The Millenium Drought had a severe impact on water quality in the Lower Lakes and Coorong. Before the Millenium Drought, salinity averaged less than 700 EC in Lake Alexandrina and less than 1,600 EC in Lake Albert. During the drought, levels increased to 9,000 EC in Lake Alexandrina and 22,000 EC in Lake Albert. Since the drought, water quality in Lake Alexandrina has returned to pre-drought conditions with average salinity generally remaining between 400 and 800 EC. Salinity levels in Lake Albert have improved more slowly than Lake Alexandrina since the drought and have remained between 2,700 EC and 2,400 EC (to mid-June 2014) which are above the long-term average concentrations of 1,500 EC (DEWNR 2014).

The economy within the sub-area is largely based on tourism, stock grazing and rural living. Irrigation occurs to the north of Lake Alexandrina, within the Eastern Mount Lofty Ranges WRP area, using local surface water and groundwater as well as River Murray water piped from the Lower Murray sub-area.

Table 1. South Australian River Murray WRP risk assessment sub-areas

Sub-area name	Sub-area abbreviation	Corresponding SDL resource unit	Resource type	Description
Upper Murray	1	SS11	Surface water	Above Lock 1 to the border with NSW/VIC
Lower Murray	2	SS11	Surface water	Below Lock 1 to Wellington (north of Lake Alexandrina)
Lower Lakes	3	SS11	Surface water	The Lower Lakes (to the barrages) including the confluences of the Finniss, Angas and Bremer rivers and Currency Creek with Lake Alexandrina

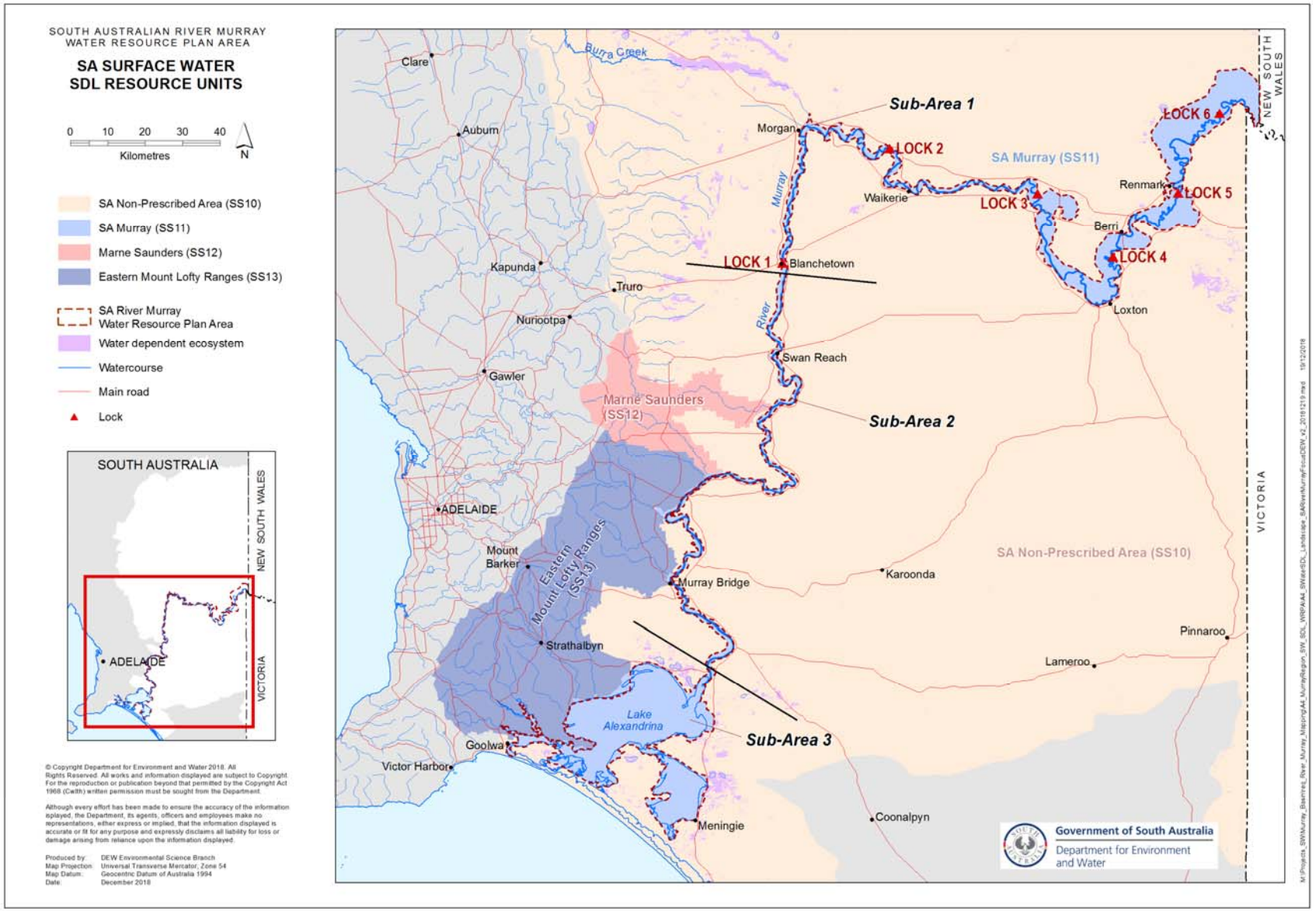

Figure 2. River Murray risk assessment sub-areas

2.3 South Australian instruments for water resource management

South Australia has a range of legislation, plans and policies addressing water planning and management issues in the state. Collectively, these instruments address risks to water resources arising from multiple sources and covering different scales.

Most importantly the *Natural Resources Management Act 2004* (NRM Act) provides the legislative framework for the sustainable management, planning and allocation of surface water and groundwater resources in South Australia. Under this legislation, water resources can be prescribed by the Minister. Where a resource is prescribed, a water allocation plan (WAP) must be prepared and must outline the principles by which the water resources are managed. The purpose of the WAP is to provide for the sustainable use of the resources while achieving an equitable balance between environmental, social and economic needs for the water. The WAPs govern access entitlements and any other rules related to the use of water resources which are managed through a water licensing system. In accordance with the NRM Act, the River Murray is a prescribed watercourse and as such the River Murray WAP is the key South Australian instrument for managing the water resources in the South Australian River Murray WRP area.

Given the importance of the River Murray to South Australia, a number of other instruments also govern the management and use of water resources of the South Australian River Murray WRP area. These include the South Australian Murray–Darling Basin regional NRM Plan, the South Australian Environment Protection (Water Quality) Policy 2003 (SA Water Quality Policy), and the *River Murray Act 2003*. These instruments control a range of activities potentially affecting the quality and quantity of water in the WRP area.

At a national level, the *Water Act 2007* and the Murray–Darling Basin Agreement (Schedule 1 of the *Water Act 2007*) provide the planning and management arrangements to ensure efficient and sustainable use of the water resources of the Murray–Darling Basin. Among other things, the intergovernmental agreement provides rules for ensuring water for critical human water needs (CHWN) is available (and allocated the highest priority) within the River Murray system. It also provides for storage rights and water sharing arrangements between the Basin States, the original long-term caps on the volume of surface water used for consumptive purposes in river valleys of the Murray–Darling Basin, as well as frameworks for salinity management and the inter-valley and interstate transfer of water entitlements and allocations.

In accordance with the directions of the Agreement on a National Water Initiative 2004, South Australia is moving towards risk-based management of the state's water resources. DEW has developed and published the Risk Management Framework for Water Planning and Management (DEWNR 2012a) and the Risk Management Policy and Guidelines for Water Allocation Plans (DEWNR 2012b). The framework and policy adopt the principles and processes of the AS/NZS ISO 31000:2009 risk management standard for assessing and managing water resource risks in South Australia.

3 Risk assessment method

3.1 Overview

Consistent with the requirements of the Basin Plan, the risk assessment applied the AS/NZS ISO 31000:2009 international standard for risk management (Joint Technical Committee OB-007, Risk Management 2009), as adapted by South Australia's risk management framework for water planning and management (DEWNR 2012a). The application of this approach promotes consistency across the risk assessments for the South Australian River Murray Water Resource Plan (WRP), the SA Murray Region WRP (DEWNR 2017) and the Eastern Mount Lofty Ranges (EMLR) WRP (DEW 2019).

AS/NZS ISO 31000:2009 defines risk as *the effect of uncertainty on* objectives. The risk management process is summarised by the following steps:

1. *Establishing context*, which involves determining the internal and external parameters (purpose, scope, principles, scales and assessment criteria) to be taken into account when managing risk and setting the risk criteria
2. *Assessing risks*, involving:
    2.1. *Risk identification*, whereby risks are identified, recognised and described
    2.2. *Risk analysis*, which involves comprehending the risk and determining the risk level, and
    2.3. *Risk evaluation*, whereby the results of the risk analysis are compared with criteria to determine the acceptability or tolerability of the risk level
3. *Risk treatment*, involving decisions regarding management response to intolerable risks (e.g. mitigation of likelihood or consequences, avoidance, transfer to another party, retain and accept).

The following sections provide an overview of the method applied for the steps of the risk assessment process.

3.2 Establishing context

The risk management context for the South Australian River Murray WRP was established through engagement with South Australian government officers having responsibility for the range of issues associated with water resource management in the South Australian River Murray. These included officers from the then Department of Environment, Water and Natural Resources (DEWNR) (including science, policy, River Murray operations, and regional water planning functions), SA Water, the Environment Protection Authority (EPA), SA Health and the Department of Primary Industry and Regions (PIRSA). This engagement process facilitated agreement on the risk criteria and risk assessment method used for the South Australian River Murray WRP.

The South Australian River Murray WRP risk management context-setting process covered themes including:

- Basin Plan requirements (section 3.2.2)
- other relevant legislation, policy and planning including state water planning instruments (section 2.3)

- definitions related to risk (section 3.2.1)
- risk assessment end points and consequence criteria (section 3.3)
- sub-area scale for risk assessment (section 2.2)
- time periods relevant for future risk (section 3.2.4)
- key parameters affecting risk identification (section 3.4)
- risk analysis methods (section 3.5).

General principles governing the risk assessment process for the South Australian River Murray were established:

- Where possible, risk consequence was assessed according to quantitative criteria describing absolute deviations from objectives (section 3.3.2).
- Risk statements described the chain of circumstances leading to risk including risk sources, events and consequences at the scale of sub-areas over the risk assessment timeframe.
- The scope of the risks assessed covered the requirements of the Water Act and Basin Plan governing the development of WRPs (section 3.2.2).
- The assessment drew on existing data and knowledge with no new investigations or monitoring programs initiated to inform the risk analysis.
- The risk assessment considered the effectiveness and implementation of controls likely to be in place during the future 10-year timeframe over which risks were assessed. Controls included legislation, policy, infrastructure and operations intended to manage risks.

3.2.1 Definitions

This risk assessment adopted the following definitions consistent with AS/NZS ISO 31000:2009:

- **Risk** is defined as the effect of uncertainty on objectives.
- **Risk level** is the combination of likelihood and consequence.
- **Consequence** is measured as the undesirable deviation from the environmental, social and economic objectives expressed for the South Australian River Murray through existing state and national policy. This includes deviations from the outcomes which would be achieved should the Basin Plan be implemented on time and in full[1].
- **Likelihood** is defined as the probability that an event of a given consequence will occur over the risk assessment's timeframe. For this assessment, likelihood considered the probability that a given level or severity of consequence is the worst observed within a sub-area over the 10-year timeframe agreed for the risk assessment.

[1] Full implementation of the Basin Plan is defined for this purpose as the recovery of 2,750 GL of water for the environment, the recovery of the additional 450 GL achieved through supply and efficiency measures, full implementation of Prerequisite Policy Measures, constraints for the system to be addressed, and for there to be no reduction in planned environmental water across the Basin.

- A **risk source** is an element which has the intrinsic potential to give rise to risk. A risk source generates hazard.
- A **risk control** is a policy, plan or program developed and/or implemented by government to manage risks.
- A **risk statement** describes the chain of circumstances leading from a risk source to an event, leading to consequence.

3.2.2 Basin Plan requirements

The risk assessment was undertaken to inform the development of the South Australian River Murray WRP in accordance with Basin Plan requirements (i.e. section 10.41, which states that *'a water resource plan must be prepared having regard to current and future risks to the condition and continued availability of the water resources of the water resource plan are'*). The risk assessment was undertaken for the surface water resources within and affected by the South Australian River Murray WRP area defined in section 3.05 of the Basin Plan.

The Water Act and the Basin Plan informed the scope of risks assessed. Section 22(1) of the Water Act (Item 3) refers to risks to the availability of Basin water resources arising from the following stressors:

a) the taking and use of water (including through interception activities)

b) the effects of climate change

c) changes to land use

d) limitations on the state of knowledge of the basis on which estimates about matters relating to Basin water resources are made.

Section 4.02 of the Basin Plan notes that the stressors outlined by the Water Act can give rise to the following risks:

- insufficient water available for the environment (risks to the capacity to meet environmental water requirements)
- water being of a quality unsuitable for use (risks arising from elevated levels of salinity or other types of water quality degradation)
- poor health of water-dependent ecosystems.

The bow-tie model template developed for risk identification (section 3.5) accounts for these requirements in the definition of risk sources, events and consequences.

For the purposes of section 4.02, Aboriginal cultural risks are considered to have been included in the social considerations of the risk assessment. While the risk assessment for the South Australian River Murray WRP area does not explicitly evaluate risks to Aboriginal values and uses, there has been some inherent consideration of these where Aboriginal values and uses overlap with environmental values and uses.

It is widely acknowledged that some Aboriginal cultural values overlap with ecological values, and this is reflected in the general support from the Ngarrindjeri Regional Authority and First Peoples for the use of water allocation plans (WAPs) to manage the use of water to ensure potential risks to the water resources are minimised and water remains available for the environment. For those Aboriginal cultural values and uses risks that are not addressed by managing environmental risks, more work is needed both within First Nations and with DEW. A project with the Goyder Institute is beginning to work with South Australian Murray–Darling Basin Nations to develop their own culturally appropriate

assessment tools. Once risks to Aboriginal values and uses arising from the use and management of the water resources have been identified, the WRP will be reviewed to consider those risks.

3.2.3 Exclusions

Risks to the structural integrity of aquifers

The Basin Plan requires a WRP to have regard to whether it is necessary to include rules to ensure that there is no structural damage to an aquifer arising from take.[2] The South Australian River Murray WRP area is a surface water resource, which means that there is no risk of structural damage to aquifers within this WRP area. Furthermore, the SA Murray Region WRP risk assessment determined that there is low risk to aquifers adjoining the River Murray arising from the management of connected water resources including the River Murray (DEWNR 2017). Given this context, risks to the structural integrity of aquifers are not specifically addressed by this risk assessment since they were determined to be low or not applicable.

Risks associated with hydraulic relationships

The Basin Plan requires that hydraulic relationships between and within groundwater and surface water systems are maintained. It was determined that risks to hydraulic relationships between water resources are considered through assessment of risks related to connected water resources. Risks to hydraulic relationships within the South Australian River Murray are covered through the analysis of potential for water resource events as defined through the risk identification method (section 3.4).

Risks caused by interception activities

The WRP must have regard for the risks related to interception activity in the WRP area.[3] It was determined that these risks are not applicable since there are no runoff dams, commercial plantations, mining activities or floodplain harvesting within the South Australian River Murray WRP area. In addition, the area is designated as the River Murray Protection Area for the purposes of the *River Murray Act 2003*, which minimises the likelihood that interception activities will have significant impact in the future. Therefore, these risks are not specifically addressed by the risk assessment.

3.2.4 Temporal scale for risk assessment

A WRP must be prepared having regard to current and future risks regarding water resources.[4] For this assessment, it was determined that the risk assessment should consider a 10-year future timeframe consistent with the review period for water planning instruments required under the NRM Act. This approach allows for the South Australian River Murray WRP to address risks that are relevant over this timeframe while mandating the periodic review of these risks and the effectiveness of risk mitigation strategies.

This risk assessment did not specifically address risks occurring over a longer timeframe than a future 10-year period, although these are likely to be correlated with risks within the agreed timeframe. It was determined that the location of the WRP area at the end of the Murray–Darling Basin means that upstream management of the river system is likely to be a significant source of risk to the South Australian River Murray over the longer term. The Basin Plan is a key control for this risk. However, at

[2] Section 10.20

[3] Section 10.23 (1)

[4] Section 10.41 (1)

the time of the assessment there was uncertainty regarding the effective implementation of the Basin Plan, which, in turn, impacts confidence in the assessment of longer-term risk. For this reason, it was determined that there is limited value in explicitly considering longer-term risks that could be effectively addressed through the review cycles mandated for South Australia's water planning instruments.

3.2.5 General approach

It was recognised that risk pathways in the South Australian River Murray WRP context can be complex as they involve multiple cause–effect relationships and interact with multiple controls. Developing a sufficient understanding of risk therefore requires a multidisciplinary approach to analysis.

To address this requirement, it was agreed that the risk assessment adopt a participatory, expert-driven approach to engage the range of South Australian government officers who have responsibility for managing water resource risks or who hold technical or policy expertise related to water resource risk. The assessment process also engaged regional officers having 'community-facing' water planning roles as a means of accessing insight into community values and attitudes. This approach to engagement and participation was applied for all steps of the risk assessment consistent with the SA Murray Region and Eastern Mount Lofty Ranges WRP area risk assessments.

3.3 Risk criteria

Risk criteria are the terms of reference against which the significance of risk is determined according to potential consequences and their likelihood. Based on the likelihood and consequence, risks were assigned ratings of low, medium and high (as per the risk matrix in Table 9 and consistent with Basin Plan requirements).

The configuration of likelihood and consequence criteria reflects the attitude to risk of those with responsibility to manage risk and of the community potentially affected by risk.

3.3.1 Likelihood criteria

The risk evaluation process requires that likelihood is categorised to determine the risk level from the risk matrix. Criteria for five likelihood categories (Table 2) were developed through the context setting and risk evaluation steps of the risk assessment. Together with the consequence criteria (section 3.3.2), they are configured to reflect the context of the South Australian River Murray, including its unique importance as a water resource in South Australia, and the attitude to risk of stakeholders.

Table 2. Likelihood levels for risk evaluation

Likelihood category	Qualitative description	Probability
Almost certain	Expected to occur in all circumstances	91–100%
Likely	Greater than even chance of occurring but not certain	51–90%
Possible	Less than even probability of occurring, but not unusual	26–50%
Unlikely	Unusual but not exceptional	11–25%
Rare	Only occurs in exceptional circumstances	0–10%

3.3.2 Consequence criteria

The end points of the risk assessment were identified as the social, environmental and economic objectives and values for the WRP area and connected water resources. Consequence criteria were developed to quantify deviation from objectives with respect to the following:

- the economic use of water (consumptive and/or non-consumptive)
- critical human water needs
- water-dependent ecosystem values
- connected water resources.

A key principle guiding the development of the criteria was linkage to existing objectives and commitments (legislative and policy) to ensure that the risk assessment does not measure deviation relative to unstated or unachievable goals.

Development of consequence criteria was undertaken through the context setting stage of the risk assessment and involved relevant technical experts and South Australian government officers. Criteria developed for other South Australian WRP risk assessments (SA Murray Region and EMLR WRP areas) were referred to as a starting point for the development of River Murray-specific criteria.

3.3.2.1 Economic use of water

It was determined that key context-driving economic risks in the River Murray WRP are the large volumes involved in and high economic values associated with consumptive use of water. Important parameters affecting potential economic outcomes include the impacts of reductions in allocations over time and economic losses associated with reduced productivity and damage to assets and infrastructure.

The following assumptions and elements of context were considered through the development of criteria:

- Economic consumptive use of water considers water to support irrigation, intensive animal production and industrial use such as mining and stock use. Excluded from this definition are metropolitan commercial use and human domestic use, which are covered under criteria for critical human water needs.
- Non-consumptive economic use of water includes activities that depend on ecosystem services provided by water resources. Ecosystem services include provisioning, regulating, supporting and cultural services, but exclude cultural services supporting Aboriginal use (to be addressed in a subsequent assessment). Economic activities that depend on these services potentially include fisheries, tourism and recreation.
- Damage to assets and infrastructure includes:
    - drying of perennial crops
    - damage to land productivity through water quality impacts
    - damage to irrigation infrastructure (e.g. cracking or corrosion).
- Economic loss due to water resource events is defined as the sum of the losses arising from reduced productivity of consumptive and non-consumptive uses and damage to assets and infrastructure.

- Loss of production in the primary industry sector can be quantified as a change in the gross value of production. The gross value of production is the market value of produce at the point of sale (when it leaves the agricultural sector of the economy).
- The market value of water not available for economic consumptive use during the worst years of the Millennium Drought provides context on the potential economic losses caused by events in the River Murray:
    - 2008–09: 18 per cent allocations corresponding to approximately 464 GL unavailable for irrigation (before trade and carryover); market value at that time = approximately $181 million ($390/ML)
    - 2007–08: 32 per cent allocation corresponding to approximately 385 GL unavailable for irrigation (before trade and carryover); market value at that time = approximately $161 million ($418/ML).
- Losses associated with reductions in allocations were determined using the South Australian government's dry allocation framework, endorsed for the 2016–17 water year. This framework covers South Australia's Entitlement Flow.
- Minimum opening allocations for 2016–17 were 36 per cent (Minister's press release, 28/4/16) (DEWNR 2016). The minimum opening allocation was intended to be conservative; it factored in the potential for the 2016–17 water year to be very dry and allowed for allocations to be revised upwards in the event of wetter conditions. The previous two water years (i.e. 2014–15 and 2015–16) were dry with below average River Murray system inflows. The water year 2015–16 was within the driest 9 per cent of years on record (MDBA 2016b).
- Economic consequence of water resource events will in turn lead to commensurate social impacts. Social impacts have not been directly quantified through these criteria but are considered to be encapsulated through economic losses.

It was determined that four consequence severity levels were adequate to cover the range of potential risks relating to the economic use of water.

3.3.2.2 Critical human water needs

The criteria associated with impacts on critical human water needs (CHWN) were deemed necessary due to the high dependence relative to the SA Murray Region and EMLR WRP areas. The majority of South Australia depends on the River Murray for CHWN (1.2 million people) with the only major population centres in the state that do not being the lower Eyre Peninsula and the lower south-east. It was therefore determined that the criteria should be adapted to take into consideration this high level of dependence and cumulative impacts associated with supply interruptions over time. This was determined to be consistent with SA Water's risk criteria related to supply security and also took into consideration South Australia's dry allocation framework for 2016–17 (DEWNR 2016).

SA Water is the principal licensed supplier of water for CHWN in South Australia and maintains two licences. One licence covers metropolitan Adelaide while the second supplies all other users (country towns licence). People who depend on the country licence supply have fewer alternative water supplies to the River Murray than those covered by the metropolitan licence, as this latter supply also has access to water from the Mount Lofty Ranges and the Adelaide desalination plant.

Table 3. Consequence criteria – economic use (consumptive and non-consumptive)

Consequence category	Description
Catastrophic (5)	Water not available for economic consumptive use purposes having market value >$50m. River Murray water allocation <30% for a single year or <50% for two or more consecutive years, or Economic losses from impacts to ecosystem service provision including reduced productivity of non-consumptive economic use and damage to assets and infrastructure with a total value of >$50m
Major (4)	Water not available for economic consumptive use purposes having market value $10m–$50m. River Murray water allocation <50% for a single year or 50–75% for two or more consecutive years, or Economic losses from impacts to ecosystem service provision including reduced productivity of non-consumptive economic use and damage to assets and infrastructure with a total value of $10m–$50m
Moderate (3)	Water not available for economic consumptive use purposes having market value $1m–$10m. River Murray water allocation 75–90%, or Economic losses from impacts to ecosystem service provision including reduced productivity of non-consumptive economic use and damage to assets and infrastructure with a total value of $1m–$10m
Minor and Insignificant (1)	River Murray Water Allocation >90 %, or Losses or damage <$1m

The following definitions and assumptions were incorporated in the CHWN consequence criteria (as shown in Table 4):

- CHWN is defined under section 86A(2) of the *Water Act 2007* as: (a) the minimum amount of water required to meet core human consumption requirements in urban and rural areas; and (b) those non-human consumption requirements that a failure to meet would cause prohibitively high social, economic or national security costs.
- CHWN does not include water for stock or dryland farming use.
- A primary source for town or community water supply is one that provides water of drinking quality and is the main source of water.
- A supplementary source for town or community water supply is provision of non-potable supply that supplements a primary potable supply and is used for things other than drinking and food preparation.
- The term 'customers' includes both domestic and commercial users covered under the definition of critical human water needs.
- These criteria apply to the customers of water providers licensed under the *Water Industry Act 2012*.

Table 4. Consequence criteria – critical human water needs

Consequence category	Description
Catastrophic (5)	Interruption of primary supply of water to >100,000 customers for >48 hours Interruption of primary supply of water to 10,000–100,000 customers for an extended period of time (>1 week)
Major (4)	Interruption to primary supply of water to 10,000–100,000 customers for >48 hours Interruption to primary supply of water to 1,000–10,000 customers for an extended period of time (>1 week)
Moderate (3)	Interruption to primary supply of water to 1,000–10,000 customers for >48 hours Interruption to primary supply of water to 100–1,000 customers for an extended period of time (>1 week)
Minor (2)	Interruption to primary supply of water to 100–1,000 customers for >48 hours Interruption to supplementary non-potable town water supply
Insignificant (1)	Interruptions of primary supply to <100 customers or for periods of <48 hours

3.3.2.3 Water-dependent ecosystems

A review of the criteria developed for impacts to water-dependent ecosystems (WDEs) was undertaken to ensure alignment of the risk assessment with the long-term environmental watering plan (LTWP) for the River Murray (DEWNR 2015). The overall objectives of the LTWP were derived in accordance with the environmental management framework in the Basin Plan (section 8.04): specifically, to protect and restore WDEs, protect and restore ecosystem function of WDEs, and ensure the resilience of WDEs. These objectives were incorporated into the consequence criteria (Table 5).

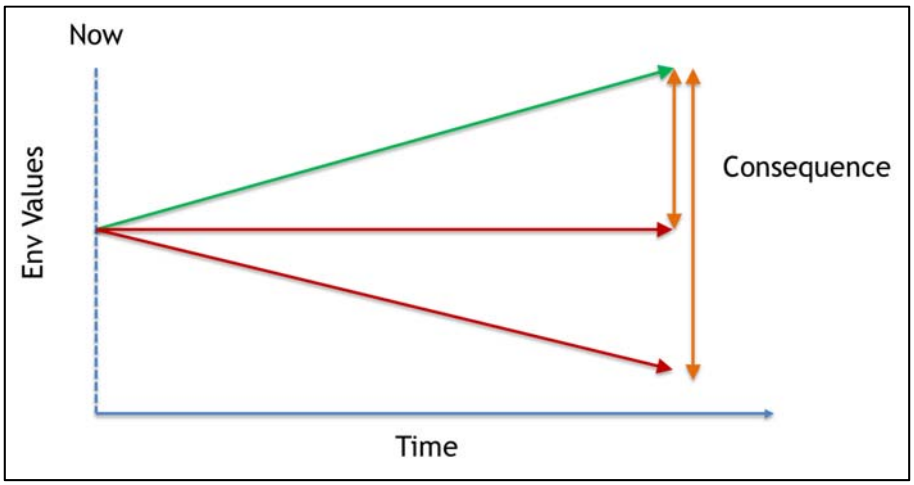

Figure 3. Effect of objectives on consequence – maintenance versus restoration of ecosystem function

Figure 3 demonstrates the effect of different types of objectives on the measurement of consequence. The green line represents the desired trajectory of environmental values where the objective is

restoration of ecosystem function over time. The potential for a decline in environmental values, leading to a severe consequence, is represented by the bottom red arrow. In this context, maintenance of ecosystem function would also be measured as consequence, albeit less severe, since it represents failure to achieve the objective.

Attributes affecting ecosystem values included:

- ecosystem condition and extent
- species diversity or functionality
- rarity or uniqueness, naturalness (Basin Plan Schedule 8)
- provision of vital habitat (Basin Plan Schedule 8)
- species listed as threatened or endangered by the Commonwealth or state (Basin Plan Schedule 8)
- formal recognition under an international agreement (Basin Plan Schedule 8)
- for Ramsar sites, water-dependent ecosystem values are the identified critical components, processes and services that are critical to the ecological character of the site.

The following definitions and assumptions were considered as part of the WDE consequence levels (Table 5):

- Expected outcomes for restoration of WDEs refer to a reasonable estimate of the achievement of the ecological targets or objectives of the LTWP assuming *full* implementation of the Basin Plan. In some cases, this may be a reduced rate of decline relative to a baseline as opposed to restoration *per se*.
- Significant loss means deviation of three or more attributes outside of natural or expected bounds causing degradation of overall ecosystem value. It may also include failure to maintain ecological character of a Ramsar site through ongoing exceedances of a limit of acceptable change.
- Some loss means deviation of one or two attributes outside of natural or expected bounds (e.g. breaching a management trigger value or threshold of potential concern) causing degradation of overall ecosystem value.
- For Ramsar sites, some loss may also mean:
    - breaching a management trigger such that management intervention is required and/or
    - temporary exceedance (for no more than a single year) of one or more limits of acceptable change threshold(s) not causing irreversible change to ecological character.
- International importance means formal recognition under an international bilateral or multilateral agreement such as the Ramsar Convention on Wetlands.
- National and state importance means listing under relevant state or national legislation such as the *Environment Protection and Biodiversity Conservation Act 1999* or the *Fisheries Management Act 2007 (SA)*.
- Regional or local importance means subject to regional or local management arrangements such as regional NRM plans.

- Assets are those defined by the LTWP for the South Australian River Murray WRP area (DEWNR 2015). In South Australia, there are three assets: the Coorong, Lower Lakes and Murray Mouth; River Murray floodplains; and the River Murray channel.
- The moderate and minor categories may be triggered by either one of the two indicators (i.e. loss of ecosystem values or failure to achieve expected outcomes). It can be expected that loss of ecosystem values will be linked to failure to achieve expected outcomes regarding Basin Plan objectives unless the expected outcome is a decline in values.

Table 5. Consequence criteria – water-dependent ecosystems

Consequence category	Description
Catastrophic (5)	Significant loss of water-dependent ecosystem values having international, national or state importance. Recovery of ecosystem values not feasible over medium term (less than a decade).
Major (4)	Significant loss of water-dependent ecosystem values having regional or local importance. Recovery of ecosystem values not feasible over medium term (less than a decade).
Moderate (3)	Some loss of water-dependent ecosystem values having international, national or state importance. Recovery of ecosystem values is feasible over medium term. Expected outcomes regarding restoration of water-dependent ecosystems not achieved at an asset scale.
Minor (2)	Some loss of water-dependent ecosystem values having international, national or state importance. Recovery of ecosystem values is feasible over medium term. Expected outcomes regarding restoration of water-dependent ecosystems not achieved at a sub-asset scale.
Insignificant (1)	Any loss of water-dependent ecosystem values is minimal.

3.3.2.4 Connected water resources

The consequence criteria related to impacts on connected water resources developed for the SA Murray Region and EMLR WRP risk assessments were deemed appropriate for the River Murray and were not changed. The criteria are provided in Table 6.

3.4 Risk identification

Risk identification involves finding, recognising and describing risks. The product of risk identification is a register of risk statements, which provide a description of the chain of circumstances giving rise to risk in each case.

Table 6. Consequence criteria – connected water resources

Consequence category	Description
Catastrophic (5)	Water quantity and/or quality effects on connected water resources having catastrophic impact on the environmental and/or beneficial use values of that resource.
Major (4)	Water quantity and/or quality effects on connected water resources having major impact on the environmental and/or beneficial use values of that resource.
Moderate (3)	Water quantity and/or quality effects on connected water resources having moderate impact on the environmental and/or beneficial use values of that resource.
Minor (2)	Water quantity and/or quality effects on connected water resources having minor impact on the environmental and/or beneficial use values of that resource.
Insignificant (1)	Water quantity and/or quality effects on connected water resources having insignificant impact on the environmental and/or beneficial use values of that resource.

In accordance with definitions of AS/NZS ISO 31000:2009, risk statements have the following generic format:

'There is the potential that [RISK SOURCE] leads to [EVENT] which results in [CONSEQUENCE]' where:

- a *risk source* is an element which alone or in combination has the intrinsic potential to give rise to risk
- an *event* is an occurrence or change of a particular set of circumstances
- a *consequence* is the outcome of an event affecting objectives and may be expressed quantitatively or qualitatively (ISO 2009a and ISO 2009b).

Risks were identified through a series of workshops involving technical experts from relevant South Australian government departments. Consistent with the risk assessment context (Section 3.2), risk identification is concerned with three types of water resource events:

- **Change in water quality –** a change in the quality of the resource attributes outside the bounds of current known qualities (for example a black water event). Water quality attributes may include salinity, sediment load, temperature, pH, pollutants, toxicants, nutrients and dissolved oxygen.
- **Change in water quantity –** a change in the amount of water available, including either an increase or decrease in the amount available.
- **Change in water regime –** a change in the timing or pattern of water flows.

3.4.1 Bow-tie diagrams for risk identification

Bow-tie diagrams were used as a tool for identifying and communicating risks consistent with the structure of risk statements. Bow-tie diagrams are visual representations of the potential chains of cause and effect in a timeline starting at risk sources, progressing to the event and then consequences. The defining feature of a bow-tie model is that an event (the 'knot') may be caused by multiple sources of risk and may in turn lead to multiple consequences independent of the source of risk. Thus:

- sources of risk are listed on the left-hand side of the bow-tie;
- consequences on the right-hand side of the bow-tie; and
- the event is represented in the centre of the bow-tie (that is, the 'knot' of the bow-tie).

Risk identification workshops used the bow-tie diagrams developed for the EMLR risk assessment (DEW 2019) as a starting point for risk identification. Because of this, participants focused on identifying or modifying sources of risk based on their understanding of the context specific to the South Australian River Murray WRP area. The final bow-tie model was then used to populate the risk register through iterative combinations of all risk sources, events and consequences (Figure 4).

3.5 Risk analysis

The risk analysis process consisted of three stages:

Stage 1: Risk prioritisation

Stage 2: Participatory analysis of priority risks using risk criteria and giving consideration to preventative and mitigation controls and other relevant factors

Stage 3: Evaluation of uncertainty and further analysis

3.5.1 Risk prioritisation

The risk identification process has the potential to produce a large number of provisional risk statements. An initial risk prioritisation process was undertaken to determine which risks can be classified as 'low' with a high level of confidence. This enabled a more rigorous analysis of those risks having higher uncertainty.

To undertake prioritisation, principles (Section 4.2.1) were developed in consultation with relevant technical experts which were then applied to the risk register by the assessment team. The remaining risks were determined to be priority risks requiring further detailed analysis.

For the purposes of this risk assessment, risk statements identified by the risk identification step (Section 3.4) are referred to as 'provisional risks'. Risks that have been prioritised for detailed analysis are referred to as 'priority risks'.

3.5.2 Participatory analysis of priority risks

Priority risks were analysed through a series of workshops involving the risk assessment team and key experts nominated through context setting (Section 3.2). The workshops followed a structured format to ensure the following outcomes:

- The risk assessment context and criteria were understood by all participants.
- There was a consistent understanding of the pathway described by each risk statement among participants.
- The most relevant evidence was identified and discussed by participants.
- Disagreements, differences or uncertainty regarding interpretation of risks or evidence were accounted for through the risk rating process.

To achieve these objectives, workshops commenced with a presentation of the context of the risk assessment including the purpose, scope, and relevant spatial and temporal scales. Participants were briefed on the criteria for consequences against which risks were to be analysed (Table 3 to Table 6).

For each risk statement, the following structure was followed during the workshops:

- Discussion of the risk statement to promote a consistent understanding of the nature of the risk including the pathways of cause and effect. This discussion allowed further elaboration or refinement of the risk statement to accurately reflect the best available information.
- Identification and discussion of factors known to affect the level of risk. This included evidence regarding: (i) the source of risk (e.g. potential for overuse); (ii) the event (e.g. the vulnerability of a resource); and (iii) consequences (e.g. environmental, social and/or economic dependencies on the resource), and consideration of the extent or frequency with which the risk pathway may have occurred in the past.
- Identification of controls for managing risk, where controls are defined as policies, plans or programs developed and/or implemented by government (South Australia or Commonwealth) to manage risk[5]. These are controls which are assumed to be in place over the future 10-year period over which risks are assessed.
- Discussion and qualitative evaluation of controls according to their inherent effectiveness at reducing the level of risk and the extent to which they will be successfully implemented.
- Individual appraisal of the likelihood and consequences of risk. Participants were asked to make judgements regarding the likelihood that each set of consequences (identified in the consequence criteria) will occur, in the sub-area over the 10-year timeframe, as a result of the risk pathway.

Ratings and additional information regarding risks were captured in worksheets by each participant for each risk statement (see example in Appendix A). Worksheets were structured according to the workshop process outlined above and included the following fields:

- the risk statement including the source of risk, event and consequence
- a summary of known risk factors, where factors are any attribute, characteristic, exposure or vulnerability that affects the level of risk
- a summary of existing controls
- fields for participants to evaluate controls according to effectiveness and implementation
- fields for participants to present their judgements on likelihood and consequence of the risk.

Criteria for evaluating implementation and effectiveness of controls (Table 7 and Table 8) were based on DEW's risk management framework for water planning and management (DEWNR 2012a). Level of implementation is the level of implementation that is assumed at the end of the planning period. Effectiveness describes the inherent efficacy of the control at reducing the level of risk in question if fully implemented.

[5] This includes legislation, water allocation plans, land use policies, regulation of activities, and infrastructure projects that are in place or will be in place at the end of the risk assessment time horizon (10 years). It is assumed that the Basin Plan will be implemented on time and in full.

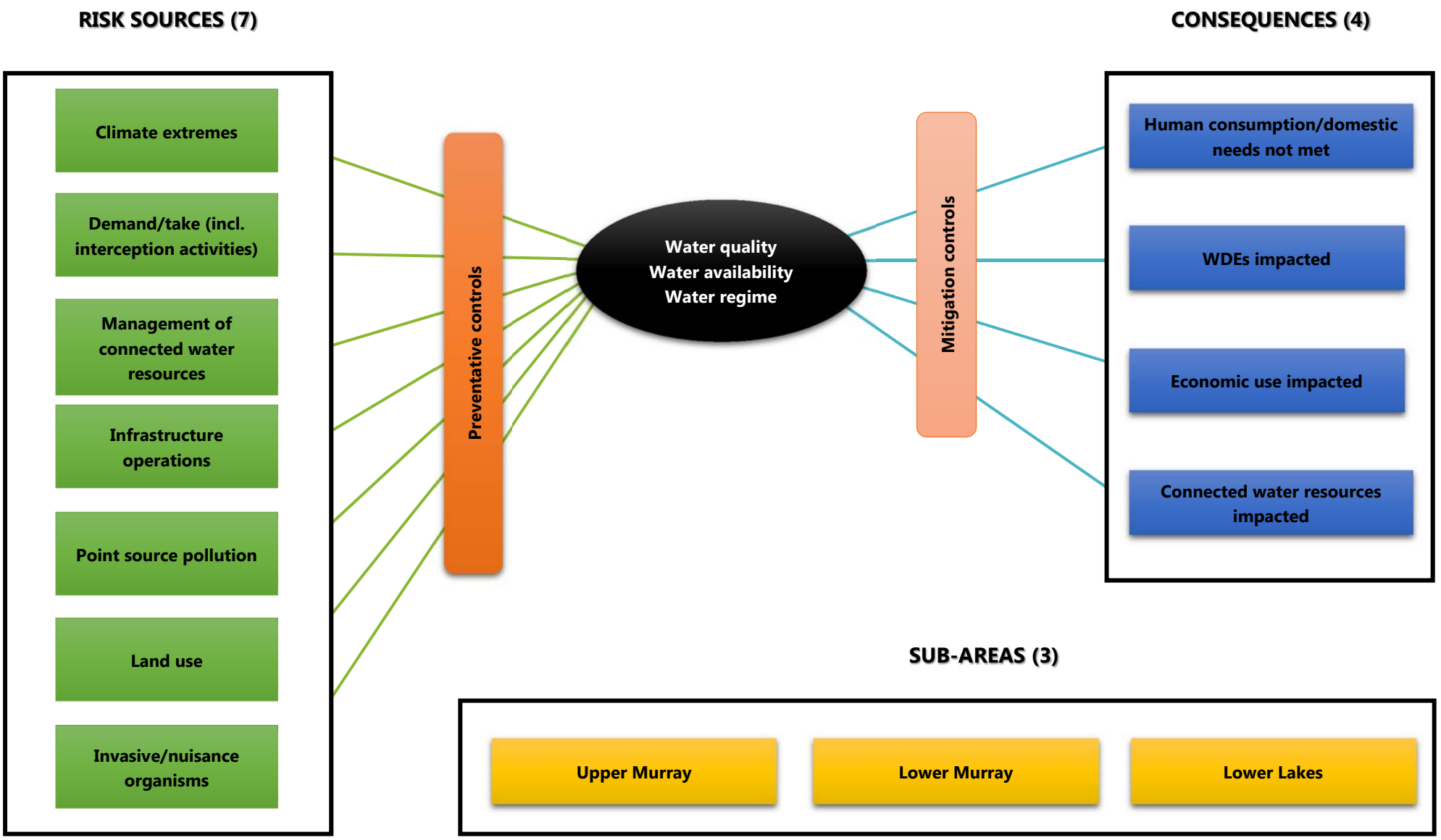

Figure 4. South Australian River Murray WRP risk identification – bow-tie model

Table 7. Evaluation of control – level of implementation (after DEWNR 2012a)

Level of implementation	Percentage completion
Complete implementation	>95% implemented
Mostly complete	75–95% implemented
Partially complete	30–75% implemented
Mostly incomplete	5–30% implemented
Not implemented	<5% implemented

Table 8. Evaluation of control – effectiveness of control (after DEWNR 2012a)

Level of control	Effectiveness	Percent effective
Controlled	Total control or mitigation of risk	>95% effective
Mostly controlled	Risk is controlled in most circumstances	75–95% effective
Partially controlled	Risk is controlled in some circumstances	30–75% effective
Mostly uncontrolled	Risk is mostly uncontrolled by measures	5–30% effective
Not controlled	Controls do not mitigate the impacts of the risk	<5% effective

Participants were required to rate the likelihood of all consequence categories occurring to produce a probability distribution of consequences with the total likelihood summing to 100 per cent. A benefit of this approach is that it allows individuals to reflect on and represent uncertainty in their assessment of what could happen over a future time period.

To build a fuller understanding of the potential risks, participants were requested to identify what they considered to be the most important factors and controls influencing their determination of likelihood and consequence. Following each workshop, data collected on the worksheets was synthesised into the risk register.

3.6 Risk evaluation

3.6.1 Assigning risk ratings from likelihood and consequence

Risk evaluation compares the results of the risk analysis with the risk matrix to determine risk level as a function of likelihood and consequence. The following principles governing risk evaluation criteria were incorporated into the risk matrix (Table 9):

- three possible levels of risk consistent with Basin Plan requirements and the other South Australian WRP risk assessments – low, medium and high
- lowest likelihood (i.e. rare) always returns low risk – this is the desired outcome for any positive consequence (i.e. minor and above)

- lowest consequence (i.e. insignificant) always returns low risk – this is the desired outcome for any positive likelihood (i.e. unlikely and above)
- likelihoods of 'likely' and 'almost certain' always return significant risk (i.e. medium or high) for a positive consequence (i.e. minor and above)
- consequences of 'major' and 'catastrophic' always return significant risk for a positive likelihood (i.e. unlikely and above).

The risk analysis workshops produced a sample of probability distributions of likelihood and consequence for each risk. The risk evaluation process calculated mean likelihood for each consequence level and then compared each aggregate likelihood and consequence rating to the risk matrix (Table 9). This returned a set of five provisional ratings per risk statement (four for risks to economic use). The highest risk from this distribution was then reported as the final risk rating for the risk statement.

Table 9. Risk matrix. Risk level according to likelihood and consequence.

	Consequence				
Likelihood	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	**L**	**M**	**H**	**H**	**H**
Likely	**L**	**M**	**M**	**H**	**H**
Possible	**L**	**L**	**M**	**M**	**H**
Unlikely	**L**	**L**	**L**	**M**	**M**
Rare	**L**	**L**	**L**	**L**	**L**

Where L = low; M = medium; and H = high

3.6.2 Rating uncertainty

Section 10.41 of the Basin Plan requires that WRPs describe any quantified uncertainties in the level of risk. The probabilistic risk analysis allowed for evaluation of the uncertainty according to the distribution of likelihood ratings determined through the analysis process. Criteria for evaluating uncertainty (outlined in Table 10) are based on the spread of likelihood values across consequence categories in the risk probability distributions.

According to these criteria, risks having likelihood concentrated into a single consequence category are rated as having low uncertainty, whereas a spread of likelihoods across consequence levels means higher uncertainty. The uncertainty rating may be used to inform decisions regarding the treatment of risks. In cases where there is higher uncertainty, it may be appropriate to prioritise further risk analysis as part of an overall risk treatment approach.

This approach to evaluating uncertainty considers the aggregate of both statistical uncertainty (i.e. variability) and true uncertainty (i.e. epistemic or systematic uncertainty).

Formal sensitivity analysis of the outcome of this assessment was not deemed necessary since the risk analysis was undertaken through a process of expert elicitation rather than quantitative modelling.

The expert elicitation process provided opportunities for participants to consider the results of relevant quantitative models, including sensitivity analysis, as evidence informing determination of likelihood and consequence.

Table 10. Risk uncertainty criteria

Level of uncertainty	Criteria
Low	Maximum likelihood level assigned to a single consequence level 60 - 100%
Moderate	Maximum likelihood level assigned to a single consequence level 40 - 59%
High	Maximum likelihood level assigned to a single consequence level 0 - 39%

It is self-evident that the outcomes of this risk assessment can be sensitive to the choice of experts, the way that evidence is presented and the process for analysing risks. The risk assessment team made reasonable endeavours to ensure there was adequate representation of relevant technical disciplines through the assessment process and that the process of assigning likelihood and consequence was as unbiased as possible (see sections 3.2 and 3.5).

4 Results

4.1 Risk identification

The risk identification process (section 3.4) produced a bow-tie diagram consisting of seven risk sources, three events and four consequence categories (Table 11 and Figure 4).

Climate change was not considered independently as a source of risk. Climate change potentially influences all risk pathways, particularly with respect to the potential for a change in the frequency of climate extremes relative to past climate. Therefore, it was agreed that it was more efficient to consider climate change as a factor affecting multiple risk pathways during the analysis process. Data pertaining to climate change studies conducted for the South Australian Murray–Darling Basin natural resources management (NRM) region as a whole (Charles and Guobin 2015) were considered by the risk analysis process. Also, outcomes of climate change scenarios prepared through the CSIRO, and through the Murray–Darling Basin Authority (MDBA) CSIRO Murray–Darling Basin Sustainable Yields Project (CSIRO 2008) as part of Basin Plan development, informed the analysis of risks related to climate extremes.

All risk sources were combined with each of the consequence categories for each of the three sub-areas to produce a total of 84 provisional risk statements for further analysis.

Table 11. Categories of risk sources and consequence (from bow-tie diagram)

Risk source	Event	Risk consequence
Climate extremes	Change in water quality	Critical human water needs not met
Demand/take (incl. interception activities)		
Management of connected water resources		Water-dependent ecosystems impacted
Infrastructure operations	Change in water quantity (availability)	Economic use impacted
Point source pollution		
Land use	Change in water regime	Connected water resources impacted
Invasive/nuisance organisms		

4.2 Risk analysis and evaluation

4.2.1 Risk prioritisation

The preliminary analysis identified principles for prioritising risks for further analysis:

- Since there are no reticulated water supplies with offtakes below Wellington, all risks affecting critical human water needs in the Lower Lakes were assessed as low with high confidence.

- The risk assessment did not assess whether the management of connected water resources could cause changes in water quality, quantity or regime, which in turn could impact other connected water resources.

    To be assessed, all risks caused by management of connected water resources must relate to a consequence *within the sub-area being assessed*. Similarly, all risks that could cause impacts to connected water resources must relate to a source of risk *arising within the sub-area being assessed*.

- Risks to connected water resources caused by 'climate extremes' were not assessed. Risks caused by climate extremes were only assessed where the consequence occurs within the sub-area being addressed.

As a result of the prioritisation process, 59 out of 84 provisional risks were taken forward to the participatory analysis stage (see Appendix B for a description of the 59 priority risks addressed by the analysis).

4.2.2 Participatory analysis and evaluation

Fifty-nine priority risks were assessed through a series of eight risk analysis workshops according to the methodology described in section 3.5.2. These workshops were held over the period from September to December 2016. The workshop analysis collated factors, controls and ratings relevant to each risk. On average, the workshop process produced approximately 10 individual ratings of likelihood and consequence per risk statement. From these ratings, the final aggregate probability distribution of worst-case consequences was calculated for each risk. These were then compared to the risk matrix (Table 9) to produce risk ratings of 'low', 'medium' or 'high' according to the agreed methodology and criteria (section 3.6.1). Uncertainty for each risk was evaluated (section 3.6.2).

The risk profile following the evaluation consists of 10 medium risks (summarised in Table 14) and 49 low risks. No risks were evaluated as being 'high'. The risk profile is discussed in detail in Section 5. The output of the risk analysis and evaluation for all priority risks is presented in detail in Appendix B. For each risk, the following information is documented:

- sub-area
- risk statement (from the risk identification) and risk number
- source of risk and consequence category
- risk matrix showing how the output of the risk analysis (i.e. probability distributions for consequences) are evaluated to produce the final risk rating
- a summary of factors affecting the level of risk, grouped according to those affecting the source of risk and potential for events and those relevant to the scale of consequences that could occur. Supporting evidence is referenced.

The risk register includes a summary of relevant existing or anticipated controls evaluated according to effectiveness and implementation for the 10 significant risks (i.e. rated 'medium'). These controls are documented in the risk register for each risk (Appendix B).

Appendix C includes a table summarising important controls for risks with cross-references to relevant risk statements. Appendix C groups controls into three categories: policy and legislation; infrastructure and operations; and proposed controls. Proposed controls are policy or operations that are not currently implemented but which are believed likely to be implemented at some point over the risk assessment timeframe.

4.3 Evaluation of uncertainty

Application of uncertainty criteria (Table 10) showed that six risks in the risk register are characterised by high uncertainty (Table 12). All of these risks describe pathways leading to impacts to water-dependent ecosystems (WDEs), with three caused by climate extremes and the other three caused by management of connected water resources. All these risks are significant, attracting a risk level of 'medium'. Uncertainties in each case are described by documentation of risk factors (Appendix B).

Six risks were found to have moderate uncertainty (Table 13). Four of these risks were caused by invasive/nuisance organisms. The uncertainty of these risks is described by the factors documented in Appendix B and the assessment of the effectiveness of controls. One risk having moderate uncertainty was evaluated as a medium risk level (r346). The remaining five risks having moderate uncertainty were determined to be low risk level.

Another 47 risks have low uncertainty with all but three of these risks (r318, r337, r374) rated 'low' risk level. The risk register (Appendix B) plots the aggregate probability distribution determined for each risk against the risk matrix (Table 9) which provides a visual representation of uncertainty.

Table 12. Risks having high uncertainty

ID	Risk source	Consequence	Risk level	Sub-area
368	Climate extremes	WDEs impacted	Medium	Upper Murray
340	Climate extremes	WDEs impacted	Medium	Lower Murray
312	Climate extremes	WDEs impacted	Medium	Lower Lakes
376	Management of connected water resources	WDEs impacted	Medium	Upper Murray
348	Management of connected water resources	WDEs impacted	Medium	Lower Murray
320	Management of connected water resources	WDEs impacted	Medium	Lower Lakes

Table 13. Risks having moderate uncertainty

ID	Risk source	Consequence	Risk level	Sub-area
392	Invasive/nuisance organisms	WDEs impacted	Low	Upper Murray
364	Invasive/nuisance organisms	WDEs impacted	Low	Lower Murray
336	Invasive/nuisance organisms	WDEs impacted	Low	Lower Lakes
389	Invasive/nuisance organisms	CHWN not met	Low	Upper Murray
346	Management of connected water resources	Economic use impacted	Medium	Lower Murray
323	Operation of infrastructure	Connected water resources impacted	Low	Lower Lakes

Table 14. Risk profile for South Australian River Murray WRP area – significant risks (rated medium or high)

Sub-area	Risk ID	Risk source	Consequence description	Likelihood rating	Consequence category	Uncertainty rating	Risk level
Upper Murray	r368	Climate extremes	Water-dependent ecosystems impacted	Unlikely	Catastrophic	High	Medium
Upper Murray	r374	Management of connected resources	Economic use of water	Unlikely	Major	Low	Medium
Upper Murray	r376	Management of connected resources	Water-dependent ecosystems impacted	Possible	Moderate	High	Medium
Lower Murray	r340	Climate extremes	Water-dependent ecosystems impacted	Unlikely	Major	High	Medium
Lower Murray	r346	Management of connected resources	Economic use of water	Unlikely	Catastrophic	Medium	Medium
Lower Murray	r348	Management of connected resources	Water-dependent ecosystems impacted	Unlikely	Major	High	Medium
Lower Murray	r337	Climate extremes	Critical human water needs not met	Unlikely	Major	Low	Medium
Lower Lakes	r312	Climate extremes	Water-dependent ecosystems impacted	Unlikely	Catastrophic	High	Medium
Lower Lakes	r318	Management of connected resources	Economic use of water	Unlikely	Catastrophic	Low	Medium
Lower Lakes	r320	Management of connected resources	Water-dependent ecosystems impacted	Possible	Major	High	Medium

5 Discussion and conclusions

5.1 Risk profile – consequences

A total of 84 provisional risk statements were identified for the South Australian River Murray water resource plan (WRP) area across three sub-areas. Following prioritisation, 59 priority risks were subject to detailed analysis. The final risk profile consists of 10 medium risks, with the remainder being rated low or not applicable. The present assessment did not rate any risks as high. The results of the risk assessment for each of the 59 priority risks are presented in Appendix B.

A review of the risk profile according to consequence categories (Table 15) identified six medium risks related to consequences for water-dependent ecosystems (WDEs), three medium risks related to the economic use of water, and one medium risk related to critical human water needs (CHWN) in the Lower Murray sub-area.

Three of the medium risks to WDEs are caused by the potential for climate extremes, with the remaining three related to management of connected water resources. These risks are spread across all three sub-areas. All three risks to the economic use of water are caused by management of connected water resources, with one risk affecting each sub-area.

Table 15. Risk profile of significant risks by consequence category

Consequence category	Medium risks	High risks
Water-dependent ecosystems impacted	6	0
Critical human water needs not met	1	0
Economic use impacted	3	0
Connected water resources impacted	0	0

5.1.1 Risks to water-dependent ecosystem values

The South Australian River Murray is host to important environmental assets including internationally recognised Ramsar wetlands, sites of state and national significance, and species having regional, state and national significance. The risk assessment found that much of the risk identified in this assessment is associated with consequences to these WDEs (Table 15). Extensive and long-term development of the water resources of the Basin has had, and is continuing to have, an impact on the biota of the South Australian River Murray. The Millennium Drought highlighted the vulnerability of WDEs to climate extremes and reduced water availability.

It is noteworthy that the assessment identified no high risks, with all six significant WDE risks rated medium. In practical terms, this means that the assessment determined that irreversible losses of the most important ecosystem values over the timeframe of the Basin Plan are unlikely. There is greater likelihood of either temporary, recoverable losses of WDE values or failure to fully achieve expected outcomes regarding restoration of WDE values at asset or sub-asset scale.

Taken out of context, this finding may seem counterintuitive given the long history of environmental decline and recent experience with the Millennium Drought. However, the context-setting phase

found recognition among stakeholders that public policy aims to achieve a balance of environmental, social and economic outcomes in the Basin as a whole and for the WRP areas in South Australia. Consequence criteria were therefore constrained to measure deviation from challenging, but realistic, goals regarding the maintenance and restoration of WDEs. They do not measure risk against unstated or unrealistic goals such as pristine natural condition over the majority of the extent of the South Australian River Murray WRP. Had risk criteria been configured against an objective of pristine natural condition at a large scale, the risk profile would likely have shown more medium and high ratings as a result.

Programs in place to maintain or restore WDE values for the WRP area are judged to be at least partially effective and implemented under most circumstances. Stressors associated with existing or increased development are well controlled in South Australia. There are joint commitments to manage issues such as salinity and the recovery of environmental water.

It is also important to note that the SA Murray Region risk assessment identified one medium risk for the groundwater underneath the Coorong and Lower Lakes as well as a high risk for the Coorong surface water relating to WDEs.

The following key factors affecting WDE risk were noted through the analysis and evaluation:

- Environmental values throughout the WRP area are sensitive to both the timing and volume of flows making them vulnerable to management of this regulated surface water system.
- A very small proportion of inflows originates from within South Australia which means that the maintenance and restoration of environmental values in the South Australian River Murray is highly dependent on flows across the border.
- Uncertainties remain regarding the manner in which key elements of the Basin Plan will be implemented and how this would affect the achievement of environmental outcomes in South Australia.
- Uncertainty regarding the potential impacts of climate change over the risk assessment timeframe remains.
- The risk to the outer floodplain, which is inundated at flows greater than 80,000 ML/day, is high because active management is unable to deliver flows of sufficient magnitude.
- South Australia's Entitlement volume alone is insufficient to cover evaporative losses from the Lower Lakes and sufficient barrage releases to maintain connectivity of the Lower Lakes with the Murray Mouth, Coorong and the ocean.
- There is potential for return flows from environmental watering actions upstream to cause water quality events in the South Australian River Murray which may in turn cause negative environmental consequences.

5.1.2 Risks to critical human water needs

The risk assessment determined that there is medium risk to CHWN caused by climate extremes for the Lower Murray sub-area (r337). While major consequences are unlikely, the evaluation criteria determined this to be a medium risk because of the very large number of people potentially affected.

The factors affecting this risk rating are documented in Appendix B. A key observation was that there is no capacity to influence the likelihood of climate extremes and that additional uncertainty is introduced by climate change. It was noted that a significant proportion of the population that depends on the Lower Murray water resource does not have access to alternative supplies, including townships in the Mount Lofty Ranges.

There is a high dependency on water resources extracted from the Upper Murray sub-area as this resource supplies towns along the river, and provides for CHWN in Port Pirie, Whyalla, Port Augusta and the upper Eyre Peninsula through the Morgan offtake and pipeline. In most cases, these significant populations may not have access to ongoing alternative supplies in the event of a failure of the primary supply. Despite the importance of this water source, the risks were determined to be low due to existing infrastructure and management practices.

A range of additional controls have been implemented for these risk pathways since the experience of the Millennium Drought. These include:

- securing additional storage rights for South Australia (private carryover and CHWN) in the upstream storages of the River Murray system
- inclusions in the Basin Plan (chapter 11) and Murray–Darling Basin Agreement to prioritise water for critical human needs in the River Murray system; this is done by setting and prioritising the volumes required to meet and deliver CHWN and by establishing a tiered approach to water sharing in the River Murray system
- development of an explicit water allocation framework for the South Australian River Murray that prioritises water from South Australia's Entitlement Flow for CHWN
- construction of additional infrastructure such as the Adelaide Desalination Plant.

5.1.3 Risks to the economic use of water

The risk assessment identified three medium risks to the economic use of water, with one medium risk per sub-area. In each case, the source of risk was determined to be management of connected water resources. Risks caused by other sources of risk were determined to be low in this context.

A key factor affecting risks to the economic use of water is the high economic dependency on the River Murray. Impacts could include: significantly reduced productivity of irrigation activities; long-term damage to horticulture plantings and infrastructure; and reduction of economic benefits from non-consumptive use, such as tourism, fisheries and ecosystem services. The level of South Australia's economic dependency on the River Murray was highlighted during the Millennium Drought, which was as devastating to economic output as it was to environmental assets.

It was determined that non-consumptive economic use, including tourism, fishing and recreation, depends on ecosystem services and perceptions regarding the condition of environmental assets in the South Australian River Murray. This suggests some correlation between risks to WDEs and risks to the economic use of water which is relevant in this context.

Despite the high level of economic dependency, the level of risk for risk sources other than management of connected resources was found to be low. However, it is important to recognise that many risk pathways that are nominally evaluated as low risk in this context could still cause economic impacts from time to time over the WRP timeframe. These impacts may affect individual enterprises and communities.

As with risks to environmental values and CHWN, inherent risks are controlled through existing or planned interventions. There are sophisticated approaches to addressing risks caused by a range of human activities including use of the resource. Provisions for carryover and the intra- and inter-state trade of water allocations and entitlements, as well as improvements in transparency and information sharing by government agencies about water allocations and water markets, help individual enterprises make decisions to better manage potential risks regarding access to water.

A comprehensive list of factors considered in the assessment of risk to the economic use of water are documented under relevant risk statements in Appendix B.

5.1.4 Risks to connected water resources

The risk assessment identified no medium or high risks to connected water resources attributed to sources of risk *within* the South Australian River Murray WRP area (as opposed to risk caused by management of water resources upstream of the South Australian border). It was found that there is some risk caused by the operation of infrastructure which could have impacts to connected groundwater.

Operation of the barrages presents a risk to the environmental values of the Coorong and Murray Mouth. However, in both cases the likelihoods of severe consequences (i.e. major and catastrophic) were determined to be rare. Relevant factors for these risks are documented in Appendix B. Risks caused to the Coorong by management of connected upstream water resources are fully described in the SA Murray Region WRP risk assessment (DEWNR 2017). Based on the findings of the present assessment, it can be concluded that much of the risk to the Coorong is caused by insufficient flows arriving from upstream of the South Australian River Murray WRP area.

5.2 Risk profile – sources of risk

5.2.1 Risks sources causing medium risks

A review of the risk profile according to risk source (Table 16) shows that climate extremes and management of connected resources cause all significant risk identified by this assessment.

Table 16. Risk profile of significant risks by source of risk

Source of risk	Medium risks
Climate extremes	4
Demand/take (incl. interception activities)	0
Management of connected water resources	6
Infrastructure operations	0
Point source pollution	0
Land use	0
Nuisance/invasive organisms	0

Climate extremes account for four medium risks. The following key factors were noted regarding these risks during the analysis and subsequent evaluation:

- The likelihood of climate extremes cannot be reduced through management actions at the Basin scale.
- Drought is more likely to cause severe consequences than floods.

- Consequences of climate extremes become progressively more difficult to mitigate over prolonged dry periods as the availability of water declines.
- Climate change could affect the frequency and intensity of climate extremes over the risk assessment period. This means that the record of past climate may be an inaccurate guide regarding the likelihood of future events.
- Water to potentially mitigate the consequences of climate extremes is held interstate as part of the South Australia Storage Right.

Management of connected water resources accounted for six medium risks. The following key factors were noted regarding these risks during analysis and evaluation:

- A critical element of context is the dependence of the South Australian River Murray on flows into South Australia.
- It is recognised that implementation of the Basin Plan in full and on time across the Basin States goes a long way towards controlling risks caused by management of the Basin upstream of the border. However, a number of uncertainties regarding both effectiveness and timely implementation of key controls upstream were raised during the risk analysis and evaluation process. This uncertainty gives rise to significant risk in South Australia.
- Return flows from proposed large-scale environmental watering potentially causes water quality events such as blackwater, salinity or algal blooms in South Australia.
- Highly saline groundwater entering the River Murray in South Australia poses a risk to the River Murray. Controls are in place for this risk (i.e. salt interception schemes and River Murray water allocation plan salinity zoning policy). While some uncertainty was expressed regarding the proposals for future operation of the salt interception schemes (e.g. implementing proposed responsive management approach), risks were deemed to be adequately controlled over the risk assessment timeframe.
- The Murray–Darling Basin Authority (MDBA) has recognised that risks associated with low water levels and acid sulfate soils in the Lower Murray Reclaimed Irrigation Area (LMRIA) (Section 2.2.2) are a Basin-wide issue meaning they are linked to management of water resources upstream (both within South Australia and upstream of the South Australian border) (Mosley et al. 2013).

5.2.2 Risks sources causing low risk

The assessment determined that take within the South Australian River Murray WRP is not a significant source of risk because an effective water planning and management regime is in place. The *Natural Resources Management Act 2004* (SA), the River Murray WAP, and associated licensing and permitting systems provide for control of the volume of water taken and the manner in which it is taken. It was considered that there is a high level of compliance and little uncontrolled take in this context. Risks caused by demand/take in upstream connected resources were covered by the assessment of risks caused by management of connected water resources.

Infrastructure operations include the operation of locks, regulators, weirs, and barrages within the three sub-areas. Active infrastructure within the South Australian River Murray is concentrated within the Upper Murray sub-area with the exception of the barrages which are located in the Lower Lakes sub-area. During the analysis process, some uncertainty was highlighted regarding the operational regime for planned or new infrastructure. It was considered that the consequences of risks relating to new infrastructure would likely be localised and managed by specific risk management plans for the new infrastructure. In general, it was concluded that risks associated with the operation of existing infrastructure within the three sub-areas are well controlled through operating policies and rules,

plans and ongoing risk management. Risks caused by operation of infrastructure upstream of the border were considered separately in the analysis of risks associated with management of connected water resources.

Programs are currently planned or in place to address risks posed by this source of pollution to water quality and environmental values. The effectiveness of these controls will depend on ongoing commitments and Basin Plan implementation to reduce the risk of low water levels in the Lower Murray. Full Basin Plan implementation and maintenance of environmental watering programs during dry periods is important for ensuring that the legacy of acid sulfate soil exposure caused by the Millennium Drought is not exacerbated in the foreseeable future.

The analysis of risks caused by nuisance/invasive organisms considered impact on water quality or quantity which in turn would lead to an impact on one of the defined risk assessment consequence categories. The risk analysis did not consider the direct impacts of nuisance/invasive organisms on (for example) a WDE. Some of the organisms identified as key risk factors included blue-green algae, carp, and *Salvinia spp* (aquatic fern).

Nuisance/invasive organisms were not considered to be a high risk for any of the sub-areas. Risks were considered to be slightly higher for the Lower Lakes (although still low) due to the inability to flush Lake Albert. Consideration was also given to potential short-term unintended water quality impacts arising from introduction of carp virus as a control for carp. However, there was significant uncertainty about the level of commitment and the timing of this program at the time of the risk assessment.

Assessment of risks caused by land use was limited to the potential effects of new or changed land use over the assessment timeframe. Impacts from existing land use were considered as baseline for the assessment, while impacts from the LMRIA were addressed through assessment of risks caused by point source pollution. It was determined that the Development Act, River Murray Act and the River Murray WAP provide for effective control of risk caused by land use changes. It is unlikely that there will be significant increases to impacts of the irrigation industry around the WRP area. However, there is potential for land use changes in the LMRIA which may bring risks or benefits to the River Murray through impacts on the quantity and quality of return flows. Also, there is potential for existing land use to constrain the delivery of high flows of water for the purposes of achieving environmental objectives in the South Australian River Murray.

5.3 Risk uncertainty

Out of the 59 risks analysed, six risks are characterised by high uncertainty, six risks have medium uncertainty and the remaining 47 risks were evaluated as low uncertainty according to the uncertainty criteria (Table 10). In general, higher uncertainty is correlated with higher risk. All risks having high uncertainty are medium risks and seven out of 10 medium risks have high or medium uncertainty (see Table 12 and Table 13). Only three medium risks were evaluated as having low uncertainty (r318, r337 and r374).

All risks having high uncertainty ratings described potential impacts to WDEs. These risks were attributed to risk sources outside of South Australian control, including management of connected water resources and climate extremes. The risk factors raised through the analysis process document perceived sources of uncertainty in each case.

The current uncertainty around the Basin Plan's implementation was identified during the risk assessment as being a key limitation on South Australia being able to meet the objectives of the long-

term environmental watering plan (LTWP) for the River Murray. [6] This risk assessment recognised that failure to implement the Basin Plan in full both in South Australia and in upstream states, could adversely affect the risk profile in the South Australian River Murray. Uncertainty remained at the time of the risk assessment, regarding the successful implementation of the Basin Plan including:

- the recovery of a long-term annual average surface water volume of 2,750 GL from consumptive uses for the environment
- The implementation of sustainable diversion limit (SDL) adjustments from supply and efficiency measures
- effectiveness of measures to address policy and physical constraints affecting the delivery of environmental water
- the extent to which the environmental equivalence test for SDL adjustment reflects the outcomes achieved through on-ground projects
- the potential for LTWPs for the River Murray upstream of South Australia to create demands for environmental water that could compete with the achievement of environmental outcomes in South Australia, especially where inconsistent with SDL offset proposals
- limited progress of interstate connected WRP development at the time of the risk assessment.

Documentation of risk pathways in Appendix B overlays the probability distributions estimated for each risk onto the risk criteria. These matrices provide a visual representation of uncertainty in each case.

5.4 Conclusion

This risk assessment identified 10 medium risks. These are considered significant by South Australia, and they must be addressed by the River Murray WRP and WRPs for connected water resources.

There is significant risk to WDE values across all three sub-areas defined for this risk assessment. These risks are caused by climate extremes and management of connected water resources. Similarly, there is significant risk to the economic use of water caused by management of connected water resources in all three sub-areas. Climate extremes also cause significant risk to critical human water needs that depend on the Lower Murray.

In general, risk was determined to be correlated with uncertainty. Key elements of uncertainty include:

- uncertainty regarding climate extremes – this uncertainty is compounded by potential impacts of climate change over the risk assessment period which could invalidate assumptions based on the historical climate

[6] Current water recovery under the Basin Plan is set at 2,750 GL/year with an additional 450 GL/year for the environment provided there are no negative socio-economic impacts. Modelling and analysis conducted by both South Australia and the MDBA (Gibbs et al. 2012 and MDBA 2012 respectively) has shown that the additional 450 GL/year would lead to better environmental outcomes for South Australia's floodplain habitats and Lower Lakes and Coorong. With the operation of adjustment measures to offset water recovery against the 2,750 GL/year target, the additional 450 GL/year is even more important to achieve Basin Plan environmental outcomes.

- uncertainty at the time of the risk assessment regarding the effectiveness of the implementation of Basin Plan.

The risk assessment also identified many pathways that were determined to be low risk in this context. While some pathways are inherently low risk, the assessment found that a significant number of risks are kept in check by a range of existing and/or planned control measures, including the Basin Plan. Key controls are listed and cross-referenced with individual risk statements in Appendix C. It is recommended that these risks continue to be monitored and controlled as appropriate. This is particularly the case for those low risks for which there is a medium level of uncertainty (Table 13).

It is concluded that the Basin Plan is a critical control for risk affecting the South Australian River Murray. A key recommendation regarding treatment of the significant risks identified by this assessment is for all Basin States to continue working together to achieve the full and timely delivery of the Basin Plan.

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Appendices

A. Example of worksheet used for assessing priority risks

Name:_____

Risk Number: **«Risk_Statement_Number»**

Sub-area number: «Subarea_Number»
Sub-area: «Subarea»

Risk Statement:

Factors

Controls	Effectiveness	Implementation

Probability of each consequence level (assigned probabilities should add up to 100)

Level	**Percent chance of consequence in 10 years**										
Very high	0	10	20	30	40	50	60	70	80	90	100
High	0	10	20	30	40	50	60	70	80	90	100
Medium	0	10	20	30	40	50	60	70	80	90	100
Minor	0	10	20	30	40	50	60	70	80	90	100
Insignificant	0	10	20	30	40	50	60	70	80	90	100

Main Factor

Main Control

B. South Australian River Murray WRP Area Risk Register

LOWER LAKES – Significant Risks

SUB-AREA: Lower Lakes

Risk r320: There is the potential that management of connected water resources could cause changes in water quality, quantity or regime which in turn causes impacts to water-dependent ecosystems

Risk source: Management of connected water resources
Consequence: Water-dependent ecosystems impacted

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely					
Possible	X		X		
Unlikely		X		X	
Rare					X

Final risk rating: **Medium** [7]
Uncertainty: High

Risk factors

Relating to source of risk and potential for events:

- The total volume of water required for delivery of many environmental water requirements exceeds South Australia's Entitlement and additional water available through recovery programs. Meeting these environmental water requirements will require water to be delivered in conjunction with unregulated flows (DEWNR 2015).
- There are a range of uncertainties regarding the implementation of the Basin Plan affecting the achievement of environmental outcomes in South Australia including:
    - commitment to, and delivery of, efficiency measures to recover an additional 450 GL
    - commitment to addressing policy and physical constraints affecting the delivery of environmental water
    - the extent to which the environmental equivalence test for sustainable diversion limit (SDL) adjustment reflects the outcomes achievable through works and measures
    - the potential for long-term environmental watering plans (LTWPs) for the river upstream of South Australia to create demands for environmental water that could negatively impact achievement of environmental outcomes in South Australia
    - the extent to which environmental water recovered is compatible with the delivery of water required to address environmental water requirements in South Australia.

[7] The risk analysis assigned a probability distribution for each risk which means that each consequence level is associated with a likelihood score and total likelihood sums to 100%. The final risk rating is the highest level of risk according to the risk matrix (see Section 3.6.1).

- Under normal (non-drought) conditions, lake levels can be managed with a low level of risk despite flow constraints. However, there is a trade-off between the risk in the Lower Lakes and the Coorong with respect to management of flow over the barrages.
- There is potential for high salinity levels in the Coorong to impact water quality in the Lower Lakes during dry periods. During the Millennium Drought, water quality in the proximity of the barrages became saline (DEH 2009).
- While proposed restoration of flows to the Coorong from the South East catchments through Salt Creek will assist salinity management in the Coorong (DEWNR 2015), it was determined that it is unlikely to have significant effect on risk management in the Lower Lakes.
- The Eastern Mount Lofty Ranges (EMLR) and SA Murray Region water resource plans (WRPs) contribute relatively minor volumes of water to the sub-area compared to flows across the border (DEWNR 2015).
- Surface water from the EMLR enters into the Lower Lakes through a number of streams (including the Angas, Bremer and Finniss rivers, and Currency Creek). These catchments are managed under the auspices of the EMLR Water Allocation Plan (WAP), and are part of the EMLR WRP area. The consumptive use limits for the EMLR WAP have been set to allow provision of water to the terminal wetlands where the EMLR streams meet Lake Alexandrina (SAMDB NRM Board 2013).
- Climate change is expected to cause incremental sea level rise over the longer term. This could cause impacts to the operation of the barrage system leading to Lake Alexandrina possibly assuming a more estuarine character (DEH 2009) (Siebentritt et al. 2014).
- Entitlement volume is insufficient to cover evaporative losses from the Lower Lakes, let alone provide for barrage releases and connectivity with the Murray Mouth, Coorong and the ocean.
- Water quality has not fully recovered from the effects of the Millennium Drought with areas retaining elevated salinity and acidity (Stone et al. 2016). The water quality in Lake Albert is inherently more sensitive to events than Lake Alexandrina since it is a shallow terminal lake. It retained elevated salinity and cyanobacteria levels for an extended period of time following the end of the Millennium Drought (DEWNR 2014) (Stone et al. 2016).
- The Millennium Drought caused widespread acidification and point source pollution events originating from the Lower Murray Reclaimed Irrigation Area (LMRIA) (Mosley et al. 2013). The resulting acid drainage from this event is likely to remain a point source of pollution in the future. This could affect water quality in the Lower Lakes. Water quality impacts from the LMRIA will be worse during periods of low flow and lower water levels (Mosley et al. 2013).

Relating to consequences:

- This sub-area is part of the Ramsar-listed Coorong and Lakes Alexandrina and Albert Wetland of International Importance (Phillips and Muller 2006). It is a priority environmental asset in the South Australian River Murray WRP area (DEWNR 2015).
- The sub-area hosts state and nationally important species such as Murray Hardyhead, which is critically endangered in South Australia (Office for Water Security 2010).
- Environmental water requirements to maintain water-dependent ecosystems at a low level of risk requires that the lakes remain a permanently freshwater system with salinity below 1,500 µS cm EC in 100 per cent of years (Lester et al. 2010).
- The Millennium Drought, combined with overuse of water resources throughout the Basin, led to significant impacts to the lower lakes (DEH 2009). Reduced flows resulted in shallow water levels, loss of habitat, exposure of acid sulfate soils leading to acidification, and elevated salinity driving a change in the system's ecology (Siebentritt et al. 2014). A wide range of emergency activities were required to prevent species extinctions, which culminated in the Drought Emergency Framework for Lakes Alexandrina and Albert (SAMDB NRM Board 2017b).
- As this sub-area is at the end of the Basin, the most important factor affecting risks to water-dependent ecosystems in the Lower Lakes is the quantity and regime of water flowing in from the River Murray. Restoration and maintenance of ecological character requires adequate frequency of flood events to flush and freshen the system, reduced duration and frequency of

detrimental no-flow periods, and sufficient water to operate fishways and provide habitat connectivity between fresh, estuarine and saline units (Phillips and Muller 2006).

Evaluation of existing/planned controls

Document/control	Effectiveness	Implementation	Notes
Reconciliation in 2024 of supply measure outcomes for the Basin Plan	Mostly controlled	Complete implementation	Any package of SDL measures agreed in 2017 needs to be implemented in full by 2024. Any projects not implemented in this timeframe will need to be reconciled. Current draft principles for the new Intergovernmental Agreement (IGA) involve proponents being responsible for addressing any shortfall risk with an equivalent volume of water.
Efficiency Measures to deliver 450 GL	Partially controlled	Complete implementation	South Australia requires full implementation of the efficiency measures to deliver the Basin Plan on time and in full. This is critical to the delivery of agreed environmental outcomes under the Basin Plan, equivalent to 3,200 GL water recovery.
Basin Plan Environmental Watering Plan objectives for the Lower Lakes and Murray Mouth (section 8.06)	Partially controlled	Mostly complete	Meeting of objectives will require Basin Plan implementation in full.
Prerequisite Policy Measures (PPMs). Ability to put environmental water onto unregulated flows. Affects water availability and water regime. Commitment to have policies in place by 2019. States and territories preparing project plans to remove policy constraints (in Basin Plan 2012).	Partially controlled	Mostly complete	PPMs are assumptions in the Basin Plan modelling and therefore must be addressed to deliver on the Basin Plan 2012 agreed outcomes.
Physical constraints management actions to address constraints in ability to deliver water to meet environmental water requirements	Mostly controlled	Mostly complete	Assumption that physical constraints at Hume, Yarrawonga, Murrumbidgee and Goulburn will have agreed business cases and mostly implemented by 2026.
MDB Agreement – entitlement (1,850 GL) and operation of	Partially controlled	Complete implementation	Entitlement does not include adequate water to maintain water levels or water quality for the Lower Lakes.

Document/control	Effectiveness	Implementation	Notes
upstream storages and other infrastructure, cap on diversions			
Basin Salinity Management 2030 Strategy and Schedule B of the Murray Darling Basin Agreement	Partially controlled	Mostly complete	Long-term salinity risk from groundwater is managed with salt interception schemes in critical areas; however, real-time operational risks and local groundwater intrusions/risks are mostly uncontrolled.
Water quality measure and water availability controls. Lake Victoria (in Lake Victoria operating strategy)	Partially controlled	Partially complete	Lake Victoria cannot be used to manage water quality without affecting the quantity of water available for South Australian Entitlement as it is limited by constraints upstream and the SDL adjustment process.
Objectives and outcomes, priority assets and functions and environmental water requirements in Basin-wide environmental watering strategy	Partially controlled	Partially complete	Effectiveness of implementation relies on coordination with other states, and resourcing for monitoring to determine the effectiveness of watering.
Annual environmental water planning, coordination and delivery (annual priorities, Basin-wide annual priorities, delivery of water under The Living Murray (TLM) and by the Commonwealth Environmental Water Holder and individual states in the Southern Connected Basin, including coordination through the Southern Connected Basin Environmental Watering Committee)	Partially controlled	Complete implementation	Delivery of water depends on priorities set across the Basin and the reliability of the water products held. This does not guarantee delivery to the Lower Lakes when required.
Long-term watering plans in NSW, Victoria and Queensland	Mostly uncontrolled	Partially complete	Integration of upstream long-term watering plans with South Australia's LTWP is critical to deliver agreed outcomes in the Lower Lakes, but may be limited by prioritisation of upstream environmental assets.
Management objectives to maintain ecological character of Coorong, Lower Lakes and Murray Mouth in Ramsar Convention and management plan	Partially controlled	Partially complete	Currently being reviewed. Supports prioritisation of the Lower Lakes and Coorong to receive water as part of a 20-year plan. Climate change and increase or decrease in extreme events

Document/control	Effectiveness	Implementation	Notes
			may impact on success of implementation.
Management triggers for the Coorong, Lower Lakes and Murray Mouth Wetland of International Importance (Ramsar)	Mostly controlled	Mostly incomplete	Management triggers are the triggers for action to avoid limits of acceptable change for the site. Implementation of the action will determine whether these triggers are breached.
Chapter 9 of Basin Plan (the MDBA must have regard to the water quality targets in management of water flows – this includes targets at Milang of 1,000 EC)	Mostly uncontrolled	Mostly complete	Have regard means its possible actions will impact on the Lower Lakes; therefore, mostly uncontrolled. All operators must have regard for salinity targets and demonstrate that consideration was given to management actions available and chosen.

SUB-AREA: Lower Lakes

Risk r312: There is the potential that climate extremes could cause changes in water quality, quantity or regime which in turn causes impact to water-dependent ecosystems

Risk source: Climate extremes
Consequence: Water-dependent ecosystems impacted

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely					
Possible		X	X		
Unlikely	X			X	X
Rare					

Final risk rating: **Medium**
Uncertainty: High

Risk factors

Relating to source of risk and potential for events:

- Extended dry periods are observed to lead to significant water quality issues. Declining water levels exposes acid sulfate soil (Phillips and Muller 2006) and causes importation of salt through the barrages. Lack of flows means that increased salinity cannot be flushed (Phillips and Muller 2006).
- Potential sea level rise caused by climate change could reduce the capacity to open barrages (Siebentritt et al. 2014). Under such a scenario, lakes will fill and spill. Moderate sea level rise combined with increased frequency of storm surges is likely to lead to frequent failure of the barrages and higher salinity in the Lower Lakes (DEH 2009) (Siebentritt et al. 2014).
- Configuration of SDLs consistent with environmental objectives is based on expectations of climatic events derived from historical climatic data (114 years of data). Restoration of water-dependent ecosystem values rests on the assumption that the future climate will be similar to the past climate. Modelling indicates that the worst-case ('dry') 2030 climate scenario is characterised by significantly reduced water availability in the Murray–Darling Basin (CSIRO 2008). Risk ratings therefore placed more weight on recent experience regarding climate to account for uncertainty regarding the potential impacts of climate change.
- Water quality has not fully recovered from the effects of the Millennium Drought with areas retaining elevated salinity and acidity (Stone et al. 2016). The water quality in Lake Albert is inherently more sensitive to events than Lake Alexandrina since it is a shallow terminal lake. It retained elevated salinity and cyanobacteria levels for an extended period of time following the end of the Millennium Drought (DEWNR 2014) (Stone et al. 2016).
- Under normal (non-drought) conditions, lake levels can be managed with a low level of risk despite flow constraints. However, there is a trade-off between the risk in the Lower Lakes and the Coorong with respect to management of flow over the barrages.

Relating to consequences:

- This sub-area is part of the Ramsar-listed Coorong and Lakes Alexandrina and Albert Wetland of International Importance (Phillips and Muller 2006). It is a priority environmental asset in the South Australian River Murray WRP area (DEWNR 2015).
- The sub-area hosts state and nationally important species such as Murray Hardyhead, which is critically endangered in South Australia (Office for Water Security, 2010).
- Environmental water requirements to maintain water-dependent ecosystems at a low level of risk requires that the lakes remain a permanently freshwater system with salinity below 1,500 µS cm EC in 100 per cent of years (Lester et al. 2010).
- The Millennium Drought, combined with overuse of water resources throughout the Basin, led to significant impacts to the Lower Lakes (DEH 2009). Reduced flows resulted in shallow water levels, loss of habitat, exposure of acid sulfate soils leading to acidification, and elevated salinity driving a change in the system's ecology (Siebentritt et al. 2014). A wide range of emergency activities were required to prevent species extinctions, which culminated in the Drought Emergency Framework for Lakes Alexandrina and Albert (SAMDB NRM Board 2017b).
- As this sub-area is at the end of the Basin, the most important factor affecting risks to water-dependent ecosystems in the Lower Lakes is the quantity and regime of water flowing in from the River Murray. Restoration and maintenance of ecological character requires adequate frequency of flood events to flush and freshen the system, reduced duration and frequency of detrimental no-flow periods, and sufficient water to operate fishways and provide habitat connectivity between fresh, estuarine and saline units (Phillips and Muller 2006).

Evaluation of existing/planned controls

Document/control	**Effectiveness**	**Implementation**	**Notes**
Management of barrages to facilitate variable lake levels – this control is in development with draft planned for 2017 (in Barrage operating strategy (proposed))	Partially controlled	Partially complete	Policy and operating strategy are designed to avoid the lake levels falling to 0.4 mAHD to the extent that is practically possible. If levels fall below 0.4 mAHD, the MDBA Drought Emergency Framework is activated. Funding for implementation has not yet been secured.
Drought emergency framework for Lakes Alexandrina and Albert (in MDBA Drought Emergency Framework for Lakes Alexandrina and Albert)	Partially controlled	Mostly complete	Framework has been agreed by the Murray–Darling Basin Ministerial Council. Aim is to avoid possibility of the lakes falling below 0.0 mAHD when the risk of acidification increases significantly. The aim is to keep the lakes above 0.0 mAHD and limit the fall below 0.4 mAHD as this causes risks to the Coorong by disconnecting barrage outflows.

Document/control	Effectiveness	Implementation	Notes
Basin Plan Environmental Watering Plan objectives for the Lower Lakes and Murray Mouth (section 8.06)	Partially controlled	Mostly complete	Meeting of objectives will require Basin Plan implementation in full.
MDB Agreement – entitlement (1,850 GL) and operation of upstream storages and other infrastructure, cap on diversions	Mostly uncontrolled	Complete implementation	Entitlement does not include adequate water to maintain water levels or water quality for the Lower Lakes and Coorong under average conditions. Under dry scenarios, lake levels or flows to the Coorong cannot be managed.
Annual environmental water planning, coordination and delivery	Partially controlled	Complete implementation	Delivery of water depends on priorities set across the Basin and the reliability of the water products held. This does not guarantee delivery to the Lower Lakes when required.
Relocation of threatened populations or in situ watering (e.g. Hall et al. 2009)	Partially controlled	Mostly complete	Successful management of Yarra and Southern Pygmy Perch during Millennium Drought.
Basin Salinity Management 2030 Strategy and Schedule B of the MDB Agreement	Partially controlled	Mostly complete	Long-term salinity risk from groundwater is mostly managed with salt interception schemes in critical areas; however, real-time operational risks and local groundwater intrusions/risks are mostly uncontrolled.
Policies for management of River Murray wetlands; wetland management plans for high risk sites (in River Murray WAP)	Mostly uncontrolled	Mostly complete	Wetlands around lakes require higher water levels – lower lake levels would require pumping to wetlands impacted by water delivery to lakes.
Management objectives to maintain ecological character of Coorong, Lower Lakes and Murray Mouth in Ramsar Convention and management plan.)	Partially controlled	Partially complete	Currently being reviewed. Supports prioritisation of Lower Lakes and Coorong to receive water as part of a 20-year plan. Climate change and increase or decrease in extreme events may impact on success of implementation.
Management triggers for the Coorong, Lower Lakes and Murray Mouth Wetland of International Importance (Ramsar)	Mostly controlled	Mostly incomplete	Management triggers are the triggers for action to avoid limits of acceptable change for the site. Implementation of the

Document/control	Effectiveness	Implementation	Notes
			action will determine whether these triggers are breached.
Objectives and outcomes, priority assets and functions and environmental water requirements in Basin-wide environmental watering strategy	Partially controlled	Partially implemented	Effectiveness of implementation relies on coordination with other states, and resourcing for monitoring to determine the effectiveness of watering.
Reconciliation in 2024 of supply measure outcomes for the Basin Plan	Mostly controlled	Complete implementation	Any package of SDL measures agreed in 2017 needs to be implemented in full by 2024. Any projects not implemented in this timeframe will need to be reconciled. Current draft principles for the new IGA involve proponents being responsible for addressing any shortfall risk in an equivalent volume of water.
Long-term environmental watering plan (LTWP) for the South Australian River Murray WRP area: Sets objectives and targets and environmental water requirements and identifies priority environmental assets and functions	Partially controlled	Mostly implemented through annual watering priorities, rules in WRPs and monitoring programs	LTWP does consider different climate scenarios.
Chapter 9 of Basin Plan (the MDBA must have regard to the water quality targets in management of water flows – this includes targets at Milang of 1,000 EC)	Mostly uncontrolled	Mostly complete	Have regard means its possible actions will impact on the Lower Lakes; therefore, mostly uncontrolled. All operators must have regard to salinity targets and demonstrate that consideration was given to management actions available and chosen.

SUB-AREA: Lower Lakes

Risk r318: Management of connected water resources could cause changes in water quality, quantity or regime which in turn impacts the economic use of water

Risk source: Management of connected water resources
Consequence: Economic use of water impacted

	Insig.	Mod.	Major	Cat.
Almost Certain				
Likely	X			
Possible				
Unlikely		X	X	X
Rare				

Final risk rating: **Medium** [8]
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- There are a range of uncertainties regarding the implementation of the Basin Plan affecting the achievement of environmental outcomes in South Australia (see r320). It was determined that these uncertainties could affect economic outcomes – particularly those related to non-consumptive economic benefits such as tourism, recreation and ecosystem services.
- Return flows from proposed large-scale environmental watering upstream potentially causes water quality events such as blackwater, salinity or algal blooms in South Australia. While operations upstream must have regard to water quality, there is uncertainty regarding the effectiveness of controls.
- Highly saline connected groundwater causes risk in the Upper Murray, which could in turn affect the Lower Murray. This risk is controlled through existing programs and policy including salt interception schemes and the salinity zoning policy of the River Murray Prescribed Watercourse Water Allocation Plan (SAMDB NRM Board 2017).
- There are proposals to modify operation of the salt interception schemes in a way that will reduce pumping and entail greater reliance on a responsive management approach. This could lead to increased risk associated with salinity in the River Murray and downstream. However, this risk was determined to be low over the assessment timeframe.
- Water levels below Lock 1 are inherently less controllable than above Lock 1
- There is potential for high salinity levels in the Coorong to impact water quality in the Lower Lakes during dry periods. During the Millennium Drought, water quality in proximity to the barrages became saline (DEH 2009).
- While proposed restoration of flows to the Coorong from the South East catchments through Salt Creek will assist salinity management in the Coorong (DEWNR 2015), it is unlikely to significantly affect risk management in the Lower Lakes.

[8] 4 consequence levels (rather than 5) were assigned for "economic use of water impacted" (see Section 3.3.2.1)

- The Eastern Mount Lofty Ranges (EMLR) and SA Murray Region WRPs contribute relatively minor volumes of water to the sub-area compared to flows across the border (DEWNR 2015).
- Climate change is expected to cause incremental sea level rise over the longer term. This could cause impacts to the operation of the barrage system potentially causing Lake Alexandrina to assume a more estuarine character, which is detrimental to consumptive and non-consumptive economic use (DEH 2009) (Siebentritt et al. 2014).

Relating to consequences:

- Lakes Alexandrina and Albert support 9 per cent of total take from the South Australian River Murray for consumptive economic use purposes.
- The Millennium Drought severely impacted irrigators that depend on the Lower Lakes, with 2008–09 allocations at 18 per cent. Many irrigators had difficulty accessing water with acceptable quality. The dairy industry, which was severely affected by the drought, is deemed to have limited capacity to adapt to ongoing reductions in water availability (Connor 2011).
- Significant expense was incurred as a result of the Millennium Drought due to levee remediation, emergency repairs on bridge footings, adjustments to ferry landings, additional pipeline infrastructure, losses to irrigation infrastructure, laser levelling following floodplain consolidation, liming, and construction of bunds to retain freshwater and prevent further acidification (Connor et al. 2011).
- Significant tourism and fishery industries depend on the Lower Lakes. These industries were severely impacted by the combination of the Millennium Drought and overuse of water resources throughout the Basin. Cumulative ecosystem services losses caused by the drought have been estimated at over $700 million, with a large proportion of the losses incurred in the period from 2008 to 2010 (Connor et al. 2011).
- There have been significant land use changes since the Millennium Drought which have reduced dependence on the Lower Lakes for irrigation water. The irrigation industry on the eastern side of the lakes has contracted and been partially supplanted by dryland farming.
- The water quality in Lake Albert is inherently sensitive to events since it is a shallow terminal lake. It retained elevated salinity for an extended period of time following the end of the Millennium Drought. This has led to ongoing concerns for some irrigators (DEWNR 2014).
- Alternative water sources such as groundwater are available to many users.
- Increased environmental flows to the Lower Lakes (i.e. through implementation of the Basin Plan) will dilute salinity and reduce risk to irrigators (Connor 2011).

Evaluation of existing/planned controls

Document/control	**Effectiveness**	**Implementation**	**Notes**
Reconciliation in 2024 of supply measure outcomes for the Basin Plan	Mostly controlled	Complete implementation	Any package of SDL measures agreed in 2017 needs to be implemented in full by 2024. Any projects not implemented in this timeframe will need to be reconciled. Current draft principles for the new IGA involve proponents being responsible for addressing any shortfall risk in an equivalent volume of water.
Efficiency Measures to deliver 450 GL	Partially controlled	Complete implementation	South Australia requires full implementation of the efficiency measures to deliver the Basin Plan on time and in full. This is critical to the delivery of agreed environmental outcomes under the Basin Plan,

Document/control	Effectiveness	Implementation	Notes
			equivalent to 3,200 GL water recovery and will also sustain economic activity in the Lower Lakes.
Prerequisite Policy Measures (PPMs). Ability to put environmental water onto unregulated flows. Affects water availability and water regime. Commitment to have policies in place by 2019. States and territories preparing project plans to remove policy constraints (in Basin Plan 2012).	Partially controlled	Mostly complete	PPMs are assumptions in the Basin Plan modelling and therefore must be addressed to deliver on the Basin Plan 2012 agreed outcomes.
Physical constraints management actions to address constraints in ability to deliver water to meet environmental water requirements.	Mostly controlled	Mostly complete	Assumption that physical constraints at Hume, Yarrawonga, Murrumbidgee and Goulburn will have agreed business cases and be mostly implemented by 2026.
MDB Agreement – entitlement (1,850 GL) and operation of upstream storages and other infrastructure, cap on diversions	Partially controlled	Complete implementation	Entitlement does not include adequate water to maintain water levels or water quality for the Lower Lakes
Basin Salinity Management 2030 Strategy and Schedule B of the Murray Darling Basin Agreement	Partially controlled	Mostly complete	Long- term salinity risk from groundwater is managed with salt interception schemes in critical areas; however, real time operational risks and local groundwater intrusions/risks are mostly uncontrolled.
Water quality measure and water availability controls, Lake Victoria (in Lake Victoria operating strategy).	Partially controlled	Partially complete	Lake Victoria cannot be used to manage water quality without affecting the quantity of water available for the South Australian Entitlement as it is limited by constraints upstream and the SDL adjustment process.
Long-term watering plans in NSW, Victoria and Queensland	Mostly uncontrolled	Partially complete	Integration of upstream long-term watering plans with South Australia's LTWP is critical to deliver agreed outcomes in the Lower Lakes, but may be limited by prioritisation of upstream environmental assets.
Management objectives to maintain the ecological character of Coorong, Lower Lakes and Murray Mouth in	Partially controlled	Partially complete	Currently being reviewed. Supports prioritisation of Lower Lakes and Coorong to receive water as part of a 20-year plan. Climate change and

Document/control	Effectiveness	Implementation	Notes
Ramsar Convention and management plan.			increase or decrease in extreme events may impact on success of implementation.
Management triggers for the Coorong, Lower Lakes and Murray Mouth Wetland of International Importance (Ramsar)	Mostly controlled	Mostly incomplete	Management triggers are the triggers for action to avoid limits of acceptable change for the site. Implementation of the action will determine whether these triggers are breached.
Chapter 9 of Basin Plan (the MDBA must have regard to the water quality targets in management of water flows – this includes targets at Milang of 1000 EC)	Mostly uncontrolled	Mostly complete	Have regard means it is possible that actions that will impact on the Lower Lakes; therefore, mostly uncontrolled. All operators must have regard for salinity targets and demonstrate that consideration was given to management actions available and chosen.

LOWER LAKES – Low Risks

SUB-AREA: Lower Lakes

Risk r310: There is the potential that climate extremes could cause changes in water quality, quantity or regime which in turn impacts economic use of water

Risk source: Climate extremes
Consequence: Economic use of water impacted

	Insig.	Mod.	Major	Cat.
Almost Certain				
Likely	**X**			
Possible				
Unlikely		**X**		
Rare			**X**	**X**

Final risk rating: **Low** [9]
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- Risks related to climate extremes were determined to be inherently uncontrollable. However, the 10-year timeframe of the assessment means that the likelihood of climate extremes having severe effects over this period is low based on historical frequencies of events (i.e. not considering the potential impacts of climate change over the assessment period). Modelling undertaken to inform the Basin Plan applied South Australia's allocations framework to 114 years of historical data to determine the risks to South Australia's Entitlement. Hindcasting against risk criteria for this assessment indicates events leading to two catastrophic, zero major, two moderate and one minor consequence over this time period.
- Modelling indicates that full implementation of the Basin Plan will achieve level of 0.4 mAHD 95 per cent of the time and >0 mAHD 100 per cent of the time (MDBA 2012).
- Climate change could cause a change in the frequency of extreme events or a long-term incremental trend towards changed water availability. Modelling indicates that the worst-case ('dry') 2030 climate scenario is characterised by significantly reduced water availability in the Murray–Darling Basin (CSIRO 2008).
- Extended dry periods lead to significant water quality issues. Declining water levels exposes acid sulfate soil (Phillips and Muller 2006) and causes importation of salt through the barrages. Lack of flows means that increased salinity cannot be flushed (Phillips and Muller 2006).
- Potential climate change causing moderate sea level rise and increased frequency of storm surges is likely to lead to frequent failure of the barrages and higher salinity in the Lower Lakes (DEH 2009) (Siebentritt et al. 2014).

[9] 4 consequence levels (rather than 5) were assigned for "economic use of water impacted" (see Section 3.3.2.1)

- Water offtake and distribution infrastructure has been augmented since the Millennium Drought through projects such as the Lower Lakes integrated Pipeline Project. This augmentation reduces risks related to access of water in the event of low water levels (DEH 2010).
- Trade is an important mechanism allowing enterprises that depend on the resource to manage their risks. Trade of water into South Australia during the Millennium Drought was critical for maintaining economic activity over this period (Kirby et al. 2012). However, recovery of water to achieve environmental goals under the Basin Plan could leave less water available for trade into South Australia during drought.

Relating to consequences:

- Lakes Alexandrina and Albert support 9 per cent of total take from the South Australian River Murray for consumptive economic use purposes
- The Millennium Drought severely impacted irrigators that depend on the Lower Lakes, with 2008–09 allocations at 18 per cent. Many irrigators had difficulty accessing water with acceptable quality. The dairy industry, which was severely affected by the drought, is deemed to have limited capacity to adapt to ongoing reductions in water availability (Connor 2011).
- Significant expense was incurred as a result of the Millennium Drought due to levee remediation, emergency repairs on bridge footings, adjustments to ferry landings, additional pipeline infrastructure, losses to irrigation infrastructure, laser levelling following floodplain consolidation, liming, and construction of bunds to retain freshwater and prevent further acidification (Connor et al. 2011).
- Significant tourism, recreation and fishery industries depend on the Lower Lakes. These industries were severely impacted by the Millennium Drought. Cumulative ecosystem services losses caused by the drought have been estimated at over $700 million, with a large proportion of the losses occurring in the period from 2008 to 2010 (Connor et al. 2011).
- There have been significant land use changes since the Millennium Drought which have reduced dependence on the Lower Lakes for irrigation water. The irrigation industry on the eastern side of the lakes has contracted and been partially supplanted by dryland farming.
- The water quality in Lake Albert is inherently sensitive to events since it is a shallow terminal lake. It retained elevated salinity for an extended period of time following the end of the Millennium Drought. This has led to ongoing concerns for some irrigators (DEWNR 2014).
- Alternative water sources such as groundwater are available to many users.
- Increased environmental flows to the Lower Lakes (i.e. through implementation of the Basin Plan) will dilute salinity and reduce risk to irrigators (Connor 2011).

SUB-AREA: Lower Lakes

Risk r314: There is the potential that demand/take (including interception activities) could cause changes in water quality, quantity or regime which in turn could impact the economic use of water

Risk source: Demand/take (including interception activities)
Consequence: Economic use of water impacted

	Insig.	Mod.	Major	Cat.
Almost Certain	X			
Likely				
Possible				
Unlikely				
Rare		X	X	X

Final risk rating: **Low** [10]
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- This risk considers risk caused by take within the sub-area, not the effects of take in connected Basin or non-Basin water resources.
- The River Murray Prescribed Watercourse Water Allocation Plan (SAMDB NRM Board 2017) and the Basin Plan control this risk. These controls are assumed to be effective, they are being implemented, and there is a high level of compliance.
- The risk of being on decreased allocations is relatively low based on existing modelling.
- There is less control over water level below Lock 1. However, it is unlikely that take by one user will affect take by other users.

Relating to consequences:

- The Lower Lakes support 9 per cent of total take from the South Australian River Murray for consumptive economic use purposes.
- There have been significant land use changes since the Millennium Drought which have reduced dependence on the Lower Lakes for irrigation water. The irrigation industry on the eastern side of the lakes has contracted and been partially supplanted by dryland farming.
- Significant tourism and fishery industries depend on the Lower Lakes.
- Alternative water sources such as groundwater are available to many users.
- The water quality in Lake Albert is inherently sensitive to events since it is a shallow terminal lake. It retained elevated salinity for an extended period of time following the end of the Millennium Drought. This has led to ongoing concerns for some irrigators (DEWNR 2014).

[10] 4 consequence levels (rather than 5) were assigned for "economic use of water impacted" (see Section 3.3.2.1)

SUB-AREA: Lower Lakes

Risk r322: There is the potential that operation of infrastructure could cause change in water quality, quantity or regime which in turn impacts economic use of water

Risk source: Operation of infrastructure
Consequence: Economic use of water impacted

	Insig.	Mod.	Major	Cat.
Almost Certain				
Likely	X			
Possible				
Unlikely				
Rare		X	X	X

Final risk rating: **Low** [11]
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- Infrastructure includes locks, regulators, weirs, barrages and levee banks. The risk assessment considers the operation of infrastructure within the sub-area and not in connected water resources. It only considers potential consequences of infrastructure operation within the sub-area.
- Operation of the barrages is the most significant factor affecting risk below Lock 1 because they control water level. Operational issues could cause the water level to be too low or too high.
- Barrage operation to maintain water levels within the desired range depends on a system of ongoing monitoring and analysis. Decision-making is affected by some uncertainty with respect to the management of connected resources and assumptions regarding flow responses in the river. The operational system was determined to be largely effective in controlling risks.
- Water offtake and distribution infrastructure has been augmented since the Millennium Drought through projects such as the Lower Lakes integrated Pipeline Project. This augmentation reduces risks related to access of water caused by low water levels (DEH 2010).
- Future infrastructure operation will aim to achieve variable water levels in the Lower Lakes, which will provide for environmental benefits which, in turn, brings economic benefits (DEH 2010).

Relating to consequences:

- The Lower Lakes support 9 per cent of total take from the South Australian River Murray for consumptive economic use purposes.

[11] 4 consequence levels (rather than 5) were assigned for "economic use of water impacted" (see Section 3.3.2.1)

- Irrigation industry dependent on the Lower Lakes collapsed during the Millennium Drought as a result of unprecedented low water levels and associated water quality problems caused by acid sulfate soils and salinity (MDBA 2010). While these consequences did not occur as a result of infrastructure operation in this instance, these outcomes are indicative of what could happen in the event of low water levels.
- There have been significant land use changes since the Millennium Drought which have reduced dependence on the Lower Lakes for irrigation water. The irrigation industry on the eastern side of the lakes has contracted and been partially supplanted by dryland farming.
- Significant tourism and fishery industries depend on the Lower Lakes. Low water levels cause navigation issues.
- Alternative water sources are available to many users.
- The water quality in Lake Albert is inherently sensitive to events since it is a shallow terminal lake. It retained elevated salinity for an extended period of time following the end of the Millennium Drought. This has led to ongoing concerns for some irrigators (DEWNR 2014).
- Increased environmental flows to the Lower Lakes (i.e. through implementation of the Basin Plan) will dilute salinity and reduce risks to irrigators (Connor 2011).

SUB-AREA: Lower Lakes

Risk r326: There is the potential that point source pollution could cause changes in water quality, quantity or regime which in turn impacts economic use

Risk source: Point source pollution
Consequence: Economic use of water impacted

	Insig.	Mod.	Major	Cat.
Almost Certain				
Likely	X			
Possible				
Unlikely		X		
Rare			X	X

Final risk rating: **Low** [12]
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- Point sources of pollution can include sewage, houseboats, chemicals, grey water, petrol station storages, industrial discharges etc. These risks are controlled through South Australia's Environment Protection Water Quality Policy (*Environment Protection Act 1993*), Development Act, stormwater management plans etc.
- The Lower Murray Reclaimed Irrigation Area (LMRIA) is a point source of pollution. The risks caused by this hazard are addressed through risks arising from the management of connected water resources (r320).
- Accumulation and remobilisation of metals in the Lower Lakes which originate from the LMRIA is a potential source of risk. There is uncertainty about the importance of this risk over the longer term.
- Lake Albert is a net acidity hazard in the event of drought causing low water levels. This risk is addressed by risks arising from climate extremes and management of connected resources (r320 and r312).

Relating to consequences:

- The Lower Lakes support 9 per cent of total take from the South Australian River Murray for consumptive economic use purposes.
- There have been significant land use changes since the Millennium Drought which have reduced dependence on the Lower Lakes for irrigation water. The irrigation industry on the eastern side of the lakes has contracted and been partially supplanted by dryland farming.
- Significant tourism and fishery industries depend on the Lower Lakes.
- Alternative water sources are available to many users.

[12] 4 consequence levels (rather than 5) were assigned for "economic use of water impacted" (see Section 3.3.2.1)

- The water quality in Lake Albert is inherently sensitive to events since it is a shallow terminal lake. It retained elevated salinity for an extended period of time following the end of the Millennium Drought. This has led to ongoing concerns for some irrigators (DEWNR 2014).

SUB-AREA: Lower Lakes

Risk r330: There is the potential that land use could cause changes in water quality, quantity or regime which in turn impacts economic use

Risk source: Land use
Consequence: Economic use of water impacted

	Insig.	Mod.	Major	Cat.
Almost Certain				
Likely	X			
Possible				
Unlikely		X		
Rare			X	X

Final risk rating: **Low** [13]
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- This risk addresses the effects of new or changed land use. It does not address land use unlikely to change over the risk assessment period.
- The Development Act and the River Murray Act control developments that could cause risk.
- It is unlikely that there will be significant increases in the size or impact of the irrigation industry given the effectiveness of existing controls and the inherent constraints related to water availability.

Relating to consequences:

- The Lower Lakes support 9 per cent of total take from the South Australian River Murray for consumptive economic use purposes.
- There have been significant land use changes since the Millennium Drought which have reduced dependence on the Lower Lakes for irrigation water. The irrigation industry on the eastern side of the lakes has contracted and been partially supplanted by dryland farming.
- Significant tourism and fishery industries depend on the Lower Lakes.
- Alternative water sources are available to many users.
- The water quality in Lake Albert is inherently sensitive to events since it is a shallow terminal lake. It retained elevated salinity for an extended period of time following the end of the Millennium Drought. This has led to ongoing concerns for some irrigators (DEWNR 2014).

[13] 4 consequence levels (rather than 5) were assigned for "economic use of water impacted" (see Section 3.3.2.1)

SUB-AREA: Lower Lakes

Risk r334: There is the potential that invasive/nuisance organisms could cause changes in water quality, quantity or regime which in turn impacts economic use of water

Risk source: Invasive/nuisance organisms
Consequence: Economic use of water impacted

	Insig.	Mod.	Major	Cat.
Almost Certain				
Likely	X			
Possible				
Unlikely		X		
Rare			X	X

Final risk rating: **Low** [14]
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- Algal blooms in Lake Albert present a greater challenge to management than elsewhere in the South Australian River Murray WRP area because it is a terminal lake. Environmental water for flushing is relatively ineffective as a control. Lake Albert retained elevated cyanobacteria levels for an extended period of time following the end of the Millennium Drought (Stone et al. 2016).
- Tubeworms were observed during the drought. However, as this was a consequence of drought, it was not considered under the present assessment. Similarly, carp harvesting was undertaken during the drought, but this factor is considered in the context of risks caused by climate extremes.
- Invasive/nuisance organisms are associated with existing impacts which are anticipated to continue to compromise achievement of desired outcomes. The baseline for the present assessment considers the context of the long-term watering plan for the South Australian River Murray (DEWNR 2015). This baseline assumes an existing level of impact.
- Blue-green algal blooms are events which can occur both naturally and in response to disturbance.
- Impacts of invasive/nuisance organisms on water-dependent ecosystems can include fluctuations in dissolved oxygen, release of toxins and direct and indirect food web impacts. The present assessment only considers impacts caused by water quality/quantity events, not direct ecological impacts.
- While proposed controls for carp, such as the carp herpes virus, are expected to bring longer-term benefits, there could be short-term acute impacts on water quality arising from a large number of dead carp.

[14] 4 consequence levels (rather than 5) were assigned for "economic use of water impacted" (see Section 3.3.2.1)

- Effects of improvements in irrigation management on water quality are assumed to reduce the likelihood of algal bloom events.

Relating to consequences:

- The Lower Lakes support 9 per cent of total take from the South Australian River Murray for consumptive economic use purposes.
- There have been significant land use changes since the Millennium Drought which have reduced dependence on the Lower Lakes for irrigation water. The irrigation industry on the eastern side of the lakes has contracted and been partially supplanted by dryland farming.
- Significant tourism and fishery industries depend on the Lower Lakes.
- Alternative water sources are available to many users.
- The water quality in Lake Albert is inherently sensitive to events since it is a shallow terminal lake. It retained elevated salinity for an extended period of time following the end of the Millennium Drought. This has led to ongoing concerns for some irrigators (DEWNR 2014).

SUB-AREA: Lower Lakes

Risk r316: There is the potential that demand/take could cause changes in water quality, quantity or regime which in turn impacts to water-dependent ecosystems

Risk source: Demand/take
Consequence: Water-dependent ecosystems impacted

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible					
Unlikely		X			
Rare			X	X	X

Final risk rating: **Low**
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- This risk considers risk caused by take within the sub-area. The risks caused by take in connected Basin or non-Basin water resources are addressed by r320.
- The River Murray Prescribed Watercourse Water Allocation Plan (SAMDB NRM Board 2017) and the Basin Plan control this risk. These controls have effective approaches to setting sustainable limits of take. Volumes taken are controlled through licensing. There is a high level of compliance.
- There is less take from the Lower Lakes than for the Lower Murray or Upper Murray.
- There have been significant changes in the composition of the irrigation industries in the region as a result of recent droughts and changed market conditions. The importance of the dairy industry, which historically placed significant demand on water resources, is greatly reduced. The extent to which the industry may recover is uncertain, although industries based on irrigated pasture are deemed less able to adapt to ongoing reductions in water availability or higher water prices (Connor 2011).
- Risk was assessed against current levels of take, and controls are those policies/plans assumed to be in place during the risk assessment period.

Relating to consequences:

- This sub-area is part of the Ramsar-listed Coorong and Lakes Alexandrina and Albert Wetland of International Importance (Phillips and Muller 2006). It is a priority environmental asset (PEA) in the South Australian River Murray WRP area (DEWNR 2015).
- Environmental water requirements to maintain water-dependent ecosystems at a low level of risk requires that the lakes remain a permanently freshwater system with salinity below 1500 µS cm EC in 100 per cent of years (Lester et al. 2010).
- The sub-area hosts state and nationally important species such as Murray Hardyhead, which is critically endangered in South Australia (Office for Water Security, 2010).

SUB-AREA: Lower Lakes

Risk r324: There is the potential that operation of infrastructure could cause changes in water quality, quantity or regime which in turn causes impacts to water-dependent ecosystems

Risk source: Operation of infrastructure
Consequence: Water-dependent ecosystems impacted

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible					
Unlikely		X			
Rare			X	X	X

Final risk rating: **Low**
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- Infrastructure includes locks, regulators, weirs, barrages and banks. The risk assessment considers the operation of infrastructure within the sub-area and not in connected water resources. It only considers potential consequences of infrastructure operation within the sub-area.
- Operation of the barrages is the most significant factor affecting risk below Lock 1. Barrages control the water level below Lock 1. Operational issues could cause the water level to be too low or too high.
- Barrage operation to maintain water levels within the desired range depends on a system of ongoing monitoring and analysis. Decision-making is affected by some uncertainty with respect to the management of connected resources and assumptions regarding flow responses in the river. The operational system was determined to be largely effective in controlling risks.
- Residual risk to water-dependent ecosystems in the Lower Lakes is caused by factors outside the control of infrastructure operation within the sub-area such as climate extremes (r312) and recovery and management of environmental water at the Basin scale (r320).
- Future infrastructure operation will aim to achieve variable water levels in the Lower Lakes, for the purposes of achieving environmental benefits (DEH 2010).

Relating to consequences:

- This sub-area is part of the Ramsar-listed Coorong and Lakes Alexandrina and Albert Wetland of International Importance (Phillips and Muller 2006). It is a priority environmental asset in the South Australian River Murray WRP area (DEWNR 2015).
- Environmental water requirements to maintain water-dependent ecosystems at a low level of risk requires that the lakes remain a permanently freshwater system with salinity below 1500 µS cm EC in 100 per cent of years (Lester et al. 2010).

- The sub-area hosts state and nationally important species such as Murray Hardyhead, which is critically endangered in South Australia (Office for Water Security, 2010).
- The Millennium Drought, combined with overuse of water resources throughout the Basin, led to significant impacts to the Lower Lakes (DEH 2009). Reduced flows resulted in shallow water levels, loss of habitat, exposure of acid sulfate soils leading to acidification, and elevated salinity driving a change in the system's ecology (Siebentritt et al. 2014). A wide range of emergency activities were required to prevent species extinctions, which culminated in the Drought Emergency Framework for Lakes Alexandrina and Albert (SAMDB NRM Board 2017b). While risks caused by climate extremes are fully addressed in r312, this factor illustrates the potential impacts of severe events causing low water level.

SUB-AREA: Lower Lakes

Risk r328: There is the potential that point source pollution could cause changes in water quality, quantity or regime which in turn causes impacts to water-dependent ecosystems

Risk source: Point source pollution
Consequence: Water-dependent ecosystems impacted

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible		X			
Unlikely					
Rare			X	X	

Final risk rating: **Low** [15]
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- Point sources of pollution can include sewage, houseboats, chemicals, grey water, petrol station storages, industrial discharges etc. These risks are controlled through South Australia's Environment Protection Water Quality Policy (*Environment Protection Act 1993*), Development Act, stormwater management plans etc.
- The LMRIA is a point source of pollution. The risks caused by this hazard are addressed through risks arising from the management of connected water resources (r320).
- Accumulation and remobilisation of metals in the Lower Lakes which originate from the LMRIA is a potential source of risk. There is uncertainty about the importance of this risk over the longer term.
- Lake Albert is a net acidity hazard in the event of drought causing low water levels. This risk is addressed by risks arising from climate extremes and management of connected resources (r320 and r312).

Relating to consequences:

- This sub-area is part of the Ramsar-listed Coorong and Lakes Alexandrina and Albert Wetland of International Importance (Phillips and Muller 2006). It is a priority environmental asset in the South Australian River Murray WRP area (DEWNR 2015).
- Environmental water requirements to maintain water-dependent ecosystems at a low level of risk requires that the lakes remain a permanently freshwater system with salinity below 1,500 µS cm EC in 100 per cent of years (Lester et al. 2010).

[15] The risk analysis determined that there was zero percent likelihood of a catastrophic consequence for this risk. Therefore there is no "x" marked against this consequence level in the risk matrix.

- The sub-area hosts state and nationally important species such as Murray Hardyhead, which is critically endangered in South Australia (Office for Water Security, 2010).

SUB-AREA: Lower Lakes

Risk r332: There is the potential that land use could cause changes in water quality, quantity or regime which in turn causes impacts to water-dependent ecosystems

Risk source: Land use
Consequence: Water dependent ecosystems impacted

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible					
Unlikely		X			
Rare			X	X	

Final risk rating: **Low**
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- This risk addresses the effects of new or changed land use. It does not address land use unlikely to change over the risk assessment period.
- The Development Act and River Murray Act control developments that could cause risk.
- It is unlikely that there will be significant increases in the size or impact of the irrigation industry given the effectiveness of existing controls and the inherent constraints related to water availability.

Relating to consequences:

- This sub-area is part of the Ramsar-listed Coorong and Lakes Alexandrina and Albert Wetland of International Importance (Phillips and Muller 2006). It is a priority environmental asset in the South Australian River Murray WRP area (DEWNR 2015).
- Environmental water requirements to maintain water-dependent ecosystems at a low level of risk requires that the lakes remain a permanently freshwater system with salinity below 1,500 µS cm EC in 100 per cent of years (Lester et al. 2010).
- The sub-area hosts state and nationally important species such as Murray Hardyhead, which is critically endangered in South Australia (Office for Water Security, 2010).

SUB-AREA: Lower Lakes

Risk r336: There is the potential that invasive/nuisance organisms could cause changes in water quality, quantity or regime which in turn causes impact to water-dependent ecosystems

Risk source: Invasive/nuisance organisms
Consequence: Water-dependent ecosystems impacted

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible		X			
Unlikely			X		
Rare				X	X

Final risk rating: **Low**
Uncertainty: Moderate

Risk factors

Relating to source of risk and potential for events:

- Algal blooms in Lake Albert present a greater challenge to management than elsewhere in the South Australian River Murray WRP area because it is a terminal lake. Environmental water for flushing is relatively ineffective as a control. Lake Albert retained elevated cyanobacteria levels for an extended period of time following the end of the Millennium Drought (Stone et al. 2016).
- Tubeworms were observed during the drought. However, this was a risk caused by climate extremes and was not considered under the present assessment. Similarly, carp harvesting was undertaken during the drought, but this factor is also considered in the context of risks caused by climate extremes.
- Invasive/nuisance organisms are associated with existing impacts which are anticipated to continue to compromise achievement of desired outcomes. The baseline for the present assessment considers the context of the long-term watering plan for the South Australian River Murray (DEWNR 2015). This baseline assumes an existing level of impact.
- Blue-green algal blooms are events which can occur both naturally and in response to disturbance.
- Impacts of invasive/nuisance organisms on water-dependent ecosystems can include fluctuations in dissolved oxygen, release of toxins and direct and indirect food web impacts. The present assessment only considers impacts caused by water quality/quantity events, not direct ecological impacts.
- While proposed controls for carp, such as the carp herpes virus, are expected to bring longer-term benefits, there could be short-term acute impacts on water quality arising from a large number of dead carp.
- Effects of improvements in irrigation management on water quality are assumed to reduce the likelihood of algal bloom events.

- It was determined that the likelihood of new invasive species (e.g. Oriental weatherloach) becoming established is low given the impacts of existing invasive species.

Relating to consequences:

- This sub-area is part of the Ramsar-listed Coorong and Lakes Alexandrina and Albert Wetland of International Importance (Phillips and Muller 2006). It is a priority environmental asset in the South Australian River Murray WRP area (DEWNR 2015).
- The sub-area hosts state and nationally important species such as Murray Hardyhead, which is critically endangered in South Australia (Office for Water Security, 2010).

SUB-AREA: Lower Lakes

Risk r323: There is the potential that the operation of infrastructure could cause changes in water quality, quantity or regime which in turn impacts connected water resources

Risk source: Operation of infrastructure
Consequence: Connected water resources impacted

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely					
Possible	X	X			
Unlikely			X		
Rare				X	

Final risk rating: **Low**
Uncertainty: Moderate

Risk factors

Relating to source of risk and potential for events:

- Infrastructure includes locks, regulators, weirs, barrages and banks. The assessment of this risk considers the effect of operation of infrastructure within the sub-area (i.e. not in connected water resources) on connected water resources.
- Operation of the barrages is the most significant factor affecting infrastructure risk below Lock 1. Barrage operation to maintain water levels within the desired range depends on a system of ongoing monitoring and analysis. Decision-making is affected by some uncertainty with respect to the management of connected resources and assumptions regarding flow responses in the river. The operational system was determined to be largely effective in controlling risks.
- Low water level can cause events in connected groundwater which can cause environmental and economic consequences outside of the sub-area (DEWNR 2017)
- The Basin Plan requires that water levels in the Lower Lakes are above 0.4 mAHD for 95 per cent of the time and 0.0 mAHD for 100 per cent of the time. As well as minimising impacts of low water levels below Lock 1 (e.g. causing acidification), this objective allows for discharge from the barrages to provide for objectives in the Murray Mouth and Coorong (DEWNR 2015).
- Future infrastructure operation will aim to achieve variable water levels in the Lower Lakes, which will provide for environmental benefits in the lakes (DEH 2010). This could affect connected water resources below Lock 1 and discharge to the Murray Mouth and Coorong environments.
- It was determined that the effectiveness of controls, including environmental watering strategies, operating plans and procedures, is important for managing the risks caused by

operation of infrastructure. Loss of corporate knowledge could impact the effectiveness of controls.

Relating to consequences:

- The assessment considered effects of operation of infrastructure within the sub-area on connected water resources outside of the sub-area. Consequences could occur in the Lower Murray channel and floodplains, connected groundwater and the Coorong and Murray Mouth.
- The Coorong and Murray Mouth are part of the Ramsar-listed Coorong and Lakes Alexandrina and Albert Wetland of International Importance (Phillips and Muller 2006). It is a priority environmental asset in the South Australian River Murray WRP area (DEWNR 2015). These areas host state and nationally important species (Office for Water Security, 2010).
- The Lower Murray wetlands are nationally important and are important for fish species having national significance.
- The Lower Murray is a key water resource supporting critical human water needs of over one million SA Water customers. There is a high level of control for these risks commensurate with the high level of dependency (see risks r349, r357, r353, r345, r361, r337).
- The Coorong and Murray Mouth supports significant non-consumptive economic and cultural use values including a commercial fishery (PIRSA 2016), tourism and other cultural values.
- The Lower Murray supports a significant irrigation industry and large-scale economic activities supported by SA Water's supplies.
- Water level in the Lower Lakes below 0.5 mAHD prevents water access for some consumptive users (DEWNR 2015). Perceptions that low water level events could recur will hinder further investment.
- Low water levels in the Lower Murray cause increased pumping costs to SA Water.
- Under low flow conditions there are trade-offs regarding the risks of operation of the barrages. The barrages are operated in a manner to minimise negative impacts to both the Coorong and the South Australian River Murray WRP area below Lock 1. However, prioritisation of water levels below Lock 1 under extreme circumstances leads to a greater likelihood of negative impacts on the Coorong and Murray Mouth as was observed during the Millennium Drought.
- The risk assessment for the SA Murray Region WRP area concluded that the water-dependent ecosystems of the Coorong sub-area are at a high level of risk caused by management of connected water resources leading to insufficient flows over the barrages. It was determined that a substantial contributor to this risk is overuse of water resources throughout the Basin rather than operation of infrastructure in the Lower Lakes (DEWNR 2017).

LOWER MURRAY – Significant Risks

SUB-AREA: Lower Murray

Risk r337: There is the potential that climate extremes could cause changes in water quality, quantity or regime which in turn causes critical human water needs not being met

Risk source: Climate extremes
Consequence: Critical human water needs not met

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible					
Unlikely		X		X	
Rare			X		X

Final risk rating: **Medium**
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- Climate change could cause a change in the frequency of extreme events or a long-term incremental trend towards changed water availability. Modelling indicates that the worst-case ('dry') 2030 climate scenario is characterised by significantly reduced water availability in the Murray–Darling Basin (CSIRO 2008). Risk ratings therefore placed more weight on recent experience regarding climate to account for uncertainty regarding the potential impacts of climate change.
- Climate extremes can be associated with algal blooms. This risk is addressed under the risks caused by invasive/nuisance organisms.
- Flood events can cause water quality impacts, such as blackwater. The risks to potable supply are effectively controlled through SA Water's treatment plants and other contingency measures.
- Drought leading to low water levels can expose acid sulfate soils in areas that are normally permanently inundated. This event occurred during the Millennium Drought when water levels below Lock 1 fell below -1 mAHD, leading to widespread acidification and point source pollution events originating from the Lower Murray Reclaimed Irrigation Area (Mosley et al. 2013). Acidification mobilises metals that present a risk to potable water supply.
- South Australia has secured 80 GL of storage rights in Dartmouth reservoirs for critical human water needs since the last drought through the addition of Schedule G to the Murray–Darling Basin Agreement. Special accounting requires each of the upstream states to have 835 GL in storage for delivery to South Australia to provide entitlement flows (MDBA 2016). Recent changes in these rules have increased the security of South Australia's supply from the River Murray to support critical human water needs.

- New measures put in place since the last drought (e.g. Schedule G of the Murray–Darling Basin Agreement, construction of the Adelaide Desalination Plant, and recovery of environmental water) provide additional levels of control for the risk of climate extremes. However, extended dry periods will limit the effectiveness of storage rights and environmental water at maintaining water levels below Lock 1.
- Water level below Lock 1 is inherently less controllable compared to water levels in the Upper Murray.
- The South Australian government's allocation framework for the River Murray prioritises critical human water needs over economic and environmental use in the event that entitlement flows are at risk (DEWNR 2016).

Relating to consequences:

- The Lower Murray is a key water resource supporting critical human water needs of over one million SA Water customers. Offtakes from the Lower Murray supply metropolitan Adelaide, townships in the Mount Lofty Ranges, and the upper South East. Consequences of rare but severe events could conceivably be catastrophic.
- Alternative sources exist for metropolitan Adelaide customers. These include the surface waters and storages of the Western Mount Lofty Ranges (WMLR) and the Adelaide Desalination Plant. These alternate sources are not available to 80–100,000 people in the Mount Lofty Ranges outside the Adelaide metropolitan area.
- There are sophisticated controls and redundancy available through SA Water's existing pipelines, storages and water treatment facilities. These are configured to address risks to the quality and availability of water. In this context, quality or quantity events affecting source waters are more likely to increase costs of delivering water to customers than to cause interruption of supply.
- Total annual critical human water needs are 150 GL for metropolitan Adelaide, 34 GL for country towns, 20 GL for stock, domestic and riparian. Total = 204 GL.

Evaluation of existing/planned controls

Control	Effectiveness	Implementation	Notes
MDB Agreement – entitlement (1,850 GL) and operation of upstream storages and other infrastructure, cap on diversions	Mostly uncontrolled	Complete implementation	Entitlement does not include adequate water to maintain water levels or water quality for the Lower Lakes and Coorong under average conditions. Under dry scenarios, lake levels or flows to the Coorong cannot be managed. In extremes there are acid sulfate and high salinity issues in the Lower Lakes which in turn impact on the Lower Murray.
Schedule H of the Murray–Darling Basin Agreement	Partially controlled	Complete implementation	The Schedule provides the way in which state water entitlements will be determined, delivered and accounted for during a period of insufficient water to meet conveyance reserve.
Basin Salinity Management 2030 Strategy and Schedule B of the Murray–Darling Basin Agreement	Partially controlled	Mostly complete	Long-term salinity risk from groundwater is mostly managed with salt interception schemes in critical areas; however, real-time operational risks and local

Control	Effectiveness	Implementation	Notes
			groundwater intrusions/risks are mostly uncontrolled.
Reconciliation in 2024 of supply measure outcomes for the Basin Plan	Mostly controlled	Complete implementation	Any package of SDL measures agreed in 2017 needs to be implemented in full by 2024. Any projects not implemented in this timeframe will need to be reconciled. Current draft principles for the new IGA involve proponents being responsible for addressing any shortfall risk in an equivalent volume of water.
Chapter 9 of the Basin Plan (the MDBA must have regard to the water quality targets in management of water flows. This includes targets at Milang (1,000 EC), Murray Bridge (830 EC) and Morgan (800 EC)	Mostly uncontrolled	Mostly complete	Have regard leaves the door open for possible actions that will impact on the Lower Murray; therefore, mostly uncontrolled. All operators must have regard for salinity targets and demonstrate that consideration was given to management actions available and chosen.
2016–17 South Australian River Murray Water Allocation Plan	Partially controlled	Mostly complete	Provides a framework for allocating water for critical human water needs and other users. Regard will be had to other water sources in delivering Adelaide's water requirements.
Management of flows at Lock 1 to manage dilution and to control water quality risks from the LMRIA	Partially controlled	Complete implementation	Water not always available to manage water quality particularly in times of drought or below-entitlement flows.
Drought emergency framework for Lakes Alexandrina and Albert (in MDBA Drought Emergency Framework for Lakes Alexandrina and Albert)	Partially controlled	Mostly complete	Framework has been agreed by Murray–Darling Basin Ministerial Council. Aim is to avoid possibility of the Lower Lakes falling below 0.0 mAHD when the risk of acidification increases significantly. The aim is to keep the lakes above 0.0 mAHD and limit the fall below 0.4 mAHD. This in turn impacts on water levels and water quality in the Lower Murray.
Basin Plan Environmental Watering Plan objectives for the Lower Lakes and Murray Mouth (section 8.06)	Partially controlled	Mostly complete	Meeting of objectives will require Basin Plan implementation in full. Meeting these objectives, in particular maintaining lake levels, in turn impacts on water levels and water quality in the Lower Murray.

SUB-AREA: Lower Murray

Risk r340: There is the potential that climate extremes could cause changes in water quality, quantity or regime which in turn impacts water-dependent ecosystems

Risk source: Climate extremes
Consequence: Water-dependent ecosystems impacted

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely					
Possible		X	X		
Unlikely	X			X	X
Rare					

Final risk rating: **Medium**
Uncertainty: High

Risk factors

Relating to source of risk and potential for events:

- Water level below Lock 1 is inherently less controllable compared to water levels in the Upper Murray.
- Lower flows are required to achieve some environmental water requirements in this sub-area compared to other sub-areas.
- Configuration of SDLs consistent with environmental objectives is based on expectations of climatic events derived from historical climatic data (114 years of data). Restoration of water-dependent ecosystem values rests on the assumption that the future climate will be similar to the past climate. Modelling undertaken through the CSIRO Sustainable Yields Project (CSIRO 2008) concluded that the worst-case ('dry') 2030 climate scenario is characterised by significantly reduced water availability in the Murray–Darling Basin. Risk ratings therefore placed more weight on recent experience regarding climate to account for uncertainty regarding the potential impacts of climate change.
- Climate extremes can be associated with algal blooms. This risk is addressed under the risks caused by invasive/nuisance organisms.
- Drought leading to low water levels can expose acid sulfate soils in areas that are normally permanently inundated. This event occurred during the Millennium Drought when water levels below Lock 1 fell below -1 mAHD, leading to widespread acidification and point source pollution events originating from the Lower Murray Reclaimed Irrigation Area (Mosley et al. 2013).
- The South Australian government's allocation framework for the River Murray prioritises critical human water needs over economic and environmental use in the event that entitlement flows are at risk (DEWNR 2016).

Relating to consequences:

- The South Australian River Murray Channel Priority Environmental Asset (Channel PEA) covers the area between Wellington, South Australia, and the border which is inundated at up to 40,000 ML/day flow to South Australia (QSA). The South Australian River Murray Floodplain Priority Environmental Asset (Floodplain PEA) covers the longitudinal extent of the Channel PEA and consists of the area inundated when flows are between 40,000 and 80,000 ML/day QSA (DEWNR 2015).
- The Channel PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the *Environment Protection and Biodiversity Act 1999* (EPBC Act), while six species are both state and nationally listed (DEWNR 2015).
- The Floodplain PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the Environment Protection and Biodiversity Act 1999 (EPBC Act), while four species are both state and nationally listed (DEWNR 2015).
- The Floodplain PEA in the Lower Murray is constrained to approximately 2–3 km, with the area between Mannum and Wellington dominated by reclaimed swamps having very little remaining floodplain habitat (DEWNR 2015).
- The outer floodplain areas, inundated at flows >80,000 ML/day QSA are not part of the Floodplain PEA because MDBA modelling indicates that 80,000 ML/day QSA is the maximum flow rate at which active management can occur (DEWNR 2015).
- Unlike the Upper Murray and Lower Lakes sub-areas, the Lower Murray sub-area hosts no Ramsar-listed wetlands of international significance.
- Potential for consequences depends on the duration of droughts. Longer dry periods lead to drying of pool-connected wetlands, exposure of acid sulfate soils, loss of aquatic habitat and loss of refuges.
- Water level, rather than salinity, is the key factor affecting risk caused by drought in this sub-area.

Evaluation of existing/planned controls

Document/control	**Effectiveness**	**Implementation**	**Notes**
Annual environmental water planning, coordination and delivery	Partially controlled	Complete implementation	Delivery of water depends on priorities set across the Basin and the reliability of the water products held. This does not guarantee delivery to the Lower Murray when required.
Relocation of threatened populations or in-situ watering (e.g. Hall et al. 2009)	Partially controlled	Mostly complete	Successful management of Yarra and Southern Pygmy Perch during Millennium Drought.
Management of flows at Lock 1 to manage dilution and to control water quality risks from the LMRIA	Partially controlled	Complete implementation	Water not always available to manage water quality particularly in times of drought or below-entitlement flows.
MDB Agreement – entitlement (1,850 GL) and operation of upstream storages and other	Partially controlled	Complete implementation	Entitlement does not include adequate water to maintain water levels or water quality for the Lower Lakes. Under dry scenarios, lake levels or flows to the Coorong cannot be managed. In extremes there are acid sulfate and high

Document/control	Effectiveness	Implementation	Notes
infrastructure, cap on diversions			salinity issues in the Lower Lakes which in turn impacts on the Lower Murray.
Basin Salinity Management 2030 Strategy and Schedule B of the Murray–Darling Basin Agreement	Partially controlled	Mostly complete	Long-term salinity risk from groundwater is mostly managed with salt interception schemes in critical areas; however, real-time operational risks and local groundwater intrusions/risks are mostly uncontrolled.
Reconciliation in 2024 of supply measure outcomes for the Basin Plan	Mostly controlled	Complete implementation	Any package of SDL measures agreed in 2017 needs to be implemented in full by 2024. Any projects not implemented in this timeframe will need to be reconciled. Current draft principles for the new IGA involve proponents being responsible for addressing any shortfall risk in an equivalent volume of water.
Chapter 9 of the Basin Plan (the MDBA must have regard to the water quality targets in management of water flows – this includes targets at Milang (1,000 EC), Murray Bridge (830 EC) and Morgan (800 EC)	Mostly uncontrolled	Mostly complete	Have regard leaves the door open for possible actions that will impact on the Lower Murray; therefore, mostly uncontrolled. All operators must have regard for salinity targets and demonstrate that consideration was given to management actions available and chosen.
Policies for management of River Murray wetlands. Wetland allocations and wetland management plans for high risk sites (in River Murray WAP).	Mostly uncontrolled	Mostly complete	Wetlands below Lock 1 are flooded at pool level but infrastructure is required to hold water or dry.
Long-Term Environmental Watering Plan for the South Australian River Murray WRP area: Sets objectives and targets and environmental water requirements and identifies priority environmental assets and functions	Partially controlled	Mostly implemented through annual watering priorities, rules in WRPs and monitoring programs	LTWP does consider different climate scenarios.
Objectives and outcomes, priority assets and functions and environmental water requirements in Basin-wide environmental watering strategy	Partially controlled	Partially implemented	Effectiveness depends on alignment with other states, and resourcing for monitoring.

Document/control	Effectiveness	Implementation	Notes
Drought emergency framework for Lakes Alexandrina and Albert (in MDBA Drought Emergency Framework for Lakes Alexandrina and Albert)	Partially controlled	Mostly complete	Framework has been agreed by Murray–Darling Basin Ministerial Council. Aim is to avoid possibility of the lakes falling below 0.0 mAHD when the risk of acidification increases significantly. The aim is to keep the lakes above 0.0 mAHD and limit the fall below 0.4 mAHD. This in turn impacts on water levels and water quality in the Lower Murray.
Basin Plan Environmental Watering Plan objectives for the Lower Lakes and Murray Mouth (section 8.06)	Partially controlled	Mostly complete	Meeting of objectives will require Basin Plan implementation in full. Meeting these objectives, in particular maintaining lake levels, in turn has impacts on water levels and water quality in the Lower Murray.

SUB-AREA: Lower Murray

Risk r348: There is the potential that management of connected water resources could cause changes in water quality, quantity or regime which in turn impacts water-dependent ecosystems

Risk source: Management of connected water resources
Consequence: Water-dependent ecosystems impacted

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely					
Possible	X		X		
Unlikely		X		X	
Rare					X

Final risk rating: **Medium**
Uncertainty: High

Risk factors

Relating to source of risk and potential for events:

- The total volume of water required for delivery of many environmental water requirements exceeds South Australia's Entitlement and additional water available through recovery programs. Meeting these environmental water requirements will require water to be delivered in conjunction with unregulated flows (DEWNR 2015).
- The Eastern Mount Lofty Ranges (EMLR) and SA Murray Region WRPs contribute relatively minor volumes of water to the sub-area compared to flows across the border (DEWNR 2015).
- Surface water from EMLR enters into the River Murray and Lake Alexandrina through a number of streams (including the Angas, Bremer, Finniss and Marne rivers, and Currency and Saunders creeks). These catchments are managed under the auspices of the EMLR and Marne Saunders Prescribed Water Resources Areas water allocation plans (WAPs). The consumptive use limits for the EMLR WAP have been set to allow provision of water to the terminal wetlands where the EMLR streams meet the River Murray and Lake Alexandrina (SAMDB NRM Board 2013). Flows into the River Murray from the Marne River and Saunders Creek occur only with significant floods (SAMDB NRM Board 2010).
- Operation of barrages is an important infrastructure-related risk below Lock 1. This risk is also addressed for the Lower Murray by risk r323.
- Saline groundwater is not a significant source of risk compared to sub-area 1 (Upper Murray).
- There are a range of uncertainties regarding the implementation of the Basin Plan affecting the achievement of environmental outcomes in South Australia including:
    - commitment to, and delivery of, efficiency measures to recover an additional 450 GL
    - commitment to addressing policy and physical constraints affecting the delivery of environmental water
    - the extent to which the environmental equivalence test for SDL adjustment reflects the outcomes achievable through works and measures

- the potential for long-term watering plans for the River upstream of South Australia to create demands for environmental water that could negatively impact achievement of environmental outcomes in South Australia
- the extent to which environmental water recovered is compatible with the delivery of water required to address environmental water requirements in South Australia.

Relating to consequences:

- The South Australian River Murray Channel Priority Environmental Asset (Channel PEA) covers the area between Wellington, South Australia, and the border which is inundated at flows up to 40,000 ML/day QSA. The South Australian River Murray Floodplain Priority Environmental Asset (Floodplain PEA) covers the longitudinal extent of the Channel PEA and consists of the area inundated when flows are between 40,000 and 80,000 ML/day QSA (DEWNR 2015).
- The Channel PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the *Environment Protection and Biodiversity Act 1999* (EPBC Act), while six species are both state and nationally listed (DEWNR 2015).
- The Floodplain PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the EPBC Act, while four species are both state and nationally listed (DEWNR 2015).
- The Floodplain PEA in the Lower Murray is constrained to approximately 2–3 km, with the area between Mannum and Wellington dominated by reclaimed swamps having very little remaining floodplain habitat (DEWNR 2015).
- The outer floodplain areas, inundated at flows >80,000 ML/day QSA are not part of the Floodplain PEA because MDBA modelling indicates that 80,000 ML/day QSA is the maximum flow rate at which active management can occur (DEWNR 2015).
- Unlike the Upper Murray and Lower Lakes sub-areas, the Lower Murray sub-area hosts no Ramsar-listed wetlands of international significance.
- Higher flows are not required to meet the majority of environmental requirements compared to the Upper Murray

Evaluation of existing/planned controls

Document/control	**Effectiveness**	**Implementation**	**Notes**
Prerequisite Policy Measures (PPMs). Ability to put environmental water onto unregulated flows. Affects water availability and water regime. Commitment to have policies in place by 2019. States and territories preparing project plans to remove policy constraints (in Basin Plan 2012).	Partially controlled	Mostly complete	PPMs are assumptions in the Basin Plan modelling and therefore must be addressed to deliver on the Basin Plan 2012 agreed outcomes.
Physical constraints management actions to address constraints in ability to deliver water to meet environmental water requirements	Mostly controlled	Mostly complete	Assumption that physical constraints at Hume, Yarrawonga, Murrumbidgee and Goulburn will have agreed business cases and mostly implemented by 2026.

Document/control	Effectiveness	Implementation	Notes
Water quality measure and water availability controls, Lake Victoria (in Lake Victoria operating strategy)	Partially controlled	Partially complete	Lake Victoria cannot be used to manage water quality without affecting the quantity of water available for South Australian Entitlement as it is limited by constraints upstream and the SDL adjustment process.
MDB Agreement – entitlement (1,850 GL) and operation of upstream storages and other infrastructure, cap on diversions	Mostly uncontrolled	Complete implementation	Entitlement does not include adequate water to maintain water levels or water quality for the Lower Lakes and Coorong under average conditions. Under dry scenarios, lake levels or flows to the Coorong cannot be managed. This in turn has implications for the Lower Murray.
Basin Salinity Management 2030 Strategy and Schedule B of the Murray Darling Basin Agreement	Partially controlled	Mostly complete	Long-term salinity risk from groundwater is mostly managed with salt interception schemes in critical areas; however, real-time operational risks and local groundwater intrusions/risks are mostly uncontrolled. Effectiveness in a drought is not as good – evaporative losses in the lakes are not accounted for under entitlement and in extremes there are acid sulfate and high salinity issues which in turn impact on the Lower Murray.
Objectives and outcomes, priority assets and functions and environmental water requirements in Basin-wide environmental watering strategy	Partially controlled	Partially implemented	Effectiveness depends on alignment with other states, and resourcing for monitoring.
Annual environmental water planning, coordination and delivery	Partially controlled	Complete implementation	Delivery of water depends on priorities set across the Basin and the reliability of the water products held. This does not guarantee delivery to the Lower Murray when required.
Long-term watering plans in NSW, Victoria and Queensland	Mostly uncontrolled	Partially complete	Integration with South Australia's long-term watering plan is critical to deliver benefits in the Lower Murray but will be limited by upstream requirements of environmental assets.

Document/control	Effectiveness	Implementation	Notes
Reconciliation in 2024 of supply measure outcomes for the Basin Plan	Mostly controlled	Complete implementation	Any package of SDL measures agreed in 2017 needs to be implemented in full by 2024. Any projects not implemented in this timeframe will need to be reconciled. Current draft principles for the new IGA involve proponents being responsible for addressing any shortfall risk in an equivalent volume of water.
Chapter 9 of Basin Plan (the MDBA must have regard to the water quality targets in management of water flows – this includes targets at Morgan (800 EC) and Murray Bridge (830 EC))	Mostly uncontrolled	Mostly complete	Have regard leaves the door open for possible actions that will impact on the Lower Murray; therefore, mostly uncontrolled. All operators must have regard for salinity targets and demonstrate that consideration was given to management actions available and chosen.
Drought emergency framework for Lakes Alexandrina and Albert (in MDBA Drought Emergency Framework for Lakes Alexandrina and Albert)	Partially controlled	Mostly complete	Framework has been agreed by Murray–Darling Basin Ministerial Council. Aim is to avoid possibility of the lakes falling below 0.0 mAHD when the risk of acidification increases significantly. The aim is to keep the lakes above 0.0 mAHD and limit the fall below 0.4 mAHD. This in turn impacts on water levels and water quality in the Lower Murray.

SUB-AREA: Lower Murray

Risk r346: There is the potential that the management of connected water resources could cause changes in water quality, quantity or regime which in turn impacts economic use of water

Risk source: Management of connected water resources
Consequence: Economic use of water impacted

	Insig.	Mod.	Major	Cat.
Almost Certain				
Likely	X			
Possible				
Unlikely		X	X	X
Rare				

Final risk rating: **Medium** [16]
Uncertainty: Moderate

Risk factors

Relating to source of risk and potential for events:

- The Eastern Mount Lofty Ranges (EMLR) and SA Murray Region WRPs contribute relatively minor volumes of water to the sub-area compared to flows across the border (DEWNR 2015). The EMLR WRP risk assessment concluded that management of surface and groundwater in the EMLR WRP area caused low risk to the River Murray (DEWNR 2016b).
- Operation of barrages is a key infrastructure-related risk potentially affecting the Lower Murray. See factors related to barrage operation for the Lower Lakes sub-area (e.g. risk r322).
- Return flows from environmental watering upstream could cause water quality events that affect economic consumptive use. While operations upstream must have regard to water quality, there is uncertainty regarding the effectiveness of controls.
- Highly saline connected groundwater causes risk in the Upper Murray, which could in turn affect the Lower Murray. This risk is controlled through existing programs and policy including salt interception schemes and the salinity zoning policy of the River Murray Prescribed Watercourse Water Allocation Plan (River Murray WAP).
- Water level below Lock 1 is inherently less controllable compared to water levels in the Upper Murray.
- There are a range of uncertainties regarding the implementation of the Basin Plan affecting the achievement of environmental outcomes in South Australia. It was determined that these uncertainties could affect economic outcomes – particularly those related to non-consumptive economic benefits such as tourism, recreation and ecosystem services.

Relating to consequences:

[16] 4 consequence levels (rather than 5) were assigned for "economic use of water impacted" (see Section 3.3.2.1)

- The Lower Murray supports 21 per cent of total take from the South Australian River Murray for consumptive economic use purposes.
- Events caused by management of connected water resources could significantly impact non-consumptive economic use including recreation and tourism.
- Water quality events could affect use for stock.
- Events leading to low water level below Lock 1 could have severe consequences on consumptive uses that depend on maintenance of water level such as gravity-fed irrigation in the LMRIA.

Evaluation of existing/planned controls

Control	Effectiveness	Implementation	Notes
MDB Agreement – entitlement (1,850 GL) and operation of upstream storages and other infrastructure, cap on diversions	Mostly uncontrolled	Complete implementation	Entitlement does not include adequate water to maintain water levels or water quality for the Lower Lakes and Coorong under average conditions. Under dry scenarios, lake levels or flows to the Coorong cannot be managed. In extremes, there are acid sulfate and high salinity issues in the Lower Lakes which in turn impact on the Lower Murray.
Schedule H of the Murray–Darling Basin Agreement	Partially controlled	Complete implementation	The Schedule provides the way in which state water entitlements will be determined, delivered and accounted for during a period of insufficient water to meet conveyance reserve.
Basin Salinity Management 2030 Strategy and Schedule B of the Murray–Darling Basin Agreement	Partially controlled	Mostly complete	Long-term salinity risk from groundwater is mostly managed with salt interception schemes in critical areas; however, real-time operational risks and local groundwater intrusions/risks are mostly uncontrolled.
Reconciliation in 2024 of supply measure outcomes for the Basin Plan	Mostly controlled	Complete implementation	Any package of SDL measures agreed in 2017 needs to be implemented in full by 2024. Any projects not implemented in this timeframe will need to be reconciled. Current draft principles for the new IGA involve proponents being responsible for addressing any shortfall risk in an equivalent volume of water.
Chapter 9 of the Basin Plan (the MDBA must have regard to the water quality targets in management of water flows – this includes targets at Milang (1,000 EC), Murray Bridge (830 EC) and Morgan (800 EC)	Mostly uncontrolled	Mostly complete	Have regard leaves the door open for possible actions that will impact on the Lower Murray; therefore, mostly uncontrolled. All operators must have regard for salinity targets and demonstrate that consideration was given to management actions available and chosen.

Control	Effectiveness	Implementation	Notes
2016–17 South Australian River Murray Water Allocation Plan	Partially controlled	Mostly complete	Provides a framework for allocating water for critical human needs and other users. Regard will be had to other water sources in delivering Adelaide's water requirements.
Management of flows at Lock 1 to manage dilution and to control water quality risks from the LMRIA	Partially controlled	Complete implementation	Water is not always available to manage water quality, particularly in times of drought or below-entitlement flows.
Drought emergency framework for Lakes Alexandrina and Albert (in MDBA Drought Emergency Framework for Lakes Alexandrina and Albert)	Partially controlled	Mostly complete	Framework has been agreed by Murray–Darling Basin Ministerial Council. Aim is to avoid possibility of the Lower Lakes falling below 0.0 mAHD when the risk of acidification increases significantly. The aim is to keep the lakes above 0.0 mAHD and limit the fall below 0.4 mAHD. This in turn impacts on water levels and water quality in the Lower Murray.
Basin Plan Environmental Watering Plan objectives for the Lower Lakes and Murray Mouth (section 8.06)	Partially controlled	Mostly complete	Meeting of objectives will require Basin Plan implementation in full. Meeting these objectives, in particular maintaining lake levels, in turn impacts on water levels and water quality in the Lower Murray.

LOWER MURRAY – Low Risks

SUB-AREA: Lower Murray

Risk r341: There is the potential that demand/take could cause changes in water quality, quantity or regime which in turn causes critical human water needs not being met

Risk source: Demand/take
Consequence: Critical human water needs not met

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain	X				
Likely					
Possible					
Unlikely					
Rare		X	X	X	

Final risk rating: **Low**
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- This risk is concerned with take from the Lower Murray and not from other connected water resources in South Australia or other Basin States. Take from connected water resources is a separate source of risk addressed by other risk statements.
- The River Murray Prescribed Watercourse Water Allocation Plan (SAMDB NRM Board 2017) and the Basin Plan control this risk. These controls have effective approaches to setting sustainable limits of take. Volumes taken are controlled through licensing. There is a high level of compliance.
- The South Australian government's allocation framework for the River Murray prioritises critical human water needs over economic and environmental use in the event that entitlement flows are at risk (DEWNR 2016).
- Water level below Lock 1 is inherently less controllable compared to water levels in the Upper Murray.

Relating to consequences:

- The Lower Murray is a key water resource supporting critical human water needs of over one million SA Water customers. Offtakes from the Lower Murray supply metropolitan Adelaide, townships in the Mount Lofty Ranges, and the upper South East. Consequences of rare but severe events could conceivably be catastrophic.
- Alternative sources exist for metropolitan Adelaide customers. These include the surface waters and storages of the Western Mount Lofty Ranges (WMLR) and the Adelaide Desalination Plant. These alternate sources are not available to 80–100,000 people in the Mount Lofty Ranges outside the Adelaide metropolitan area.

- There are sophisticated controls and redundancy available through SA Water's existing pipelines, storages and water treatment facilities. These are configured to address risks to the quality and availability of water. In this context, quality or quantity events affecting source waters are more likely to increase costs of delivering water to customers than to cause interruption of supply.
- Total annual critical human water needs are 150 GL for metropolitan Adelaide, 34 GL for country towns, 20 GL for stock, domestic and riparian. Total = 204 GL.

SUB-AREA: Lower Murray

Risk r345: There is the potential that the management of connected water resources could cause changes in water quality, quantity or regime which in turn causes critical human water needs not being met

Risk source: Management of connected water resources
Consequence: Critical human water needs not met

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible					
Unlikely		X			
Rare			X	X	X

Final risk rating: **Low**
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- There are a range of uncertainties regarding Basin Plan implementation in connected resources which affect risk. These include:
    - commitment to, and delivery of, efficiency measures to recover an additional 450 GL
    - commitment to addressing policy and physical constraints affecting the delivery of environmental water
    - the extent to which the environmental equivalence test for SDL adjustment reflects the outcomes achievable through works and measures
    - the potential for long-term watering plans for the River upstream of South Australia to create demands for environmental water that could negatively impact achievement of environmental outcomes in South Australia
    - the extent to which environmental water recovered is compatible with the delivery of water required to address environmental water requirements in South Australia.
- Highly saline groundwater does not pose a direct risk to the Lower Murray. However, impacts to the Upper Murray could also lead to consequences downstream of Lock 1. This risk is controlled through the salt interception schemes and the salinity zoning policy of the River Murray Prescribed Watercourse Water Allocation Plan.
- The EMLR WRP risk assessment concluded that management of surface water and groundwater in the EMLR WRP area caused low risk to the River Murray (DEWNR 2016b).
- Operation of barrages is the most important infrastructure-related risk potentially affecting the Lower Murray. See factors related to barrage operation for the Lower Lakes sub-area (e.g. risk r322)
- Return flows from environmental watering upstream could cause water quality events that increase treatment costs or cause exceedances against water quality guidelines.

- New measures put in place since the last drought (storage rights, desalination plant, environmental water) reduce the level of risk associated with management of connected water resources (SAMDB NRM Board 2014).
- Water level below Lock 1 is inherently less controllable compared to water levels in the Upper Murray.

Relating to consequences:

- The Lower Murray is a key water resource supporting critical human water needs of over one million SA Water customers. Offtakes from the Lower Murray supply metropolitan Adelaide, townships in the Mount Lofty Ranges, and the upper South East. Consequences of rare but severe events could conceivably be catastrophic.
- Alternative sources exist for metropolitan Adelaide customers. These include the surface waters and storages of the Western Mount Lofty Ranges (WMLR) and the Adelaide Desalination Plant. These alternate sources are not available to 80–100,000 people in the Mount Lofty Ranges outside the Adelaide metropolitan area.
- There are sophisticated controls and redundancy available through SA Water's existing pipelines, storages and water treatment facilities. These are configured to address risks to the quality and availability of water. In this context, quality or quantity events affecting source waters are more likely to increase costs of delivering water to customers than to cause interruption of supply.
- Total annual critical human water needs are 150 GL for metropolitan Adelaide, 34 GL for country towns, 20 GL for stock, domestic and riparian. Total = 204 GL.

SUB-AREA: Lower Murray

Risk r349: There is the potential that the operation of infrastructure could cause changes in water quality, quantity or regime which in turn causes critical human water needs not being met

Risk source: Operation of infrastructure
Consequence: Critical human water needs not met

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible					
Unlikely		X			
Rare			X		

Final risk rating: **Low**
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- Infrastructure includes locks, regulators, weirs, barrages and banks. The assessment of this risk considers the effect of operation of infrastructure within the sub-area (i.e. not in connected water resources) on critical human water needs.
- New infrastructure, including new operational approaches, to achieve environmental benefits are proposed for managing water above Lock 1 or in the Lower Lakes. These risks are not addressed by r349.
- The most important risk factor related to operation of infrastructure below Lock 1 is operation of the barrages. The extent to which this risk impacts the Lower Murray is addressed through assessment of risks to connected water resources of the Lower Lakes (r323).
- It was determined that the effectiveness of controls, including environmental watering strategies, operating plans and procedures, is important for managing the risks caused by operation of infrastructure. Loss of corporate knowledge could impact the effectiveness of controls.
- Operation of infrastructure within the sub-area was determined to have localised water quality impacts not likely to cause significant impacts on critical human water use that depends on the Lower Murray

Relating to consequences:

- The Lower Murray is a key water resource supporting critical human water needs of over one million SA Water customers. Offtakes from the Lower Murray supply metropolitan Adelaide, townships in the Mount Lofty Ranges, and the upper South East. Consequences of rare but severe events could conceivably be catastrophic.
- Alternative sources exist for metropolitan Adelaide customers. These include the surface waters and storages of the Western Mount Lofty Ranges (WMLR) and the Adelaide

Desalination Plant. These alternate sources are not available to 80–100,000 people in the Mount Lofty Ranges outside the Adelaide metropolitan area.

- There are sophisticated controls and redundancy available through SA Water's existing pipelines, storages and water treatment facilities. These are configured to address risks to the quality and availability of water. In this context, quality or quantity events affecting source waters are more likely to increase costs of delivering water to customers than to cause interruption of supply.
- Total annual critical human water needs are 150 GL for metropolitan Adelaide, 34 GL for country towns, 20 GL for stock, domestic and riparian. Total = 204 GL.

SUB-AREA: Lower Murray

Risk r353: There is the potential that point source pollution could cause changes in water quality, quantity or regime which in turn causes critical human water needs not being met

Risk source: Point source pollution
Consequence: Critical human water needs not met

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible					
Unlikely		X			
Rare			X	X	X

Final risk rating: **Low**
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- The Millennium Drought caused water levels below Lock 1 to fall below -1 mAHD, leading to widespread acidification and point source pollution events originating from the Lower Murray Reclaimed Irrigation Area (LMRIA) (Mosley et al. 2013). The resulting acid drainage from this event is likely to remain a point source of pollution in the future. Acidification mobilises metals that present a risk to potable water supply.
- Water quality impacts from the LMRIA will be worse during periods of low flow and lower water levels. For example, modelling indicates that soluble manganese could more regularly exceed SA Water treatment guidelines (non-health guideline) at Tailem Bend when flows fall below 5,000 ML/day (Mosley et al. 2013).
- Acid drainage from the LMRIA is rapidly neutralised in the discharge zones in the River Murray with precipitation of solid metal phases occurring before entering the main river channel (Mosley et al. 2013). Anoxic conditions caused by stratification events (e.g. thermal stratification in summer or ingress of salinity upriver from Lake Alexandrina) could cause remobilisation.
- Future land use and intensity of irrigation in the LMRIA could affect the quantity of the return flows to the river.
- There have been investigations to address both the quantity and quality of drainage from the LMRIA such as liming and other measures. The success of these types of interventions into the future is uncertain.
- The contraction of the dairy industry since the drought has caused reduced microbial pollution from the LMRIA.
- Other point sources of pollution can include sewage, houseboats, chemicals, grey water, petrol station storages, industrial discharges etc. These risks are controlled through South Australia's Environment Protection Water Quality Policy (*Environment Protection Act 1993*), Development Act, stormwater management plans etc.

Relating to consequences:

- The Lower Murray is a key water resource supporting critical human water needs of over one million SA Water customers. Offtakes from the Lower Murray supply metropolitan Adelaide, townships in the Mount Lofty Ranges, and the upper South East. Consequences of rare but severe events could conceivably be catastrophic.
- Alternative sources exist for metropolitan Adelaide customers. These include the surface waters and storages of the Western Mount Lofty Ranges (WMLR) and the Adelaide Desalination Plant. These alternate sources are not available to 80–100,000 people in the Mount Lofty Ranges outside the Adelaide metropolitan area.
- There are sophisticated controls and redundancy available through SA Water's existing pipelines, storages and water treatment facilities. These are configured to address risks to the quality and availability of water. In this context, quality or quantity events affecting source waters are more likely to increase costs of delivering water to customers than to cause interruption of supply.
- Total annual critical human water needs are 150 GL for metropolitan Adelaide, 34 GL for country towns, 20 GL for stock, domestic and riparian. Total = 204 GL.

SUB-AREA: Lower Murray

Risk r357: There is the potential that land use could cause changes in water quality, quantity or regime which in turn causes critical human water needs not being met

Risk source: Land use
Consequence: Critical human water needs not met

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible					
Unlikely					
Rare		X	X		

Final risk rating: **Low**
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- This risk addresses the effects of new or changed land use. It does not address land use unlikely to change over the risk assessment period.
- Existing impacts of the LMRIA are addressed as a point source pollution risk.
- Changes of land use in the LMRIA which increase return flows could cause some risk. This risk is addressed as a point source pollution risk.
- The Development Act, River Murray Act and EPA water quality policy are effective for controlling the impacts of development on the floodplain and outside the sub-area.
- Existing land use may represent a constraint to the delivery of high flows of water to achieve environmental objectives.

Relating to consequences:

- The Lower Murray is a key water resource supporting critical human water needs of over one million SA Water customers. Offtakes from the Lower Murray supply metropolitan Adelaide, townships in the Mount Lofty Ranges, and the upper South East. Consequences of rare but severe events could conceivably be catastrophic.
- Alternative sources exist for metropolitan Adelaide customers. These include the surface waters and storages of the Western Mount Lofty Ranges (WMLR) and the Adelaide Desalination Plant. These alternate sources are not available to 80–100,000 people in the Mount Lofty Ranges outside the Adelaide metropolitan area.
- There are sophisticated controls and redundancy available through SA Water's existing pipelines, storages and water treatment facilities. These are configured to address risks to the quality and availability of water. In this context, quality or quantity events affecting source waters are more likely to increase costs of delivering water to customers than to cause interruption of supply.

- Total annual critical human water needs are 150 GL for metropolitan Adelaide, 34 GL for country towns, 20 GL for stock, domestic and riparian. Total = 204 GL.

SUB-AREA: Lower Murray

Risk r361: There is the potential that invasive/nuisance organisms could cause changes in water quality, quantity or regime which in turn causes critical human water needs not being met

Risk source: Invasive/nuisance organisms
Consequence: Critical human water needs not met

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible					
Unlikely		X			
Rare			X	X	

Final risk rating: **Low**
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- Impacts of invasive/nuisance organisms on water-dependent ecosystems can include fluctuations in dissolved oxygen, release of toxins and direct and indirect food web impacts. The present assessment only considers impacts caused by water quality/quantity events, not direct ecological impacts.
- Blue-green algal blooms are events which can occur both naturally and in response to disturbance. Algal bloom events affecting water supply for critical human water needs are less likely in the Lower Murray compared to the Upper Murray.
- Geosmin (an organic compound with a distinct earthy flavour and aroma) associated with algae has occurred in this sub-area. This causes aesthetic issues rather than interruption of supply.
- While proposed controls for carp, such as the carp herpes virus, are expected to bring longer-term benefits, there could be short-term acute impacts on water quality arising from a large number of dead carp.
- Effects of improvements in irrigation management on water quality are assumed to reduce the likelihood of algal bloom events.

Relating to consequences:

- The Lower Murray is a key water resource supporting critical human water needs of over one million SA Water customers. Offtakes from the Lower Murray supply metropolitan Adelaide, townships in the Mount Lofty Ranges, and the upper South East. Consequences of rare but severe events could conceivably be catastrophic.
- Alternative sources exist for metropolitan Adelaide customers. These include the surface waters and storages of the Western Mount Lofty Ranges (WMLR) and the Adelaide Desalination Plant. These alternate sources are not available to 80–100,000 people in the Mount Lofty Ranges outside the Adelaide metropolitan area.

- There are sophisticated controls and redundancy available through SA Water's existing pipelines, storages and water treatment facilities. These are configured to address risks to the quality and availability of water. In this context, quality or quantity events affecting source waters are more likely to increase costs of delivering water to customers than to cause interruption of supply.
- Total annual critical human water needs are 150 GL for metropolitan Adelaide, 34 GL for country towns, 20 GL for stock, domestic and riparian. Total = 204 GL.
- Water treatment plants are configured to address risks caused by algal blooms. The potential for interruption to supply is low.

SUB-AREA: Lower Murray

Risk r338: There is the potential that climate extremes could cause changes in water quality, quantity or regime which in turn impacts economic use of water

Risk source: Climate extremes
Consequence: Economic use of water impacted

	Insig.	Mod.	Major	Cat.
Almost Certain				
Likely	X			
Possible				
Unlikely		X		
Rare			X	X

Final risk rating: **Low** [17]
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- Climate change could cause a change in the frequency of extreme events or a long-term incremental trend towards changed water availability. Modelling indicates that the worst-case ('dry') 2030 climate scenario is characterised by significantly reduced water availability in the Murray–Darling Basin (CSIRO 2008). Risk ratings therefore placed more weight on recent experience regarding climate to account for uncertainty regarding the potential impacts of climate change.
- Climate extremes could cause reduced water level below Lock 1, which in turn affects physical access to water by irrigators. The Millennium Drought caused unprecedented falls in water level below 0 mAHD. However, modelling indicates that full implementation of the Basin Plan will achieve a level of 0.4 mAHD 95 per cent of the time and >0 mAHD 100 per cent of the time (MDBA 2012).
- Water level below Lock 1 is inherently less controllable than water levels in the Upper Murray.
- Climate extremes can be associated with algal blooms. This risk is addressed as risks caused by invasive/nuisance organisms.
- Flood events can cause water quality impacts, such as blackwater.
- The South Australian government's allocation framework for the River Murray prioritises critical human water needs over economic and environmental use in the event that entitlement flows are at risk (DEWNR 2016).
- Water quality impacts from the LMRIA will be worse during periods of low flow and lower water levels. For example, modelling indicates that soluble manganese could more regularly exceed SA Water treatment guidelines (non-health guideline) at Tailem Bend when flows fall below 5,000 ML/day (Mosley et al. 2013). This factor is also addressed in risks caused by point source pollution.

[17] 4 consequence levels (rather than 5) were assigned for "economic use of water impacted" (see Section 3.3.2.1)

- Trade is an important mechanism allowing enterprises that depend on the resource to manage their risks. Trade of water into South Australia during the Millennium Drought was critical for maintaining economic activity over this period (Kirby et al. 2012). However, recovery of water to achieve environmental goals under the Basin Plan could leave less water available for trade into South Australia during drought.
- Modelling undertaken to inform the Basin Plan applied South Australia's allocations framework to 114 years of historical data to determine the risks to South Australia's Entitlement. Hindcasting against risk criteria for this assessment indicates events leading to two catastrophic, zero major, two moderate and one minor consequence over this time period.

Relating to consequences:

- The Lower Murray supports 21 per cent of total take from the South Australian River Murray for consumptive economic use purposes.
- The Millennium Drought severely impacted economic consumptive use from the Lower Murray, with 2008–09 allocations at 18 per cent. Many irrigators had difficulty accessing water, particularly in the LMRIA where low water levels prevented gravity-fed irrigation.
- Events caused by climate extremes could significantly impact non-consumptive economic use including recreation and tourism. For example, Connor et al. 2011 concluded that the Millennium Drought caused very significant losses due to impact on ecosystem services in the region around the Lower Lakes.
- The Millennium Drought caused significant damage including riverbank collapse along the river below Lock 1, drying and cracking of rehabilitated irrigation bays in the LMRIA, and damage to associated infrastructure (Leyden et al. 2012).
- Water quality events could affect use for stock.
- A major flood event may cause damage to levee banks. The likelihood of such an event is low.

SUB-AREA: Lower Murray

Risk r342: There is the potential that demand/take (including interception activities) could cause changes in water quality, quantity or regime which in turn impacts economic use of water

Risk source: Demand/take (including interception activities)
Consequence: Economic use of water impacted

	Insig.	Mod.	Major	Cat.
Almost Certain	X			
Likely				
Possible				
Unlikely				
Rare		X	X	X

Final risk rating: **Low** [18]
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- This risk is concerned with take from the Lower Murray and not from other connected water resources in South Australia or other Basin States. Take from connected water resources is a separate source of risk addressed by other risk statements.
- The River Murray Prescribed Watercourse Water Allocation Plan (SAMDB NRM Board 2017) and the Basin Plan control this risk. These controls have effective approaches to setting sustainable limits of take. Volumes taken are controlled through licensing. There is a high level of compliance.
- The South Australian government's allocation framework for the River Murray prioritises critical human water needs over economic and environmental use in the event that entitlement flows are at risk (DEWNR 2016).
- The risk of being on decreased allocations is relatively low based on existing modelling.
- There is less control over water level below Lock 1. However, it is unlikely that take by one user will affect take by other users.

Relating to consequences:

- The Lower Murray supports 21 per cent of total take from the South Australian River Murray for consumptive economic use purposes.
- Water quality events could affect use for stock.

[18] 4 consequence levels (rather than 5) were assigned for "economic use of water impacted" (see Section 3.3.2.1)

SUB-AREA: Lower Murray

Risk r350: There is the potential that operation of infrastructure could cause change in water quality, quantity or regime which in turn impacts the economic use of water

Risk source: Operation of infrastructure
Consequence: Economic use of water impacted

	Insig.	Mod.	Major	Cat.
Almost Certain				
Likely	X			
Possible				
Unlikely				
Rare		X	X	X

Final risk rating: **Low** [19]
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- Infrastructure includes locks, regulators, weirs, barrages and banks. The assessment of this risk considers the effect of operation of infrastructure within the sub-area (i.e. not in connected water resources) on economic use.
- The most important risk factor related to operation of infrastructure below Lock 1 is operation of the barrages. The extent to which this risk impacts the Lower Murray is addressed through assessment of risks to connected water resources of the Lower Lakes (r323).
- For the purposes of this assessment, Lock 1 is located in the Upper Murray sub-area.
- There are wetland regulators and levees in the sub-area. Operation of these potentially causes risk to small sites.
- It was determined that the effectiveness of controls, including environmental watering strategies, operating plans and procedures, is important for managing the risks caused by operation of infrastructure. Loss of corporate knowledge could impact the effectiveness of controls.
- Operation of infrastructure within the sub-area was determined to have localised water quality impacts and is not likely to cause significant impacts on economic use that depends on the Lower Murray.

Relating to consequences:

- The Lower Murray supports 21 per cent of total take from the South Australian River Murray for consumptive economic use purposes.
- Events caused by management of connected water resources could significantly impact non-consumptive economic use including recreation and tourism.

[19] 4 consequence levels (rather than 5) were assigned for "economic use of water impacted" (see Section 3.3.2.1)

- Water quality events could affect use for stock.

SUB-AREA: Lower Murray

Risk r354: There is the potential that point source pollution could cause changes in water quality, quantity or regime which in turn impacts the economic use of water

Risk source: Point source pollution
Consequence: Economic use of water

	Insig.	Mod.	Major	Cat.
Almost Certain				
Likely	**X**			
Possible				
Unlikely				
Rare		**X**	**X**	**X**

Final risk rating: **Low** [20]
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- The Millennium Drought caused water levels below Lock 1 to fall below -1 mAHD, leading to widespread acidification and point source pollution events originating from the Lower Murray Reclaimed Irrigation Area (LMRIA) (Mosley et al. 2013). The resulting acid drainage from this event is likely to remain a point source of pollution in the future. There have been investigations to address both the quantity and quality of drainage from the LMRIA such as liming and other measures. The success of these types of interventions into the future is uncertain.
- Water quality impacts from the LMRIA will be worse during periods of low flow and lower water levels (Mosley et al. 2013).
- Acid drainage from the LMRIA is rapidly neutralised in the discharge zones in the River Murray with precipitation of solid metal phases occurring before entering the main river channel (Mosley et al. 2013). Anoxic conditions caused by stratification events (e.g. thermal stratification in summer or ingress of salinity upriver from Lake Alexandrina) could cause remobilisation.
- Future land use and intensity of irrigation in the LMRIA could affect the quantity of the return flows to the river.
- The contraction of the dairy industry since the drought has caused reduced microbial pollution from the LMRIA.

[20] 4 consequence levels (rather than 5) were assigned for "economic use of water impacted" (see Section 3.3.2.1)

- Other point sources of pollution can include sewage, houseboats, chemicals, grey water, petrol station storages, industrial discharges etc. These risks are controlled through South Australia's Environment Protection Water Quality Policy (*Environment Protection Act 1993*), Development Act, stormwater management plans etc.

Relating to consequences:

- The Lower Murray supports 21 per cent of total take from the South Australian River Murray for consumptive economic use purposes.
- Water quality events could affect use for stock.
- The potential for point source pollution from the LMRIA to cause significant economic impacts within the sub-area over the risk assessment timeframe was determined to be low.

SUB-AREA: Lower Murray

Risk r358: There is the potential that land use could cause changes in water quality, quantity or regime which in turn impacts the economic use of water

Risk source: Land use
Consequence: Economic use of water

	Insig.	Mod.	Major	Cat.
Almost Certain				
Likely	X			
Possible				
Unlikely		X		
Rare			X	X

Final risk rating: **Low** [21]
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- This risk addresses the effects of new or changed land use. It does not address land use unlikely to change over the risk assessment period.
- Existing impacts of the LMRIA are addressed as a point source pollution risk.
- Changes of land use in the LMRIA which increase return flows could cause some risk. This risk is addressed as a point source pollution risk.
- The Development Act, River Murray Act and EPA water quality policy are effective for controlling the impacts of development on the floodplain and outside the sub-area.
- Existing land use may represent a constraint to the delivery of high flows of water to achieve environmental objectives.

Relating to consequences:

- The Lower Murray supports 21 per cent of total take from the South Australian River Murray for consumptive economic use purposes.
- Water quality events could affect use for stock.
- The potential for events caused by land use change to cause significant economic impacts within the sub-area over the risk assessment timeframe was judged to be low.

[21] 4 consequence levels (rather than 5) were assigned for "economic use of water impacted" (see Section 3.3.2.1)

SUB-AREA: Lower Murray

Risk r362: There is the potential that invasive/nuisance organisms could cause changes in water quality, quantity or regime which in turn impacts the economic use of water

Risk source: Invasive/nuisance organisms
Consequence: Economic use of water impacted

	Insig.	Mod.	Major	Cat.
Almost Certain				
Likely	X			
Possible				
Unlikely		X		
Rare			X	X

Final risk rating: **Low** [22]
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- Impacts of invasive/nuisance organisms on water quality can include fluctuations in dissolved oxygen, release of toxins, and increased turbidity.
- Invasive/nuisance organisms are associated with existing impacts which are anticipated to continue to compromise achievement of agreed outcomes. The baseline for the present assessment considers the context of the long-term watering plan for the South Australian River Murray (DEWNR 2015). This baseline assumes an existing level of impact.
- There has been an increase in the duration of individual algal blooms observed in the upper reaches of the River Murray correlating with increasing concentrations of Anabaena, Aphanizomenon, Microcystis and other Cyanophyceae (MDBA 2012b).
- The potential for the LMRIA to release pathogens is considered as a point source pollution risk.
- Blue-green algal blooms are events which can occur both naturally and in response to disturbance. Algal bloom events affecting the economic use of water were determined to be less likely in the Lower Murray compared to the Upper Murray. The capacity to manage these events may be improved under the Basin Plan due to additional environmental water.
- Willows can impact water quality and water temperature. However, it is unlikely there will be an increase in willow stands in this sub-area over the risk assessment period.
- While proposed controls for carp, such as the carp herpes virus, are expected to bring longer-term benefits, there could be short-term acute impacts on water quality arising from a large number of dead carp.

Relating to consequences:

[22] 4 consequence levels (rather than 5) were assigned for "economic use of water impacted" (see Section 3.3.2.1)

- Tourism, recreation and livestock are negatively impacted by blue-green algal blooms. Impacts on other economic uses such as irrigated agriculture is less clear. However, these uses often do not rely on high-quality raw water (Ernst & Young 2010).
- The Lower Murray supports 21 per cent of total take from the South Australian River Murray for consumptive economic use purposes.

SUB-AREA: Lower Murray

Risk r344: There is the potential that demand/take including interception activities could cause changes in water quality, quantity or regime which in turn impacts water-dependent ecosystems

Risk source: Demand/take including interception activities
Consequence: Water-dependent ecosystems impacted

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible					
Unlikely		X			
Rare			X	X	X

Final risk rating: **Low**
Uncertainty High

Risk factors

Relating to source of risk and potential for events:

- This risk is concerned with take from the Lower Murray and not from other connected water resources in South Australia or other Basin States. Take from connected water resources is a separate source of risk addressed by other risk statements.
- Change in demand could impact environmental watering. However, the River Murray Prescribed Watercourse Water Allocation Plan (SAMDB NRM Board 2017) and the Basin Plan control this risk. These controls have effective approaches to setting sustainable limits of take. Volumes taken are controlled through licensing. There is a high level of compliance.
- Risk was assessed against current levels of take, and controls are those policies/plans assumed to be in place during the risk assessment period.
- The South Australian government's allocation framework for the River Murray prioritises critical human water needs over economic and environmental use in the event that entitlement flows are at risk. This allocation framework applies only to the South Australian Entitlement and not to environmental watering traded from or to South Australia (guided by other arrangements) (DEWNR 2016).
- There have been significant changes in the composition of industry as a result of recent droughts and changed market conditions (Regional Development Australia 2012). The importance of the dairy industry, which placed significant demand on water resources in this region, is greatly reduced (Regional Development Australia 2012). The extent to which demand in the LMRIA will recover over the risk assessment timeframe is uncertain.

Relating to consequences:

- The South Australian River Murray Channel Priority Environmental Asset (Channel PEA) covers the area between Wellington, South Australia, and the border which is inundated at flows up to 40,000 ML/day QSA. The South Australian River Murray Floodplain Priority Environmental Asset

(Floodplain PEA) covers the longitudinal extent of the Channel PEA and consists of the area inundated when flows are between 40,000 and 80,000 ML/day QSA (DEWNR 2015).

- The Channel PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the *Environment Protection and Biodiversity Act 1999* (EPBC Act), while six species are both state and nationally listed (DEWNR 2015).
- The Floodplain PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the EPBC Act, while four species are both state and nationally listed (DEWNR 2015).
- The Floodplain PEA in the Lower Murray is constrained to approximately 2–3 km, with the area between Mannum and Wellington dominated by reclaimed swamps having very little remaining floodplain habitat (DEWNR 2015).
- The outer floodplain areas, inundated at flows >80,000 ML/day QSA are not part of the Floodplain PEA because MDBA modelling indicates that 80,000 ML/day QSA is the maximum flow rate at which active management can occur (DEWNR 2015).
- Species listed under the EPBC Act are present in this sub-area, which could be impacted by changes in water level as a result of climate extremes.
- Unlike the Upper Murray and Lower Lakes sub-areas, the Lower Murray sub-area hosts no Ramsar-listed wetlands of international significance.
- Water level rather than salinity is the key factor affecting risk to water-dependent ecosystems in this sub-area.

SUB-AREA: Lower Murray

Risk r352: There is the potential that the operation of infrastructure could cause changes in water quality, quantity or regime which in turn impacts water-dependent ecosystems

Risk source: Operation of infrastructure
Consequence: Water-dependent ecosystems impacted

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible					
Unlikely		X			
Rare			X	X	X

Final risk rating: **Low**
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- Infrastructure includes locks, regulators, weirs, barrages and banks. The assessment of this risk considers the effect of operation of infrastructure within the sub-area (i.e. not in connected water resources) on water-dependent ecosystems.
- New infrastructure, including new operational approaches, to achieve environmental benefits are proposed for managing water above Lock 1 and in the Lower Lakes. These risks are not addressed by r352 (Lock 1 is considered in risks to the Upper Murray sub-area).
- The most important risk factor related to operation of infrastructure below Lock 1 is operation of the barrages. The extent to which this risk impacts the Lower Murray is addressed through assessment of risks to connected water resources of the Lower Lakes (r323).
- It was determined that the effectiveness of controls, including environmental watering strategies, operating plans and procedures, is important for managing the risks caused by operation of infrastructure. Loss of corporate knowledge could impact the effectiveness of controls.
- Operation of infrastructure within the sub-area was determined to have localised water quality impacts not likely to cause significant impacts on water-dependent ecosystems in the Lower Murray
- There are wetland regulators and levees in the sub-area. Operation of these potentially causes risk to small sites.
- The LMRIA levee banks maintain significantly altered hydrology.

Relating to consequences:

- The South Australian River Murray Channel Priority Environmental Asset (Channel PEA) covers the area between Wellington and the South Australian border which is inundated at flows up to 40,000 ML/day QSA. The South Australian River Murray Floodplain Priority Environmental Asset (Floodplain PEA) covers the longitudinal extent of the Channel PEA and consists of the area inundated when flows are between 40,000 and 80,000 ML/day QSA (DEWNR 2015).
- The Channel PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the *Environment Protection and Biodiversity Act 1999* (EPBC Act), while six species are both state and nationally listed (DEWNR 2015).
- The Floodplain PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the EPBC Act, while four species are both state and nationally listed (DEWNR 2015).
- The Floodplain PEA in the Lower Murray is constrained to approximately 2–3 km, with the area between Mannum and Wellington dominated by reclaimed swamps having very little remaining floodplain habitat (DEWNR 2015).
- The outer floodplain areas, inundated at flows >80,000 ML/day QSA are not part of the Floodplain PEA because MDBA modelling indicates that 80,000 ML/day QSA is the maximum flow rate at which active management can occur (DEWNR 2015).
- Species listed under the EPBC Act are present in this sub-area, which could be impacted by changes in water level as a result of climate extremes.
- Unlike the Upper Murray and Lower Lakes sub-areas, the Lower Murray sub-area hosts no Ramsar-listed wetlands of international significance.
- Water level rather than salinity is the key factor affecting risk to water-dependent ecosystems in this sub-area.

SUB-AREA: Lower Murray

Risk r356: There is the potential that point source pollution could cause changes in water quality, quantity or regime which in turn impacts water-dependent ecosystems

Risk source: Point source pollution
Consequence: Water dependent ecosystems impacted

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible		X			
Unlikely					
Rare			X	X	

Final risk rating: **Low**
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- The Millennium Drought caused water levels below Lock 1 to fall below -1 mAHD, leading to widespread acidification and point source pollution events originating from the Lower Murray Reclaimed Irrigation Area (LMRIA) (Mosley et al. 2013). The resulting acid drainage from this event is likely to remain a point source of pollution in the future.
- Water quality impacts from the LMRIA will be worse during periods of low flow and lower water levels (Mosley et al. 2013).
- Acid drainage from the LMRIA is rapidly neutralised in the discharge zones in the River Murray with precipitation of solid metal phases occurring before entering the main river channel (Mosley et al. 2013). Anoxic conditions caused by stratification events (e.g. thermal stratification in summer or ingress of salinity upriver from Lake Alexandrina) could cause remobilisation.
- Future land use and intensity of irrigation in the LMRIA could affect the quantity of the return flows to the river.
- There have been efforts to address both the quantity and quality of drainage from the LMRIA such as liming and other measures. The success of these types of interventions into the future is uncertain.
- The contraction of the dairy industry since the drought has caused reduced microbial pollution from the LMRIA.
- Other point sources of pollution can include sewage, houseboats, chemicals, grey water, petrol station storages, industrial discharges etc. These risks are controlled through South Australia's Environment Protection Water Quality Policy (*Environment Protection Act 1993*), Development Act, stormwater management plans etc.

Relating to consequences:

- Acid drainage from the LMRIA causes local-scale impacts to biota in the plumes of the outfalls. Observations indicate that acid tolerant macroinvertebrate species dominate in these areas with acid-sensitive species being heavily impacted in the mixing zone. Benthic species community composition in the Jervois discharge zone appeared unaffected relative to an upstream control. Further assessments are needed before these results can be generalised. Characterisation of sub-lethal impacts of acid drainage outside of the mixing zone requires further assessment (Mosley et al. 2013).
- The South Australian River Murray Channel Priority Environmental Asset (Channel PEA) covers the area between Wellington and the South Australian border which is inundated at flows up to 40,000 ML/day QSA. The South Australian River Murray Floodplain Priority Environmental Asset (Floodplain PEA) covers the longitudinal extent of the Channel PEA and consists of the area inundated when flows are between 40,000 and 80,000 ML/day QSA (DEWNR 2015).
- The Channel PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the *Environment Protection and Biodiversity Act 1999* (EPBC Act), while six species are both state and nationally listed (DEWNR 2015).
- The Floodplain PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the EPBC Act, while four species are both state and nationally listed (DEWNR 2015).
- The Floodplain PEA in the Lower Murray is constrained to approximately 2–3 km, with the area between Mannum and Wellington dominated by reclaimed swamps having very little remaining floodplain habitat (DEWNR 2015).
- Unlike the Upper Murray and Lower Lakes sub-areas, the Lower Murray sub-area hosts no Ramsar-listed wetlands of international significance.

SUB-AREA: Lower Murray

Risk r360: There is the potential that land use could cause changes in water quality, quantity or regime which in turn impacts water-dependent ecosystems

Risk source: Land use
Consequence: Water-dependent ecosystems impacted

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible					
Unlikely		X			
Rare			X	X	X

Final risk rating: **Low**
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- This risk addresses the effects of new or changed land use. It does not address land use unlikely to change over the risk assessment period.
- Existing impacts of the LMRIA are addressed as a point source pollution risk.
- Changes of land use in the LMRIA which increase return flows could cause some risk. This risk is addressed as a point source pollution risk.
- The Development Act, River Murray Act and EPA water quality policy are effective for controlling the impacts of development on the floodplain and outside the sub-area.
- Existing land use may represent a constraint to the delivery of high flows of water to achieve environmental objectives.

Relating to consequences:

- The South Australian River Murray Channel Priority Environmental Asset (Channel PEA) covers the area between Wellington and the South Australian border which is inundated at flows up to 40,000 ML/day QSA. The South Australian River Murray Floodplain Priority Environmental Asset (Floodplain PEA) covers the longitudinal extent of the Channel PEA and consists of the area inundated when flows are between 40,000 and 80,000 ML/day QSA (DEWNR 2015).
- The Channel PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the *Environment Protection and Biodiversity Act 1999* (EPBC Act), while six species are both state and nationally listed (DEWNR 2015).
- The Floodplain PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as

nationally threatened under the EPBC Act, while four species are both state and nationally listed (DEWNR 2015).

- The Floodplain PEA in the Lower Murray is constrained to approximately 2–3 km, with the area between Mannum and Wellington dominated by reclaimed swamps having very little remaining floodplain habitat (DEWNR 2015).
- The outer floodplain areas, inundated at flows >80,000 ML/day QSA are not part of the Floodplain PEA because MDBA modelling indicates that 80,000 ML/day QSA is the maximum flow rate at which active management can occur (DEWNR 2015).
- Species listed under the EPBC Act are present in this sub-area, which could be impacted by changes in water level as a result of climate extremes.
- Unlike the Upper Murray and Lower Lakes sub-areas, the Lower Murray sub-area hosts no Ramsar-listed wetlands of international significance.
- Water level rather than salinity is the key factor affecting risk to water-dependent ecosystems in this sub-area.

SUB-AREA: Lower Murray

Risk r364: There is the potential that invasive/nuisance organisms could cause changes in water quality, quantity or regime which in turn impacts water-dependent ecosystems

Risk source: Invasive/nuisance organisms
Consequence: Water-dependent ecosystems impacted

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible		X			
Unlikely			X		
Rare				X	X

Final risk rating: **Low**
Uncertainty: Moderate

Risk factors

Relating to source of risk and potential for events:

- Impacts of invasive/nuisance organisms on water-dependent ecosystems can include fluctuations in dissolved oxygen, release of toxins and direct and indirect food web impacts. The present assessment only considers impacts caused by water quality/quantity events, not direct ecological impacts.
- Invasive/nuisance organisms are associated with existing impacts which are anticipated to continue to compromise achievement of agreed outcomes. The baseline for the present assessment considers the context of the long-term watering plan for the South Australian River Murray (DEWNR 2015). This baseline assumes an existing level of impact.
- There has been an increase in the duration of individual algal blooms observed in the upper reaches of the River Murray correlating with increasing concentrations of Anabaena, Aphanizomenon, Microcystis and other Cyanophyceae (MDBA 2012b).
- Blue-green algal blooms are events which can occur both naturally and in response to disturbance. Algal bloom events were determined to be less likely in the Lower Murray compared to the Upper Murray. The capacity to manage these events may be improved under the Basin Plan due to additional environmental water.
- The potential for the LMRIA to release pathogens is considered as a point source pollution risk.
- Willows can impact water quality and water temperature. However, it is unlikely that there will be an increase in willow stands in this sub-area over the risk assessment period.
- While proposed controls for carp, such as the carp herpes virus, are expected to bring longer-term benefits, there could be short-term acute impacts on water quality arising from a large number of dead carp.
- Effects of improvements in irrigation management on water quality are assumed to reduce the likelihood of algal bloom events.

Relating to consequences:

- The South Australian River Murray Channel Priority Environmental Asset (Channel PEA) covers the area between Wellington, South Australia, and the border which is inundated at flows up to 40,000 ML/day QSA. The South Australian River Murray Floodplain Priority Environmental Asset (Floodplain PEA) covers the longitudinal extent of the Channel PEA and consists of the area inundated when flows are between 40,000 and 80,000 ML/day QSA (DEWNR 2015).
- The Channel PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the *Environment Protection and Biodiversity Act 1999* (EPBC Act), while six species are both state and nationally listed (DEWNR 2015).
- The Floodplain PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the EPBC Act, while four species are both state and nationally listed (DEWNR 2015).
- The Floodplain PEA in the Lower Murray is constrained to approximately 2–3 km, with the area between Mannum and Wellington dominated by reclaimed swamps having very little remaining floodplain habitat (DEWNR 2015).
- The outer floodplain areas, inundated at flows >80,000 ML/day QSA are not part of the Floodplain PEA because MDBA modelling indicates that 80,000 ML/day QSA is the maximum flow rate at which active management can occur (DEWNR 2015).
- Species listed under the EPBC Act are present in this sub-area, which could be impacted by changes in water level as a result of climate extremes.
- Unlike the Upper Murray and Lower Lakes sub-areas, the Lower Murray sub-area hosts no Ramsar-listed wetlands of international significance.
- Water level rather than salinity is the key factor affecting risk to water-dependent ecosystems in this sub-area.

SUB-AREA: Lower Murray

Risk r351: There is the potential that the operation of infrastructure could cause changes in water quality, quantity or regime which in turn impacts connected water resources

Risk source: Operation of infrastructure
Consequence: Connected water resources impacted

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible					
Unlikely		X			
Rare			X		

Final risk rating: **Low**
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- Infrastructure includes locks, regulators, weirs, barrages and banks. The assessment of this risk considers the effect of operation of infrastructure within the sub-area (i.e. not in connected water resources) on water-dependent ecosystems.
- New infrastructure, including new operational approaches, to achieve environmental benefits are proposed for managing water above Lock 1 and in the Lower Lakes. These risks are not addressed by r351 (Lock 1 is considered in risks to the Upper Murray sub-area).
- The most important risk factor related to operation of infrastructure below Lock 1 is operation of the barrages. This extent to which this risk impacts the Lower Murray is addressed through assessment of risks to connected water resources of the Lower Lakes (r323).
- It was determined that the effectiveness of controls, including environmental watering strategies, operating plans and procedures, is important for managing the risks caused by operation of infrastructure. Loss of corporate knowledge could impact the effectiveness of controls.

Relating to consequences:

- The assessment considered the impact of infrastructure operation within the sub-area on values outside the sub-area.
- It was determined that risks of infrastructure operation within the sub-area are relevant factors affecting risk to connected water resources. The assessment of risks r349, r350 and r352 determined that operation of infrastructure within the sub-area was determined to have localised water quality impacts not likely to cause significant impacts to critical human water needs, the economic use of water, or to water-dependent ecosystems.

UPPER MURRAY – Significant Risks

SUB-AREA: Upper Murray

Risk r368: There is the potential that climate extremes could cause changes in water quality, quantity or regime which in turn cause impacts to water-dependent ecosystems

Risk source: Climate extremes
Consequence: Water-dependent ecosystems impacted

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely					
Possible		X			
Unlikely	X		X	X	X
Rare					

Final risk rating: **Medium**
Uncertainty: High

Risk factors

Relating to source of risk and potential for events:

- Configuration of SDLs consistent with environmental objectives is based on expectations of climatic events derived from historical climatic data (114 years of data). Restoration of water-dependent ecosystem values rests on the assumption that the future climate will be similar to the past climate. Modelling undertaken through the CSIRO Sustainable Yields Project (CSIRO 2008) concluded that the worst-case ('dry') 2030 climate scenario is characterised by significantly reduced water availability in the Murray–Darling Basin. Risk ratings therefore placed more weight on recent experience regarding climate to account for uncertainty regarding the potential impacts of climate change.
- Risks related to climate extremes were determined to be inherently uncontrollable. However, the 10-year timeframe of the assessment means that the likelihood of climate extremes having severe effects over this period is low based on historical frequencies of events (i.e. not considering the potential impacts of climate change over the assessment period).
- Drought, and not flooding, was determined to be the key issue when judging likelihood of impacts to water-dependent ecosystems. The duration of dry events is important with longer droughts correlated with worse environmental outcomes. Controls become less effective as droughts are prolonged.
- Water levels above Lock 1 are controlled and maintained during times of drought. Low water levels causing exposure of acid sulfate soils are less likely in the Upper Murray compared with downstream.
- The South Australian government's allocation framework for the River Murray prioritises critical human water needs over economic and environmental use in the event that entitlement flows are at risk (DEWNR 2016).

- Dry conditions cause salinity to accumulate in wetlands and floodplains. Return of wetter conditions can cause a pulse of salinity in the river.
- Most water is held interstate, not in South Australia. South Australia can influence but not directly control how this water is used to address impacts of climate extremes.
- Climate extremes can be associated with algal blooms. This risk is addressed under the risks caused by invasive/nuisance organisms.

Relating to consequences:

- The South Australian River Murray Channel Priority Environmental Asset (Channel PEA) covers the area inundated at flows up to 40,000 ML/day QSA from the South Australian border to Wellington. The South Australian River Murray Floodplain Priority Environmental Asset (Floodplain PEA) covers the longitudinal extent of the Channel PEA and consists of the area inundated when flows are between 40,000 and 80,000 ML/day QSA (DEWNR 2015).
- The Channel PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the *Environment Protection and Biodiversity Act 1999* (EPBC Act), while six species are both state and nationally listed (DEWNR 2015).
- The Floodplain PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the EPBC Act, while four species are both state and nationally listed (DEWNR 2015).
- The outer floodplain areas, inundated at flows >80,000 ML/day QSA are not part of the Floodplain PEA because MDBA modelling indicates that 80,000 ML/day QSA is the maximum flow rate at which active management can occur (DEWNR 2015).
- The Channel and Floodplain PEAs intersect the Riverland and Banrock Ramsar-listed wetlands in the Upper Murray sub-area (DEWNR 2015). These wetlands are of international significance (Butcher et al. 2009, Newall et al. 2009, DEWNR 2015).
- The Floodplain PEA intersects the portion of the Chowilla Floodplain TLM (The Living Murray) Icon Site that is inundated by flows between 40,000 and 80,000 ML/day QSA (DEWNR 2015).

Evaluation of existing/planned controls

Document/control	**Effectiveness**	**Implementation**	**Notes**
Annual environmental water planning, coordination and delivery	Partially controlled	Complete implementation	Delivery of water depends on priorities set across the Basin and the reliability of the water products held. This does not guarantee delivery to the Upper Murray when required.
Relocation of threatened populations or in-situ watering (e.g. Hall et al. 2009)	Partially controlled	Mostly complete	Successful management of Murray Hardyhead during Millennium Drought.
MDB Agreement – entitlement (1,850 GL) and operation of upstream storages and other infrastructure, cap on diversions	Partially controlled	Complete implementation	MDB Agreement arrangements do not prevent significant impacts on floodplain and wetlands in Upper Murray during extreme dry periods.

Document/control	Effectiveness	Implementation	Notes
Basin Salinity Management 2030 Strategy and Schedule B of the Murray–Darling Basin Agreement	Partially controlled	Mostly complete	Long-term salinity risk from groundwater is mostly managed with salt interception schemes in critical areas; however, real-time operational risks from floodplain inundation and local groundwater intrusions/risks are mostly uncontrolled.
Reconciliation in 2024 of supply measure outcomes for the Basin Plan	Mostly controlled	Complete implementation	Any package of SDL measures agreed in 2017 needs to be implemented in full by 2024. Any projects not implemented in this timeframe will need to be reconciled. Current draft principles for the new IGA involve proponents being responsible for addressing any shortfall risk in an equivalent volume of water.
Chapter 9 of Basin Plan (the MDBA must have regard to the water quality targets in the management of water flows – this includes targets at Morgan (800 EC))	Mostly uncontrolled	Mostly complete	All operators must have regard to salinity targets and demonstrate that consideration was given to management actions available and chosen.
Policies for management of River Murray wetlands – wetland allocations and wetland management plans for high risk sites (in River Murray WAP)	Partially controlled	Mostly complete	Wetlands can be managed through wetting and drying cycles and are allocated water from the dilution and loss component of South Australia's Entitlement.
Management objectives to maintain the ecological character of the Riverland, and Banrock in Ramsar Convention and management plan	Partially controlled	Partially complete	Riverland management plan is in development and Banrock management plan is completed. Climate change and increase or decrease in extreme events may impact on success of implementation.
Proposed operating plans for Pike and Katarapko and weir manipulation	Partially controlled	Mostly complete	Estimated 2020 completion. Need minimum flows to operate; therefore, potentially remains at risk in drought.
Long-Term Environmental Watering Plan (LTWP) for the South Australian River Murray WRP area: sets objectives and targets and environmental water requirements and identifies priority environmental assets and functions	Partially controlled	Mostly implemented through annual watering priorities, rules in WRPs and monitoring programs	LTWP does consider different climate scenarios.

Document/control	Effectiveness	Implementation	Notes
Objectives and outcomes, priority assets and functions and environmental water requirements in Basin-wide environmental watering strategy	Partially controlled	Partially implemented	Effectiveness depends on alignment with other states, and resourcing for monitoring.

SUB-AREA: Upper Murray

Risk r376: There is the potential that the management of connected water resources could cause changes in water quality, quantity or regime which in turn impacts water-dependent ecosystems

Risk source: Management of connected water resources
Consequence: Water-dependent ecosystems impacted

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely					
Possible		X	X		
Unlikely	X			X	
Rare					X

Final risk rating: **Medium**
Uncertainty: High

Risk factors

Relating to source of risk and potential for events:

- The total volume of water required for delivery of many environmental water requirements exceeds South Australia's Entitlement and additional water available through recovery programs. Meeting these environmental water requirements will require water to be delivered in conjunction with unregulated flows (DEWNR 2015).
- There are a range of uncertainties regarding the implementation of the Basin Plan affecting the achievement of environmental outcomes in South Australia including:
    - commitment to, and delivery of, efficiency measures to recover an additional 450 GL
    - commitment to addressing policy and physical constraints affecting the delivery of environmental water
    - the extent to which the environmental equivalence test for SDL adjustment reflects the outcomes achievable through works and measures
    - the potential for long-term watering plans for the river upstream of South Australia to create demands for environmental water that could negatively impact achievement of environmental outcomes in South Australia
    - the extent to which environmental water recovered is compatible with the delivery of water required to address environmental water requirements in South Australia.
- Highly saline groundwater poses a risk to the River Murray. This risk is partially controlled through measures such as salt interception schemes and the salinity zoning policy of the River Murray Prescribed Watercourse Water Allocation Plan (SAMDB NRM Board 2017a).
- It was determined that the design and operation of the salt interception schemes is not configured to address salinity impacts to water-dependent ecosystems. It was assumed that effectiveness in reducing floodplain salinisation is likely to be localised although no supporting monitoring data was presented to support this assumption. There is uncertainty

regarding the extent to which changed management of the salt interception schemes could affect accumulation of salt on the floodplain.
- Operation of Lake Victoria could affect saline groundwater movement into the River Murray.
- The South Australian Riverland Floodplains Integrated Infrastructure Program (SARFIIP) aimed at providing environmental watering to the floodplain (Pike and Katarapko) could cause localised impacts to connected groundwater, including saline groundwater and freshwater lenses. These risks are addressed under risks caused by operation of infrastructure.
- The risk assessment for the SA Murray Region WRP area determined that connected saline groundwater posed low risk to water-dependent ecosystems in the River Murray over the 10-year timeframe of the risk assessment (DEWNR 2017).

Relating to consequences:

- The South Australian River Murray Channel Priority Environmental Asset (Channel PEA) covers the area inundated at flows up to 40,000 ML/day QSA from the South Australian border to Wellington. The South Australian River Murray Floodplain Priority Environmental Asset (Floodplain PEA) covers the longitudinal extent of the Channel PEA and consists of the area inundated when flows are between 40,000 and 80,000 ML/day QSA (DEWNR 2015).
- The Channel PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the *Environment Protection and Biodiversity Act 1999* (EPBC Act), while six species are both state and nationally listed (DEWNR 2015).
- The Floodplain PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the EPBC Act, while four species are both state and nationally listed (DEWNR 2015).
- The outer floodplain areas, inundated at flows >80,000 ML/day QSA are not part of the Floodplain PEA because MDBA modelling indicates that 80,000 ML/day QSA is the maximum flow rate at which active management can occur (DEWNR 2015).
- The Channel and Floodplain PEAs intersect the Riverland and Banrock Ramsar-listed wetlands in the Upper Murray sub-area (DEWNR 2015). These wetlands are of international significance (Butcher et al. 2009, Newall et al. 2009, DEWNR 2015).
- The Floodplain PEA intersects the portion of the Chowilla Floodplain TLM Icon Site that is inundated by flows between 40,000 and 80,000 ML/day QSA (DEWNR 2015).

Evaluation of existing/planned controls

Document/control	**Effectiveness**	**Implementation**	**Notes**
Prerequisite Policy Measures (PPMs). Ability to put environmental water onto unregulated flows. Affects water availability and water regime. Commitment to have policies in place by 2019. States and territories preparing project plans to remove policy constraints (in Basin Plan 2012).	Partially controlled	Mostly complete	PPMs are assumptions in the Basin Plan modelling and therefore must be addressed to deliver on the Basin Plan 2012 agreed outcomes.

Document/control	Effectiveness	Implementation	Notes
Physical constraints management actions to address constraints in ability to deliver water to meet environmental water requirements	Mostly controlled	Mostly complete	Assumption that physical constraints at Hume, Yarrawonga, Murrumbidgee and Goulburn will have agreed business cases and mostly implemented by 2026.
Water quality measure and water availability controls, Lake Victoria (in Lake Victoria operating strategy)	Partially controlled	Partially complete	Lake Victoria cannot be used to manage water quality without affecting the quantity of water available for South Australian Entitlement as it is limited by constraints upstream and the SDL adjustment process.
MDB Agreement – entitlement (1,850 GL) and operation of upstream storages and other infrastructure, cap on diversions	Partially controlled	Complete implementation	MDB Agreement arrangements do not prevent significant impacts on floodplain and wetlands in Upper Murray during extreme dry periods.
Basin Salinity Management 2030 Strategy and schedule B of the Murray–Darling Basin Agreement	Partially controlled	Mostly complete	Long-term salinity risk from groundwater is mostly managed with salt interception schemes in critical areas; however, real-time operational risks from floodplain inundation and local groundwater intrusions/risks are mostly uncontrolled.
Objectives and outcomes, priority assets and functions and environmental water requirements in Basin-wide environmental watering strategy	Partially controlled	Partially implemented	Effectiveness depends on alignment with other states, and resourcing for monitoring.
Annual environmental water planning, coordination and delivery	Partially controlled	Complete implementation	Delivery of water depends on priorities set across the Basin and the reliability of the water products held. This does not guarantee delivery to the Upper Murray when required.
Long-term watering plans in NSW, Victoria and Queensland	Mostly uncontrolled	Partially complete	Integration with South Australia's long-term watering plan is critical to deliver benefits in the Upper Murray but will be limited by upstream requirements of environmental assets.

Document/control	Effectiveness	Implementation	Notes
Reconciliation in 2024 of supply measure outcomes for the Basin Plan	Mostly controlled	Complete implementation	Any package of SDL measures agreed in 2017 needs to be implemented in full by 2024. Any projects not implemented in this timeframe will need to be reconciled. Current draft principles for the new IGA involve proponents being responsible for addressing any shortfall risk in an equivalent volume of water.
Chapter 9 of Basin Plan (the MDBA must have regard to the water quality targets in management of water flows – this includes targets at Morgan (800 EC))	Mostly uncontrolled	Mostly complete	All operators must have regard for salinity targets and demonstrate that consideration was given to management actions available and chosen.
Salt interception schemes	Mostly controlled	Mostly implemented	Evaluation from SA Murray Region risk assessment. Potential for management change which could impact effectiveness.
Salinity zoning policy	Partially controlled	Mostly implemented	From SA Murray Region risk assessment.

SUB-AREA: Upper Murray

Risk r374: There is the potential that the management of connected water resources could cause changes in water quality, quantity or regime which in turn impacts the economic use of water

Risk source: Management of connected water resources
Consequence: Economic use of water impacted

	Insig.	Mod.	Major	Cat.
Almost Certain				
Likely	X			
Possible				
Unlikely		X	X	
Rare				X

Final risk rating: **Medium** [23]
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- There are a range of uncertainties regarding the implementation of the Basin Plan affecting the achievement of environmental outcomes in South Australia. It was determined that these uncertainties could affect economic outcomes – particularly those related to non-consumptive economic benefits such as tourism, recreation and ecosystem services.
- Highly saline groundwater poses a risk to the River Murray. This risk is partially controlled through measures such as salt interception schemes and the salinity zoning policy of the River Murray Prescribed Watercourse Water Allocation Plan (SAMDB NRM Board 2017a).
- A responsive management approach has been proposed for the operation of the salt interception schemes. It was determined that the effect of this change is unlikely to cause significant risk to economic outcomes that depend on the River Murray over the risk assessment timeframe.
- The risk assessment for the SA Murray Region WRP area determined that connected saline groundwater posed low risk to economic activities that depend on the River Murray over the 10-year timeframe of the risk assessment (DEWNR 2017).
- Operation of Lake Victoria could affect saline groundwater movement into the South Australian River Murray.
- Return flows from proposed large-scale environmental watering upstream potentially cause water quality events in South Australia including salinity, blackwater and algal blooms. While these operations must have regard to water quality, there is uncertainty regarding the effectiveness of controls.
- New measures put in place since the last drought (storage rights, environmental water) reduce the level of risk associated with management of connected water resources (SAMDB NRM Board 2014).

[23] 4 consequence levels (rather than 5) were assigned for "economic use of water impacted" (see Section 3.3.2.1)

- Water level is well controlled through locks and is unlikely to be affected by upstream management.
- Programs to construct infrastructure and/or change infrastructure operation to undertake floodplain watering over the risk assessment timeframe could cause changes in connected groundwater resources which in turn lead to water quality impacts in the floodplains and channel. These risks are assessed under operation of infrastructure.

Relating to consequences:

- The Upper Murray supports the majority of take for economic (irrigation) purposes in South Australia. Seventy per cent of class 3 water is taken above Lock 1, compared with 21 per cent for the Lower Murray and 9 per cent for the Lower Lakes.
- The SA Water offtake at Morgan supplies major townships and industry in the upper Eyre Peninsula and the iron triangle.
- Water quality/quantity events could significantly impact non-consumptive economic use including recreation and tourism.
- Water quality events could affect use for stock.

Evaluation of existing/planned controls

Document/control	**Effectiveness**	**Implementation**	**Notes**
Water quality measure and water availability controls, Lake Victoria (in Lake Victoria operating strategy)	Partially controlled	Partially complete	Lake Victoria cannot be used to manage water quality without affecting the quantity of water available for South Australian Entitlement as it is limited by constraints upstream and the SDL adjustment process.
MDB Agreement – entitlement (1,850 GL) and operation of upstream storages and other infrastructure, cap on diversions	Partially controlled	Complete implementation	MDB Agreement arrangements do not prevent significant impacts on floodplain and wetlands in the Upper Murray during extreme dry periods.
Basin Salinity Management 2030 Strategy and Schedule B of the Murray–Darling Basin Agreement	Partially controlled	Mostly complete	Long-term salinity risk from groundwater is mostly managed with salt interception schemes in critical areas; however, real-time operational risks from floodplain inundation and local groundwater intrusions/risks are mostly uncontrolled.
Schedule H of the Murray–Darling Basin Agreement	Partially controlled	Complete implementation	The Schedule provides the way in which state water entitlements will be determined, delivered and accounted for during a period of insufficient water to meet conveyance reserve.

Document/control	Effectiveness	Implementation	Notes
Reconciliation in 2024 of supply measure outcomes for the Basin Plan	Mostly controlled	Complete implementation	Any package of SDL measures agreed in 2017 needs to be implemented in full by 2024. Any projects not implemented in this timeframe will need to be reconciled. Current draft principles for the new IGA involve proponents being responsible for addressing any shortfall risk in an equivalent volume of water.
Chapter 9 of the Basin Plan (the MDBA must have regard to the water quality targets in management of water flows – this includes targets at Morgan (800 EC))	Mostly uncontrolled	Mostly complete	All operators must have regard to salinity targets and demonstrate that consideration was given to management actions available and chosen.
2016–17 South Australian River Murray Water Allocation Plan	Partially controlled	Mostly complete	Provides a framework for allocating water for critical human water needs and other users. Regard will be had to other water sources in delivering Adelaide's water requirements.
Salt interception schemes	Mostly controlled	Mostly implemented	Evaluation from the SA Murray Region risk assessment. Potential for management change which could impact effectiveness.
Salinity zoning policy	Partially controlled	Mostly implemented	From SA Murray Region risk assessment.

UPPER MURRAY – Low Risks

SUB-AREA: Upper Murray

Risk r365: There is the potential that climate extremes could cause changes in water quality, quantity or regime which in turn causes critical human water needs not being met

Risk source: Climate extremes
Consequence: Critical human water needs not met

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible					
Unlikely		X	X		
Rare				X	X

Final risk rating: **Low**
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- Risks related to climate extremes were determined to be inherently uncontrollable. However, the 10-year timeframe of the assessment means that the likelihood of climate extremes having severe effects over this period is low based on historical frequencies of events (i.e. not considering the potential impacts of climate change over the assessment period).
- Climate change could cause a change in the frequency of extreme events or a long-term incremental trend towards changed water availability. Modelling indicates that the worst-case ('dry') 2030 climate scenario is characterised by significantly reduced water availability in the Murray–Darling Basin (CSIRO 2008).
- The South Australian government's allocation framework for the River Murray prioritises critical human water needs over economic and environmental use in the event that entitlement flows are at risk (DEWNR 2016).
- Climate extremes can be associated with algal blooms. This risk is addressed under the risks caused by invasive/nuisance organisms.
- Flood events can cause water quality impacts, such as blackwater. The risks to potable supply are controlled through SA Water's treatment plants and other contingency measures. It was determined that there is some risk that smaller treatment plants in this sub-area may be overwhelmed by some extreme events.
- South Australia has secured 80 GL of storage rights in Dartmouth reservoirs for critical human water needs since the last drought through the addition of Schedule G to the Murray–Darling Basin Agreement. Special accounting requires each of the upstream states to have 835 GL in storage for delivery to South Australia to provide entitlement flows (MDBA 2016). Recent changes in these rules have increased security of South Australia's supply from the River Murray to support critical human water needs.

- New measures put in place since the last drought (e.g. Schedule G of the Murray–Darling Basin Agreement and recovery of environmental water) provide additional levels of control for the risk of climate extremes.
- Acidification during drought can mobilise metals which affects water treatment for potable supply.

Relating to consequences:

- The SA Water offtake at Morgan supplies major townships and industry in the upper Eyre Peninsula and the iron triangle. The River Murray also supports townships along the river. In total, 70–80,000 customers could be impacted by a severe event.
- SA Water's existing infrastructure provides a level of control and redundancy to address risks to the quality and availability of water. Events affecting source waters are more likely to increase costs of delivering water to customers than to cause interruption of supply.
- Water levels are controlled and maintained above Lock 1. It is unlikely that events will significantly affect physical access to water as a result of reduced water levels.
- It was determined that there are few alternative sources of water available for communities that depend on the Upper Murray.

SUB-AREA: Upper Murray

Risk r369: There is the potential that demand/take could cause changes in water quality, quantity or regime which in turn causes critical human water needs not being met

Risk source: Demand/take
Consequence: Critical human water needs not met

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain	X				
Likely					
Possible					
Unlikely					
Rare		X	X	X	

Final risk rating: **Low**
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- This risk is concerned with take from the Upper Murray and not from other connected water resources in South Australia or other Basin States. Take from connected water resources is a separate source of risk addressed by other risk statements.
- The River Murray Prescribed Watercourse Water Allocation Plan (SAMDB NRM Board 2017) and the Basin Plan control this risk. These controls have effective approaches to setting sustainable limits of take. Volumes taken are controlled through licensing. There is a high level of compliance.
- The South Australian government's allocation framework for the River Murray prioritises critical human water needs over economic and environmental use in the event that entitlement flows are at risk (DEWNR 2016).
- Risk is assessed against current levels of take, and controls are those policies/plans assumed to be in place during the risk assessment period.
- Water levels above Lock 1 are likely to be maintained during drought.

Relating to consequences:

- The SA Water offtake at Morgan supplies major townships and industry in the upper Eyre Peninsula and the iron triangle. The River Murray also supports townships along the river. In total, 70–80,000 customers could be impacted by a severe event.
- SA Water's existing infrastructure provides a level of control and redundancy to address risks to the quality and availability of water. Events affecting source waters are more likely to increase costs of delivering water to customers than to cause interruption of supply.

- Water levels are controlled and maintained above Lock 1. It is unlikely that events will significantly affect physical access to water as a result of reduced water levels.
- It was determined that there are few alternative sources of water available for communities that depend on the Upper Murray.

SUB-AREA: Upper Murray

Risk r373: There is the potential that the management of connected water resources could cause changes in water quality, quantity or regime which in turn causes critical human water needs not being met

Risk source: Management of connected water resources
Consequence: Critical human water needs not met

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible					
Unlikely		X			
Rare			X	X	

Final risk rating: **Low**
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- There are a range of uncertainties regarding Basin Plan implementation in connected resources that affect risk. While these uncertainties are mostly relevant for recovery and delivery of environmental water, there may be some effect on risk to non-environmental values.
- Highly saline groundwater poses a risk to the River Murray. This risk is partially controlled through measures such as salt interception schemes and the salinity zoning policy of the River Murray Prescribed Watercourse Water Allocation Plan (SAMDB NRM Board 2017a).
- A responsive management approach has been proposed for the operation of the salt interception schemes. It was determined that the effect of this change is unlikely to cause significant risk to critical human water needs over the risk assessment timeframe.
- The risk assessment for the SA Murray Region WRP area determined that connected saline groundwater posed low risk to critical human water needs that depend on the River Murray over the 10-year timeframe of the risk assessment (DEWNR 2017).
- It was determined that return flows from large-scale environmental watering activities upstream could cause water quality events that increase treatment costs or cause exceedances against water quality guidelines.
- New measures put in place since the last drought (storage rights, desalination plant, environmental water) reduce the level of risk associated with management of connected water resources (SAMDB NRM Board 2014).
- Operation of Lake Victoria could affect saline groundwater movement into the South Australian River Murray.

Relating to consequences:

- The SA Water offtake at Morgan supplies major townships and industry in the upper Eyre Peninsula and the iron triangle. The River Murray also supports townships along the river. In total, 70–80,000 customers could be impacted by a severe event.
- SA Water's existing infrastructure provides a level of control and redundancy to address risks to the quality and availability of water. Events affecting source waters are more likely to increase costs of delivering water to customers than to cause interruption of supply.
- Water levels are controlled and maintained above Lock 1. It is unlikely that events will significantly affect physical access to water as a result of reduced water levels.
- It was determined that there are few alternative sources of water available for communities that depend on the Upper Murray.

SUB-AREA: Upper Murray

Risk r377: There is the potential that the operation of infrastructure could cause changes in water quality, quantity or regime which in turn causes critical human water needs not being met

Risk source: Operation of infrastructure
Consequence: Critical human water needs not met

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible					
Unlikely		X			
Rare			X		

Final risk rating: **Low**
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- Infrastructure includes locks, regulators, weirs, and levee banks. The risk assessment considers the operation of infrastructure within the sub-area and not in connected water resources.
- The risk assessment does not address the operation of salt interception schemes. These schemes operate outside of the South Australian River Murray WRP area. Risks associated with their operation are addressed in risks caused by management of connected water resources (i.e. r373).
- There are proposals and/or commitments to build and/or operate infrastructure to achieve environmental objectives in a water-efficient manner over the risk assessment timeframe. These include:
    - infrastructure for watering Chowilla, Pike and Katarapko floodplains to achieve benefits to floodplain vegetation and other ecological benefits
    - weir pool raising and lowering (independent of what is required for floodplain watering) to achieve a more natural water regime to achieve environmental benefits.
- Infrastructure operations intended for environmental benefits within the sub-area have the potential to cause a range of unintended water quality events in the River Murray channel including increased salinity, algal blooms, exposure of acid sulfate soils from weir pool lowering and the potential for blackwater events arising from inundated floodplains. These risks are the subject of ongoing investigations. There is a commitment to adopt an appropriate risk management approach with respect to construction and operation of this infrastructure.
- It was determined that the effectiveness of controls, including environmental watering strategies, operating plans and procedures, is important for managing the risks caused by operation of infrastructure. Loss of corporate knowledge could impact the effectiveness of controls.

Relating to consequences:

- The SA Water offtake at Morgan supplies major townships and industry in the upper Eyre Peninsula and the iron triangle. The River Murray also supports townships along the river. In total, 70–80,000 customers could be impacted by a severe event.
- SA Water's existing infrastructure provides a level of control and redundancy to address risks to the quality and availability of water. Events affecting source waters are more likely to increase costs of delivering water to customers than to cause interruption of supply.
- Water levels are controlled and maintained above Lock 1. It is unlikely that events will significantly affect physical access to water as a result of reduced water levels.
- It was determined that there are few alternative sources of water available for communities that depend on the Upper Murray.

SUB-AREA: Upper Murray

Risk r381: There is the potential that point source pollution could cause changes in water quality, quantity or regime which in turn causes critical human water needs not being met

Risk source: Point source pollution
Consequence: Critical human water needs not met

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible					
Unlikely		X			
Rare			X	X	

Final risk rating: **Low**
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- Point sources of pollution can include sewage, houseboats, chemicals, grey water, petrol station storages, industrial discharges etc. These risks are controlled through South Australia's Environment Protection Water Quality Policy (*Environment Protection Act 1993*), Development Act, stormwater management plans etc.
- There is potential for point source pollution as a result of accidents. The likelihood of accidents causing severe consequences was judged to be very low.
- It was determined that no high-risk activities are likely to occur on the floodplain.

Relating to consequences:

- The SA Water offtake at Morgan supplies major townships and industry in the upper Eyre Peninsula and the iron triangle. The River Murray also supports townships along the river. In total, 70–80,000 customers could be impacted by a severe event.
- SA Water's existing infrastructure provides a level of control and redundancy to address risks to the quality and availability of water. Events affecting source waters are more likely to increase costs of delivering water to customers than to cause interruption of supply.
- It was determined that there are few alternative sources of water available for communities that depend on the Upper Murray.

SUB-AREA: Upper Murray

Risk r385: There is the potential that land use could cause changes in water quality, quantity or regime which in turn causes critical human water needs not being met

Risk source: Land use
Consequence: Critical human water needs not met

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible					
Unlikely					
Rare		X	X		

Final risk rating: **Low**
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- This risk addresses the effects of new or changed land use. It does not address land use unlikely to change over the risk assessment period.
- There is potential for intensification of land use and the development of marinas. It was determined that the risks caused by these factors are relatively low over a 10-year timeframe. The Development Act, River Murray Act and EPA water quality policy are effective for controlling the impacts of development.
- It was determined that significant increases in the size or impact of the irrigation industry are unlikely.
- Existing land use may represent a constraint to the delivery of high flows of water to achieve environmental objectives.

Relating to consequences:

- The SA Water offtake at Morgan supplies major townships and industry in the upper Eyre Peninsula and the iron triangle. The River Murray also supports townships along the river. In total, 70–80,000 customers could be impacted by a severe event.
- SA Water's existing infrastructure provides a level of control and redundancy to address risks to the quality and availability of water. Events affecting source waters are more likely to increase costs of delivering water to customers than to cause interruption of supply.
- It was determined that there are few alternative sources of water available for communities that depend on the Upper Murray.

SUB-AREA: Upper Murray

Risk r389: There is the potential that invasive/nuisance organisms could cause changes in water quality, quantity or regime which in turn causes critical human water needs not being met

Risk source: Invasive/nuisance organisms
Consequence: Critical human water needs not met

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible					
Unlikely		X	X		
Rare				X	

Final risk rating: **Low**
Uncertainty: Moderate

Risk factors

Relating to source of risk and potential for events:

- It was judged that the risks of algal blooms are higher in the Upper Murray relative to the Lower Murray. Algal blooms may flow over the border from upstream.
- An algal bloom affecting source water for potable supply recently occurred in this sub-area. The water quality impacts were effectively treated through use of activated carbon. There was no interruption of supply. Aesthetics were temporarily impacted.
- The likelihood of events affecting water supply offtakes can be controlled through river operations.

Relating to consequences:

- The SA Water offtake at Morgan supplies major townships and industry in the upper Eyre Peninsula and the iron triangle. The River Murray also supports townships along the river. In total, 70–80,000 customers could be impacted by a severe event.
- Water levels were maintained above Lock 1 during the drought. It is very unlikely that climate extremes will significantly affect physical access to water as a result of reduced water levels.
- There are few alternative sources of water available for communities that depend on the Upper Murray.
- SA Water's existing infrastructure provides a level of control and redundancy to address risks to the quality and availability of water. Events affecting source waters are more likely to increase costs of delivering water to customers than to cause interruption of supply. However, it was determined that there is risk of large-scale algal bloom events overwhelming smaller water treatment plants.
- Effective control of water quality risk caused by invasive/nuisance organisms relies on appropriate monitoring. There have been no known interruptions to supply as a result of nuisance organisms in recent history.

SUB-AREA: Upper Murray

Risk r366: There is the potential that climate extremes could cause changes in water quality, quantity or regime which in turn impacts the economic use of water

Risk source: Climate extremes
Consequence: Economic use of water impacted

	Insig.	Mod.	Major	Cat.
Almost Certain				
Likely	X			
Possible				
Unlikely		X		
Rare			X	X

Final risk rating: **Low** [24]
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- Risks related to climate extremes were determined to be inherently uncontrollable. However, the 10-year timeframe of the assessment means that the likelihood of climate extremes having severe effects over this period is low based on historical frequencies of events (i.e. not considering the potential impacts of climate change over the assessment period). Modelling undertaken to inform the Basin Plan applied South Australia's allocations framework to 114 years of historical data to determine the risks to South Australia's Entitlement. Hindcasting against risk criteria for this assessment indicates events leading to two catastrophic, zero major, two moderate and one minor consequence over this time period.
- Climate change could cause a change in the frequency of extreme events or a long-term incremental trend towards changed water availability. Modelling indicates that the worst-case ('dry') 2030 climate scenario is characterised by significantly reduced water availability in the Murray–Darling Basin (CSIRO 2008).
- Trade is an important mechanism allowing enterprises that depend on the resource to manage their risks. Trade of water into South Australia during the Millennium Drought was critical for maintaining economic activity over this period (Kirby et al. 2012). However, recovery of water to achieve environmental goals under the Basin Plan could leave less water available for trade into South Australia during drought.
- The South Australian government's allocation framework for the River Murray prioritises critical human water needs over economic and environmental use in the event that entitlement flows are at risk (DEWNR 2016).
- Water levels were maintained above Lock 1 during the Millennium Drought. It is unlikely that climate extremes will significantly affect physical access to water as a result of reduced inflows.

[24] 4 consequence levels (rather than 5) were assigned for "economic use of water impacted" (see Section 3.3.2.1)

- Climate extremes can be associated with algal blooms. This risk is addressed under the risks caused by invasive/nuisance organisms.
- Flood events can cause water quality impacts, such as blackwater.

Relating to consequences:

- The Upper Murray supports the majority of take for economic (irrigation) purposes in South Australia. Seventy per cent of class 3 water is taken above Lock 1, compared with 21 per cent for the Lower Murray and 9 per cent for the Lower Lakes.
- Water quality events caused by climate extremes could also affect use for stock.
- The SA Water offtake at Morgan supplies major townships and industry in the upper Eyre Peninsula and the iron triangle.
- Climate extremes affect non-consumptive economic use including recreation and tourism. Since water levels are maintained above Lock 1, it is assumed negative effects of climate extremes to these uses are largely a result of public perceptions regarding drought impacts.
- The Millennium Drought impacted civic assets, public spaces and businesses such as nurseries. There was also impact to heavy industry including BHP in Whyalla, which receives water via the Morgan pipeline. These impacts were largely the result of demand management actions implemented during drought. The potential for similar impacts in the future will be reduced to some extent by the implementation of storage rights for South Australia implemented since the Millennium Drought.

SUB-AREA: Upper Murray

Risk r370: There is the potential that demand/take (including interception activities) could cause changes in water quality, quantity or regime which in turn impacts the economic use of water

Risk source: Demand/take (including interception activities)
Consequence: Economic use of water impacted

	Insig.	Mod.	Major	Cat.
Almost Certain	X			
Likely				
Possible				
Unlikely				
Rare		X	X	X

Final risk rating: **Low** [25]
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- This risk is concerned with take from the Upper Murray and not from other connected water resources in South Australia or other Basin States. Take from connected water resources is a separate source of risk addressed by other risk statements.
- The River Murray Prescribed Watercourse Water Allocation Plan (SAMDB NRM Board 2017) and the Basin Plan control this risk. These controls have effective approaches to setting sustainable limits of take. Volumes taken are controlled through licensing. There is a high level of compliance.
- The South Australian government's allocation framework for the River Murray prioritises critical human water needs over economic and environmental use in the event that entitlement flows are at risk (DEWNR 2016).
- It was determined that maintenance of weir pools at full supply levels above Lock 1 means that take by any given user is very unlikely to affect take by other users.

Relating to consequences:

- The Upper Murray supports the majority of take for economic (irrigation) purposes in South Australia. Seventy per cent of class 3 water is taken above Lock 1, compared with 21 per cent for the Lower Murray and 9 per cent for the Lower Lakes.
- The SA Water offtake at Morgan supplies major townships and industry in the upper Eyre Peninsula and the iron triangle.
- Water quality/quantity events could significantly impact non-consumptive economic use including recreation and tourism.
- Water quality events could affect use for stock.

[25] 4 consequence levels (rather than 5) were assigned for "economic use of water impacted" (see Section 3.3.2.1)

SUB-AREA: Upper Murray

Risk r378: There is the potential that the operation of infrastructure could cause changes in water quality, quantity or regime which in turn impacts the economic use of water

Risk source: Operation of infrastructure
Consequence: Economic use of water impacted

	Insig.	Mod.	Major	Cat.
Almost Certain				
Likely	X			
Possible				
Unlikely				
Rare		X	X	X

Final risk rating: **Low** [26]
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- Infrastructure includes locks, regulators, weirs, and levee banks. The risk assessment considers the operation of infrastructure within the sub-area and not in connected water resources. Similarly, it considers potential consequences occurring within the sub-area and not in connected resources.
- The risk assessment does not address the operation of salt interception schemes. These schemes operate outside of the South Australian River Murray WRP area. Risks associated with their operation are addressed in risks caused by management of connected water resources (i.e. r373).
- There are proposals and/or commitments to build and/or operate infrastructure to achieve environmental objectives in a water-efficient manner over the risk assessment timeframe. These include:
    - infrastructure for watering Chowilla, Pike and Katarapko floodplains to achieve benefits to floodplain vegetation and other ecological benefits
    - weir pool raising and lowering (independent of what is required for floodplain watering) to achieve a more natural water regime to achieve environmental benefits.
- Infrastructure operations intended for environmental benefits within the sub-area have the potential to cause a range of unintended water quality events including increased salinity, algal blooms, exposure of acid sulfate soils from weir pool lowering and the potential for blackwater events arising from inundated floodplains. It was determined that these events, if they occur, will likely be localised in nature. These risks are the subject of existing and ongoing investigations. There is a commitment to adopt an appropriate risk management approach with respect to construction and operation of this infrastructure.

[26] 4 consequence levels (rather than 5) were assigned for "economic use of water impacted" (see Section 3.3.2.1)

- It was determined that the effectiveness of controls, including environmental watering strategies, operating plans and procedures, is important for managing the risks caused by operation of infrastructure. Loss of corporate knowledge could impact the effectiveness of controls.
- Disturbance caused by construction of infrastructure could lead to water quality impacts (e.g. disturbance of acid sulfate soils). It was determined that construction of additional infrastructure across the river channel is unlikely over the risk assessment timeframe.

Relating to consequences:

- The Upper Murray supports the majority of take for economic (irrigation) purposes in South Australia. Seventy per cent of class 3 water is taken above Lock 1, compared with 21 per cent for the Lower Murray and 9 per cent for the Lower Lakes.
- The SA Water offtake at Morgan supplies major townships and industry in the upper Eyre Peninsula and the iron triangle.
- Water quality/quantity events could significantly impact non-consumptive economic use including recreation and tourism.
- Irrigators could be impacted by direct impacts of infrastructure design and operation. For example, there are irrigation offtakes on the Pike River that could be affected by water quality events.
- It was determined that groundwater risk to irrigators on the highlands is negligible.
- Weir pool raising and lowering could affect infrastructure such as ferries, landings and pumps potentially causing economic and social impacts. It was assumed that infrastructure operation to achieve environmental benefit will have regard for potential third-party impacts.
- Water quality events could affect use for stock.

SUB-AREA: Upper Murray

Risk r382: There is the potential that point source pollution could cause changes in water quality, quantity or regime which in turn impacts the economic use of water

Risk source: Point source pollution
Consequence: Economic use of water

	Insig.	Mod.	Major	Cat.
Almost Certain				
Likely	X			
Possible				
Unlikely				
Rare		X	X	X

Final risk rating: **Low** [27]
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- Point sources of pollution can include sewage, houseboats, chemicals, grey water, petrol station storages, industrial discharges etc. These risks are controlled through South Australia's Environment Protection Water Quality Policy (*Environment Protection Act 1993*), Development Act, stormwater management plans etc.
- There is potential for point source pollution as a result of accidents. The likelihood of accidents causing severe consequences was judged to be very low.
- It was determined that high-risk activities are unlikely to occur on the floodplain.

Relating to consequences:

- The Upper Murray supports the majority of take for economic (irrigation) purposes in South Australia. Seventy per cent of class 3 water is taken above Lock 1, compared with 21 per cent for the Lower Murray and 9 per cent for the Lower Lakes.
- The SA Water offtake at Morgan supplies major townships and industry in the upper Eyre Peninsula and the iron triangle.
- Water quality/quantity events could significantly impact non-consumptive economic use including recreation and tourism.
- Water quality events could affect use for stock.

[27] 4 consequence levels (rather than 5) were assigned for "economic use of water impacted" (see Section 3.3.2.1)

SUB-AREA: Upper Murray

Risk r386: There is the potential that land use could cause changes in water quality, quantity or regime which in turn impacts the economic use of water

Risk source: Land use
Consequence: Economic use of water

	Insig.	Mod.	Major	Cat.
Almost Certain				
Likely	X			
Possible				
Unlikely		X		
Rare			X	X

Final risk rating: **Low** [28]
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- This risk addresses the effects of new or changed land use. It does not address land use unlikely to change over the risk assessment period.
- There is potential for intensification of land use and the development of marinas. It was determined that the risks caused by these factors are relatively low over a 10-year timeframe. The Development Act, River Murray Act and EPA water quality policy are effective for controlling the impacts of development.
- It was determined that significant increases in the size or impact of the irrigation industry are unlikely.
- Existing land use may represent a constraint to the delivery of high flows of water to achieve environmental objectives.

Relating to consequences:

- The Upper Murray supports the majority of take for economic (irrigation) purposes in South Australia. Seventy per cent of class 3 water is taken above Lock 1, compared with 21 per cent for the Lower Murray and 9 per cent for the Lower Lakes.
- SA Water has an offtake at Morgan. This supplies major townships and industry in the upper Eyre Peninsula and the iron triangle.
- The effects of severe point source pollution could significantly impact non-consumptive economic use including recreation and tourism.
- Water quality impacts could affect use for stock.

[28] 4 consequence levels (rather than 5) were assigned for "economic use of water impacted" (see Section 3.3.2.1)

SUB-AREA: Upper Murray

Risk r390: There is the potential that invasive/nuisance organisms could cause changes in water quality, quantity or regime which in turn impacts the economic use of water

Risk source: Invasive/nuisance organisms
Consequence: Economic use of water impacted

	Insig.	Mod.	Major	Cat.
Almost Certain				
Likely	X			
Possible				
Unlikely		X		
Rare			X	X

Final risk rating: **Low** [29]
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- Impacts of invasive/nuisance organisms on water quality can include fluctuations in dissolved oxygen, release of toxins, and increased turbidity.
- Invasive/nuisance organisms are associated with existing impacts which are anticipated to continue to compromise achievement of agreed outcomes. The baseline for the present assessment considers the context of the long-term watering plan for the South Australian River Murray (DEWNR 2015). This baseline assumes an existing level of impact.
- Blue-green algal blooms are events which can occur both naturally and in response to disturbance. Significant blue-green algal blooms have not affected the Upper Murray for over a decade. The capacity to manage these events may be improved under the Basin Plan due to additional environmental water.
- Willows can impact water quality and water temperature. However, it is unlikely that there will be an increase in willow stands in this sub-area over the risk assessment period.
- While proposed controls for carp, such as the carp herpes virus, are expected to lead to longer-term benefits, there could be short-term acute impacts on water quality arising from a large number of dead carp.
- Effects of improvements in irrigation management on water quality are assumed to reduce the likelihood of algal bloom events.

Relating to consequences:

- The Upper Murray supports the majority of take for economic (irrigation) purposes in South Australia. Seventy per cent of class 3 water is taken above Lock 1, compared with 21 per cent for the Lower Murray and 9 per cent for the Lower Lakes.

[29] 4 consequence levels (rather than 5) were assigned for "economic use of water impacted" (see Section 3.3.2.1)

- SA Water has an offtake at Morgan. This supplies major townships and industry in the upper Eyre Peninsula and the iron triangle.
- Water quality/quantity events could significantly impact non-consumptive economic use including recreation and tourism.
- Water quality events associated with algal blooms could affect use for stock.

SUB-AREA: Upper Murray

Risk r372: There is the potential that demand/take (including interception activities) could cause changes in water quality, quantity or regime which in turn impacts water-dependent ecosystems

Risk source: Demand/take (including interception activities)
Consequence: Water-dependent ecosystems impacted

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible					
Unlikely		X			
Rare			X	X	X

Final risk rating: **Low**
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- Take is controlled through water allocation plans under *Natural Resources Management Act 2004*. There are effective approaches to setting limits. Volumes are controlled through licensing. There is a high level of compliance.
- Risk is assessed against current levels of take, and controls are those policies/plans assumed to be in place during the risk assessment period.
- The South Australian government's allocation framework for the River Murray prioritises critical human water needs over economic and environmental use in the event that entitlement flows are at risk (DEWNR 2016)
- Water levels above Lock 1 are controlled and maintained during times of drought.

Relating to consequences:

- The South Australian River Murray Channel Priority Environmental Asset (Channel PEA) covers the area inundated at flows up to 40,000 ML/day QSA from the South Australian border to Wellington. The South Australian River Murray Floodplain Priority Environmental Asset (Floodplain PEA) covers the longitudinal extent of the Channel PEA and consists of the area inundated when flows are between 40,000 and 80,000 ML/day QSA (DEWNR 2015).
- The Channel PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the *Environment Protection and Biodiversity Act 1999* (EPBC Act), while six species are both state and nationally listed (DEWNR 2015).
- The Floodplain PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the EPBC Act, while four species are both state and nationally listed (DEWNR 2015).

- The outer floodplain areas, inundated at flows >80,000 ML/day QSA are not part of the Floodplain PEA because MDBA modelling indicates that 80,000 ML/day QSA is the maximum flow rate at which active management can occur (DEWNR 2015).
- The Channel and Floodplain PEAs intersect the Riverland and Banrock Ramsar-listed wetlands in the Upper Murray sub-area (DEWNR 2015). These wetlands are of international significance (Butcher et al. 2009, Newall et al. 2009, DEWNR 2015).
- The Floodplain PEA intersects the portion of the Chowilla Floodplain TLM Icon Site that is inundated by flows between 40,000 and 80,000 ML/day QSA (DEWNR 2015).

SUB-AREA: Upper Murray

Risk r380: There is the potential that the operation of infrastructure could cause changes in water quality, quantity or regime which in turn impacts water-dependent ecosystems

Risk source: Operation of infrastructure
Consequence: Water-dependent ecosystems impacted

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible					
Unlikely		X	X		
Rare				X	X

Final risk rating: **Low**
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- Infrastructure includes locks, regulators, weirs, and levee banks. The risk assessment considers the operation of infrastructure within the sub-area and not in connected water resources.
- The risk assessment does not address the operation of salt interception schemes. These schemes operate outside of the River Murray WRP area. Risks associated with their operation are addressed in risks caused by management of connected water resources (i.e. r373).
- There are proposals and/or commitments to build and/or operate infrastructure to achieve environmental objectives in a water-efficient manner over the risk assessment timeframe. These include:
    - infrastructure for watering Chowilla, Pike and Katarapko floodplains to achieve benefits to floodplain vegetation and other ecological benefits
    - weir pool raising and lowering (independent of what is required for floodplain watering) to achieve a more natural water regime potentially benefitting both vegetation and fish.
- Existing and planned floodplain infrastructure and weir pool manipulations to achieve environmental benefits have the potential to cause a range of unintended effects including salinity impacts on the fringes of inundated areas, increased salinity in the river channel, exposure of acid sulfate soils, algal blooms, excessive carp recruitment, changes in appropriate hydraulic habitat valuable to native aquatic fauna, and potential for blackwater events, low dissolved oxygen and other impacts (Wallace 2012). These risks are the subject of ongoing investigations. There is a commitment to adopt an appropriate risk management approach with respect to construction and operation of this infrastructure.
- It was determined that the effectiveness of controls, including environmental watering strategies, operating plans and procedures, is important for managing the risks caused by operation of infrastructure. Loss of corporate knowledge could impact the effectiveness of controls.

Relating to consequences:

- The South Australian River Murray Channel Priority Environmental Asset (Channel PEA) covers the area inundated at flows up to 40,000 ML/day QSA from the South Australian border to Wellington. The South Australian River Murray Floodplain Priority Environmental Asset (Floodplain PEA) covers the longitudinal extent of the Channel PEA and consists of the area inundated when flows are between 40,000 and 80,000 ML/day QSA (DEWNR 2015).
- The Channel PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the *Environment Protection and Biodiversity Act 1999* (EPBC Act), while six species are both state and nationally listed (DEWNR 2015).
- The Floodplain PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the EPBC Act, while four species are both state and nationally listed (DEWNR 2015).
- The outer floodplain areas, inundated at flows >80,000 ML/day QSA are not part of the Floodplain PEA because MDBA modelling indicates that 80,000 ML/day QSA is the maximum flow rate at which active management can occur (DEWNR 2015).
- The Channel and Floodplain PEAs intersect the Riverland and Banrock Ramsar-listed wetlands in the Upper Murray sub-area (DEWNR 2015). These wetlands are of international significance (Butcher et al. 2009, Newall et al. 2009, DEWNR 2015).
- The Floodplain PEA intersects the portion of the Chowilla Floodplain TLM Icon Site that is inundated by flows between 40,000 and 80,000 ML/day QSA (DEWNR 2015).

SUB-AREA: Upper Murray

Risk r384: There is the potential that point source pollution could cause changes in water quality, quantity or regime which in turn causes impact to water-dependent ecosystems

Risk source: Point source pollution
Consequence: Water-dependent ecosystems impacted

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible					
Unlikely					
Rare		X	X		

Final risk rating: **Low**
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- Point sources of pollution can include sewage, houseboats, chemicals, grey water, petrol station storages, industrial discharges etc. These risks are controlled through South Australia's Environment Protection Water Quality Policy (*Environment Protection Act 1993*), Development Act, stormwater management plans etc.
- There is potential for point source pollution as a result of accidents. The likelihood of accidents causing severe consequences was judged to be very low.
- It was determined that high-risk activities are unlikely to occur on the floodplain.

Relating to consequences:

- The South Australian River Murray Channel Priority Environmental Asset (Channel PEA) covers the area inundated at flows up to 40,000 ML/day QSA from the South Australian border to Wellington. The South Australian River Murray Floodplain Priority Environmental Asset (Floodplain PEA) covers the longitudinal extent of the Channel PEA and consists of the area inundated when flows are between 40,000 and 80,000 ML/day QSA (DEWNR 2015).
- The Channel PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the *Environment Protection and Biodiversity Act 1999* (EPBC Act), while six species are both state and nationally listed (DEWNR 2015).
- The Floodplain PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the EPBC Act, while four species are both state and nationally listed (DEWNR 2015).
- The outer floodplain areas, inundated at flows >80,000 ML/day QSA are not part of the Floodplain PEA because MDBA modelling indicates that 80,000 ML/day QSA is the maximum flow rate at which active management can occur (DEWNR 2015).

- The Channel and Floodplain PEAs intersect the Riverland and Banrock Ramsar-listed wetlands in the Upper Murray sub-area (DEWNR 2015). These wetlands are of international significance (Butcher et al. 2009, Newall et al. 2009, DEWNR 2015).
- The Floodplain PEA intersects the portion of the Chowilla Floodplain TLM Icon Site that is inundated by flows between 40,000 and 80,000 ML/day QSA (DEWNR 2015).

SUB-AREA: Upper Murray

Risk r388: There is the potential that land use could cause change in water quality, quantity or regime which in turn impacts water-dependent ecosystems

Risk source: Land use
Consequence: Water-dependent ecosystems impacted

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible					
Unlikely		X			
Rare			X	X	

Final risk rating: **Low**
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- This risk addresses the effects of new or changed land use. It does not address land use unlikely to change over the risk assessment period.
- There is potential for intensification of land use and the development of marinas. It was determined that the risks caused by these factors are relatively low over a 10-year timeframe. The Development Act, River Murray Act and EPA water quality policy are effective for controlling the impacts of development.
- It was determined that significant increases in the size or impact of the irrigation industry are unlikely.
- Existing land use may represent a constraint to the delivery of high flows of water to achieve environmental objectives.

Relating to consequences:

- The South Australian River Murray Channel Priority Environmental Asset (Channel PEA) covers the area inundated at flows up to 40,000 ML/day QSA from the South Australian border to Wellington. The South Australian River Murray Floodplain Priority Environmental Asset (Floodplain PEA) covers the longitudinal extent of the Channel PEA and consists of the area inundated when flows are between 40,000 and 80,000 ML/day QSA (DEWNR 2015).
- The Channel PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the *Environment Protection and Biodiversity Act 1999* (EPBC Act), while six species are both state and nationally listed (DEWNR 2015).
- The Floodplain PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the EPBC Act, while four species are both state and nationally listed (DEWNR 2015).

- The outer floodplain areas, inundated at flows >80,000 ML/day QSA are not part of the Floodplain PEA because MDBA modelling indicates that 80,000 ML/day QSA is the maximum flow rate at which active management can occur (DEWNR 2015).
- The Channel and Floodplain PEAs intersect the Riverland and Banrock Ramsar-listed wetlands in the Upper Murray sub-area (DEWNR 2015). These wetlands are of international significance (Butcher et al. 2009, Newall et al. 2009, DEWNR 2015).
- The Floodplain PEA intersects the portion of the Chowilla Floodplain TLM Icon Site that is inundated by flows between 40,000 and 80,000 ML/day QSA (DEWNR 2015).

SUB-AREA: Upper Murray

Risk r392: There is the potential that invasive/nuisance organisms could cause changes in water quality, quantity or regime which in turn impacts water-dependent ecosystems

Risk source: Invasive/nuisance organisms
Consequence: Water-dependent ecosystems impacted

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible		X			
Unlikely			X		
Rare				X	X

Final risk rating: **Low**
Uncertainty: Moderate

Risk factors

Relating to source of risk and potential for events:

- Invasive/nuisance organisms are associated with existing impacts which are anticipated to continue to compromise achievement of agreed outcomes. The baseline for the present assessment considers the context of the long-term watering plan for the South Australian River Murray (DEWNR 2015). This baseline assumes an existing level of impact.
- Blue-green algal blooms are events which can occur both naturally and in response to disturbance. It was determined that the capacity to manage these events may be improved under the Basin Plan due to additional environmental water.
- Impacts of invasive/nuisance organisms on water-dependent ecosystems can include fluctuations in dissolved oxygen, release of toxins and direct and indirect food web impacts. The present assessment only considers impacts caused as a result of water quality/quantity events, not direct ecological impacts.
- Willows can impact water quality and water temperature. However, it is unlikely that there will be an increase in willow stands in this sub-area over the risk assessment period.
- While proposed controls for carp, such as the carp herpes virus, are expected to lead to longer-term benefits, there could be short-term acute impacts on water quality arising from a large number of dead carp.
- Effects of improvements in irrigation management on water quality are assumed to reduce the likelihood of algal bloom events.

Relating to consequences:

- The South Australian River Murray Channel Priority Environmental Asset (Channel PEA) covers the area inundated at flows up to 40,000 ML/day QSA from the South Australian border to Wellington. The South Australian River Murray Floodplain Priority Environmental Asset (Floodplain PEA) covers the longitudinal extent of the Channel PEA and consists of the area inundated when flows are between 40,000 and 80,000 ML/day QSA (DEWNR 2015).

- The Channel PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the *Environment Protection and Biodiversity Act 1999* (EPBC Act), while six species are both state and nationally listed (DEWNR 2015).
- The Floodplain PEA is host to flora and fauna species listed as endangered, vulnerable or rare under the South Australian *National Parks and Wildlife Act 1972*. Two species are listed as nationally threatened under the EPBC Act, while four species are both state and nationally listed (DEWNR 2015).
- The outer floodplain areas, inundated at flows >80,000 ML/day QSA are not part of the Floodplain PEA because MDBA modelling indicates that 80,000 ML/day QSA is the maximum flow rate at which active management can occur (DEWNR 2015).
- The Channel and Floodplain PEAs intersect the Riverland and Banrock Ramsar-listed wetlands in the Upper Murray sub-area (DEWNR 2015). These wetlands are of international significance (Butcher et al. 2009, Newall et al. 2009, DEWNR 2015).
- The Floodplain PEA intersects the portion of the Chowilla Floodplain TLM Icon Site that is inundated by flows between 40,000 and 80,000 ML/day QSA (DEWNR 2015).

SUB-AREA: Upper Murray

Risk r379: There is the potential that the operation of infrastructure could cause changes in water quality, quantity or regime which in turn impacts connected water resources

Risk source: Operation of infrastructure
Consequence: Connected water resources impacted

	Insig.	Minor	Mod.	Major	Cat.
Almost Certain					
Likely	X				
Possible					
Unlikely		X			
Rare			X		

Final risk rating: **Low**
Uncertainty: Low

Risk factors

Relating to source of risk and potential for events:

- Infrastructure includes locks, regulators, weirs, and levee banks. The risk assessment considers the operation of infrastructure within the sub-area and not in connected water resources.
- The risk assessment does not address the operation of salt interception schemes. These schemes operate outside of the South Australian River Murray WRP area. Risks associated with their operation are addressed in risks caused by management of connected water resources (i.e. r373).
- There are proposals and/or commitments to build and/or operate infrastructure to achieve environmental objectives in a water-efficient manner over the risk assessment timeframe. These include:
    - infrastructure for watering Chowilla, Pike and Katarapko floodplains to achieve benefits to floodplain vegetation and other ecological benefits
    - weir pool raising and lowering (independent of what is required for floodplain watering) to achieve a more natural water regime to achieve environmental benefits.
- Existing and planned floodplain infrastructure and weir pool manipulations to achieve environmental benefits have the potential to cause a range of unintended effects including salinity impacts on the fringes of inundated areas, increased salinity in the river channel, exposure of acid sulfate soils, algal blooms, excessive carp recruitment, changes in appropriate hydraulic habitat valuable to native aquatic fauna and potential for blackwater events, low dissolved oxygen and other impacts (Wallace 2012). These risks are the subject of ongoing investigations. There is a commitment to adopt an appropriate risk management approach with respect to construction and operation of this infrastructure.
- It was determined that the effectiveness of controls, including environmental watering strategies, operating plans and procedures, is important for managing the risks caused by operation of infrastructure. Loss of corporate knowledge could impact the effectiveness of controls.

Relating to consequences:

- The assessment considered potential consequences occurring outside, and not within, the sub-area.
- Infrastructure operations for the purposes of watering floodplains and reintroducing more natural flow regimes in the channel to achieve environmental benefits potentially impact connected groundwater. This, in turn, potentially causes water quality events and consequences within the sub-area. These risks are addressed under r377, r378, and r380 for consequences within the sub-area to critical human water needs, economic use of water, and water-dependent ecosystems respectively.
- The potential for infrastructure operations to impact critical human water needs and economic use of water in upstream states was determined to be insignificant. There is no known consumptive use in upstream states that is in the vicinity of areas affected by infrastructure operations in South Australia.
- The potential for infrastructure operations to impact consumptive use of groundwater on the highlands (i.e. outside of the sub-area) within South Australia was determined to be insignificant. The SA Murray Region risk assessment (DEWNR 2017) determined that management of the River Murray caused low risk to these connected groundwater resources.
- There is uncertainty regarding the impacts of fringing effects from floodplain watering and/or weir pool raising on water-dependent ecosystems outside of the sub-area. It is assumed that these risks will be considered and addressed through planning for operation of floodplain infrastructure.
- There is potential for water quality events caused by infrastructure operations within the sub-area to cause impacts downstream of Lock 1.

C. Index of controls and risks

Controls – Policy and legislation

Control – Policy and legislation	Risk rating	Risk IDs per sub-area		
		Lakes Alexandrina & Albert	Lower Murray	Upper Murray
Basin Plan 2012	Medium	312, 318, 320	337, 340, 348	368, 374, 376
	Low	310, 322, 316, 323	338, 342, 345, 362, 344, 364	373, 390, 392
Basin Plan Chapter 9 (MDBA must have regard for water quality targets in management of water flows)	Medium	312, 318, 320	337, 340, 346, 348,	368, 374, 376
	Low			
Basin Plan environmental watering objectives	Medium	312, 320	337, 340, 346	368, 376
	Low			
Basin Salinity Management 2030 Strategy, MDB Agreement Schedule B	Medium	318, 320	337, 340, 346	368, 376
	Low			
Development Act 1993	Medium			
	Low	330, 332	350, 353, 357, 358, 360	381, 382, 384, 385, 386, 388
Efficiency measures to recover an additional 450 GL	Medium	318, 320	348	376
	Low		345	
Environment Protection (Water Quality) Policy 2015 (linked to ***Environment Protection Act 1993***)	Medium			
	Low	326, 328	350, 353, 356, 357, 358, 360	381,382, 384, 385, 386, 388
Lake Victoria Operating Strategy	Medium	318, 320	348	374, 376

Control – Policy and legislation	Risk rating	Risk IDs per sub-area		
		Lakes Alexandrina & Albert	Lower Murray	Upper Murray
	Low			
Long-Term Environmental Watering Plan for the South Australian River Murray WRP area	Medium	312	340	368
	Low			
MDBA Drought Emergency Framework for Lakes Alexandrina and Albert	Medium	312	337, 340, 346, 348	
	Low			
MDB Agreement (operation of storages & infrastructure, cap & entitlement)	Medium	312, 318, 320	337, 340, 346, 348	368, 374, 376
	Low			
MDB Agreement Schedule D (interstate trade)	Medium			
	Low	310	338	366
MDB Agreement Schedule G (South Australia's storage rights)	Medium		337	374
	Low		345	365, 366, 373
MDB Agreement Schedule H (water sharing, provision for South Australia's storage rights)	Medium		337, 346	374
	Low			
Prerequisite Policy Measures (PPMs) – enabling environmental water with unregulated flows (in Basin Plan 2012)	Medium	318, 320	348	376
	Low			
Ramsar Convention and management plan	Medium	312, 318, 320		
	Low			

Control – Policy and legislation	Risk rating	Risk IDs per sub-area		
		Lakes Alexandrina & Albert	Lower Murray	Upper Murray
Reconciliation in 2024 of supply measure outcomes for the Basin Plan	Medium	312, 318, 320	337, 340, 346, 348	368, 374, 376
	Low			
River Murray Act 2003	Medium			
	Low	330, 332	357, 358, 360	381, 385
Water Allocation Plan for the River Murray Prescribed Watercourse[30]	Medium	312	337, 340, 346	368, 376, 374
	Low	314, 316	341, 342, 344, 345	369, 370, 372, 373
Stormwater management plans	Medium			
	Low	326, 328,	353, 354, 356	381, 382, 384
Water allocation framework for the River Murray[31]	Medium			
	Low		341	365, 369
Victoria, NSW long-term watering plans	Medium	318, 320	348	376
	Low			

30 It is assumed that the WAP in operation at the time in writing will be superseded by a revised and fully Basin Plan-compliant instrument in 2019.

31 DEWNR (2016). It is assumed that this framework will be incorporated as part of the 2019 WAP for the River Murray Prescribed Watercourse.

Controls – Infrastructure and operations

Control – Infrastructure and operations	Risk rating	Risk IDs per sub-area		
		Lakes Alexandrina & Albert	Lower Murray	Upper Murray
Alternative sources for critical human water needs – SA Water infrastructure	Medium		337	
	Low		341, 345, 349, 353, 357, 361	
Annual environmental water planning (the Commonwealth Environmental Water Holder, The Living Murray, Southern Connected Basin Environmental Watering Committee)	Medium	312, 320	340, 348	368, 376
	Low			
Relocation of threatened populations or in-situ watering (e.g. Hall et al. 2009)	Medium	312	340	368
	Low			
Environmental water to flush algal blooms	Medium			
	Low	334, 336		
Lock 1 (maintenance of water levels during drought)	Medium			
	Low			366, 369, 370, 373, 389
Lock 1 – flows to manage dilution and control the LMRIA risks	Medium		337, 340, 346	
	Low			
Lower Lakes integrated Pipeline Project	Medium			
	Low	310, 322		
Monitoring and river operations (control risks related to algal blooms)	Medium			
	Low			389

Control – Infrastructure and operations	Risk rating	Risk IDs per sub-area		
		Lakes Alexandrina & Albert	Lower Murray	Upper Murray
Physical constraints management actions enabling delivery of environmental water requirements	Medium	318, 320	348	376
	Low		345	
Risk management for operation of infrastructure (including barrages)	Medium			
	Low	323, 324	345, 349, 350, 351, 352	377, 378, 379, 380
SA Water treatment guidelines	Medium			
	Low		338, 353	
Salt interception schemes	Medium	312, 318, 320	337, 340, 346, 348	368, 374, 376
	Low		345	373
System for operation of barrages	Medium			
	Low	323, 324	345	

Proposed controls

Control – Proposed controls	Risk rating	Risk IDs per sub-area		
		Lakes Alexandrina & Albert	Lower Murray	Upper Murray
Control of European carp by release of herpes virus	Medium			
	Low	334	361, 362, 364	390, 392
Operation of infrastructure for variable lake levels (Lower Lakes)	Medium	312		
	Low	322, 323, 324		
Risk management for planned infrastructure and operations (e.g. weir pool raising and lowering, floodplain infrastructure)	Medium			368
	Low			377, 378, 379, 380

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