Government of South Australia
South Australian Murray-Darling Basin
Natural Resources Management Board

South Australian Murray-Darling Basin
Natural Resources Management Board

The Water Allocation Plan for the Marne Saunders Prescribed Water Resources Area

For more information about this publication please contact:
Natural Resources SA Murray–Darling Basin
P.O. Box 2343
Murray Bridge SA 5253
Phone: (08) 8532 9100

Document Status

This publication has been prepared by the SA MDB NRM Board and when adopted forms state government policy.

Document history

Date	Version
18 January 2010	First Water Allocation Plan for the Marne Saunders Prescribed Water Resources Area adopted by the Minister for the River Murray
28 June 2018	Minor amendments made by SA MDB NRM Board under section 89 (1)(a) of the *Natural Resources Management Act 2004*
13 February 2019	Amendments to include information on Aboriginal water interests made by the Minister for Environment and Water under section 89 (2) of the *Natural Resources Management Act 2004*

Water Allocation Plan for the Marne Saunders Prescribed Water Resources Area

Prepared by the South Australian Murray–Darling Basin Natural Resources Management Board

Adopted 18 January 2010

As amended 28 June 2018 and 13 February 2019

I, Karlene Maywald, Minister for the River Murray, hereby adopt this Water Allocation Plan pursuant to section 80 (3) (a) of the Natural Resources Management Act 2004

Hon. Karlene Maywald MP Date: 18/1/10

Minister for the River Murray

I, David Speirs MP, Minister for Environment and Water, after taking into account and in accordance with the requirements of section 89(2) of the *Natural Resources Management Act 2004* hereby adopt these amendments to the Water Allocation Plan for the Marne Saunders Prescribed Water Resources Area.

DAVID SPEIRS
MINISTER FOR ENVIRONMENT AND WATER
Date: 13/02/2019

Acknowledgement

The South Australian Government acknowledges and respects Aboriginal people as the State's first peoples and nations and recognises Aboriginal people as traditional owners and occupants of land and waters in South Australia. Aboriginal peoples' spiritual, social, cultural and economic practices come from their lands and waters and they continue to maintain their cultural heritage, economies, languages and laws, which are of ongoing importance.

It is acknowledged that the lands and waters of the Marne Saunders Prescribed Water Resources Area forms part of the traditional country of the Ngadjuri and Peramangk Aboriginal nations and the South Australian Murray–Darling Basin Natural Resources Management (SA MDB NRM) Board recognises the continuing connection to lands, waters and communities. The SA MDB NRM Board pays its respects to Aboriginal culture and to Elders both past and present.

The recognition of the aspirations that the Aboriginal nations have to legal rights to Aboriginal water interests in this Plan was a starting point in 2019 for ongoing commitment to engage with Aboriginal nations in water planning.

Aboriginal people should be aware that this document contains names of people who have since passed away.

The term "Aboriginal" is used throughout this Plan instead of "Indigenous" as endorsed by the former South Australian Aboriginal State-wide Advisory Committee.

"Aboriginal nations" is also used throughout the Plan and is defined for the purposes of the Plan as a group or community of Aboriginal people who identify as descendants of the original inhabitants of the Plan area and may share a single common territory, or may be located as a nation within another larger nation. Where a native title determination has been made, the native title holders will have native title interests within the nation and is the body that the SA MDB NRM Board will deal with for native title. It may also be the legal entity that represents the Nation for other purposes or be included as a member of a wider group representing a nation (e.g. a Regional Authority).

Currently the two nations that assert or aspire to have Aboriginal water interests in the Marne Saunders prescribed water resources area are Ngadjuri and Peramangk.

Whilst the area that is currently recognised as the traditional country of Peramangk is not currently the subject of a native title claim, should a claim be made, the SA MDB NRM Board will have regard to the native title claimants.

These nations have distinct culture and identities and do not necessarily identify with the words 'Aboriginal' or 'cultural' as these are English terms that do not capture the complexity of their culture and identity. Therefore, where possible, we identify nations and their objectives as either Ngadjuri or Peramangk.

Table of contents

List of Figures

List of Tables

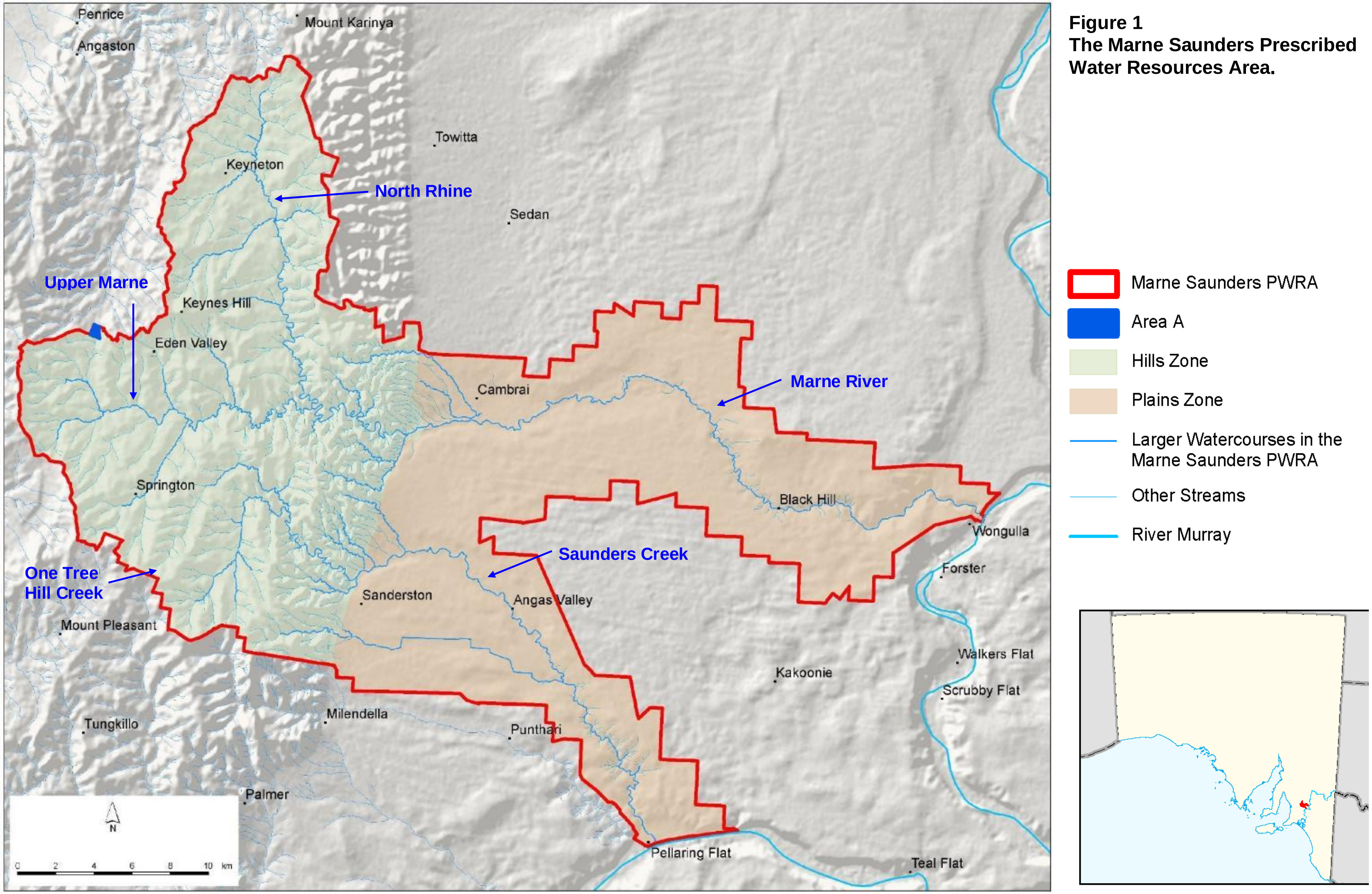


Figure 1
The Marne Saunders Prescribed Water Resources Area.

1 Introduction

This document is the Water Allocation Plan for the Marne Saunders Prescribed Water Resources Area (PWRA) (the Plan), pursuant to Chapter 4, Part 2, Divisions 2 - 3 of the *Natural Resources Management Act 2004* (the NRM Act). It has been prepared by the South Australian Murray–Darling Basin Natural Resources Management Board (the SA MDB NRM Board) working in partnership with agencies, stakeholder groups and the community.

A water allocation plan guides the granting of licences and allocations to take and use prescribed water resources for licensed purposes, transfer of licences and water allocations and ongoing management of water allocations in prescribed water resource areas. In addition, it guides the granting of permits for relevant water affecting activities.

The Marne Saunders PWRA is part of the South Australian Murray–Darling Basin. It lies in the Eastern Mount Lofty Ranges approximately 70 km north east of Adelaide and includes the townships of Springton, Eden Valley, Keyneton and Cambrai (Figure 1). The Marne Saunders PWRA encompasses the catchments of the Marne River (including the North Rhine) and the Saunders Creek as well as the underground water within the PWRA boundary. These water resources are used for a range of purposes including domestic, stock, irrigation, industrial and recreational uses, and also support important water-dependent ecosystems.

The Marne Saunders PWRA covers part of the traditional lands and waters of the Peramangk and Ngadjuri people. It is the obligation of Aboriginal nations in this area of the Adelaide Hills, Plains, Fleurieu Peninsula and River Murray to maintain kinship through the interconnectivity between these lands, waters, spirit and all living things.

The Ngadjuri nation registered the Ngadjuri Nation #2 native title claim in 2011 (SAD304/2011). The Native Title Claim Boundary does not overlap the Marne Saunders PWRA boundary but is adjacent and the Ngadjuri nation assert a cultural interest in the area. Neither the Peramangk people or any other Aboriginal people have made a native title claim nor entered into an Indigenous Land Use Agreement over the Plan area. It is possible that a future native title claim or claims may be made over the Plan area and should this occur, the interests of claimants will be considered and taken into account.

Figure 1A shows native title boundaries in the area, but is not intended to define the boundaries of an individual nation's traditional country.

1.1 Objectives of the Marne Saunders Water Allocation Plan

The objects of the NRM Act include assistance in the achievement of ecologically sustainable development, which "comprises the use, conservation, development and enhancement of natural resources in a way, and at a rate, that will enable people and communities to provide for their economic, social and physical well-being while—

(a) sustaining the potential of natural resources to meet the reasonably foreseeable needs of future generations; and
(b) safeguarding the life-supporting capacities of natural resources; and
(c) avoiding, remedying or mitigating any adverse effects of activities on natural resources." (Section 7 (2) of the NRM Act).

Natural resources as defined in the NRM Act include soil, water resources, geological features and landscapes, native vegetation, native animals and other native organisms, and ecosystems.

A series of objectives have been developed for the Plan that reflect the objects of the NRM Act, the State Natural Resources Management Plan's (State NRM Plan) guidelines for water allocation and management, and the role of the water allocation plan. These objectives are:

Allocation and transfer of licences and allocations

Objective A	Allocate water sustainably
Objective B	Provide for efficient use of water resources
Objective C	Protect quantity and quality of water for all uses
Objective D	Maintain and where possible rehabilitate water-dependent ecosystems by providing their water needs
Objective E	Minimise adverse impacts of taking and using water on the environment, water resources and water users

Water affecting activities

Objective A	Protect water-dependent ecosystems
Objective B	Protect waterbody and floodplain geomorphology and aquifer structure
Objective C	Provide for equitable and sustainable water sharing
Objective D	Protect water quality for all uses
Objective E	Maintain hydrological and hydrogeological systems, including natural discharge and recharge between water resources
Objective F	Minimise interference between users
Objective G	Minimise adverse impacts of water affecting activities on the environment, water resources and water users

The environment is referred to here in the broad sense defined in the State Natural Resources Management Plan as the interaction of climate, geology, water, soil, topography and biota that provides landscapes that are comprised of bioregions, ecosystems, catchments and land systems that may be natural and/or managed by people.

Aboriginal cultural objectives

In addition to the Plan's objectives set out above, Aboriginal nations have developed cultural objectives through the Water Resource Planning process (see section 1.5.3) and by participating in the Plan's engagement process conducted for the purpose of amending the Plan in 2019. The cultural objectives developed by nations through this process are set out below.

Where and how the Plan is able to address some of these objectives is further discussed in section 1.5.4.

Aboriginal Cultural Objectives:

a) To pursue opportunities for legally recognised water entitlements for nations.

b) For the hydrological and ecological conditions of the landscape to resemble, as closely as possible, those experiences by nations' ancestors.

c) For water resources to be managed in a way that supports the ongoing spiritual, cultural, environmental, social and economic needs of current and future generations.

d) For adequate monitoring and evaluation to be undertaken to ensure compliance with water management rules and to assess whether objectives are being achieved.

e) To seek support to build capacity for nations' voices in water planning and management, building on and further developing nations' water co-ordinator roles.

f) To create opportunities for nations' businesses to engage in the delivery of on-ground water planning, monitoring and evaluation, particularly cultural health assessments of waterways.

g) For water allocation plans and other water planning and management tools and instruments to promote awareness and respect for nations' cultural values, perspectives and worldview of water and its critical importance to the health of nations' cultural water and cultural living landscape.

h) For continued conversation through meaningful engagement between nations and government to be invested in as an on-going priority and not be undertaken as disjointed and sporadic engagement driven by government planning and management timeframes.

1.2 Structure of the Plan

This Plan is made up of three main parts covering the following themes:

- understanding water resource **supply and demand**;
- a **policy framework** that aims to balance social, economic and environmental demands for water within the supply or capacity of the water resources; and
- a **monitoring and evaluation** framework to facilitate adaptive management.

Aboriginal water interests are discussed in section 1.5. This section identifies both aspirational and current uses of water as Aboriginal water interests, describes Aboriginal cultural objectives and sets out the engagement principles for Peramangk and Ngadjuri nations. Should a native title claim or Indigenous land use agreement (ILUA) be made over the area of the Plan, the native title claimants will be engaged according to these principles and as required under the *Native Title Act 1993* (Cth) or the terms of the ILUA. Aboriginal water interests are referred to throughout, where relevant.

1.2.1 Supply and demand

The available water supply is examined in section 2. This section describes key drivers of water resource behaviour (landscape, geology and climate) and the characteristics of the different water resources, including the paths and quantities of natural water input and output across the landscape.

The Plan focuses on two main types of water demand, being environmental water requirements and consumptive use. Section 3 describes the environmental water requirements of the different water-dependent ecosystems across the Marne Saunders PWRA. Section 4.1 examines the current and likely future demand for water for consumptive purposes, including licensed and non-licensed purposes.

The interactions between supply and demand are discussed in sections 4.2 and 4.3. The capacity of the water resources to meet the current demands is assessed in section 4.2, by examining the impact of the current level of water resource development on the resources and water-dependent ecosystems.

Section 4.3 provides the basis for a management framework to be implemented through the Plan that provides a new balance between social, economic and environmental needs for water. The underpinning philosophy is to keep demand within supply (on average), and to develop a set of rules for allocating water for licensed use that accounts for and protects non-licensed needs and provides an acceptable pattern or regime of water to maintain water-dependent ecosystems. An assessment of the capacity of the water resources to supply demands under the new management framework is made in section 4.3, while section 5 assesses impacts on other water resources.

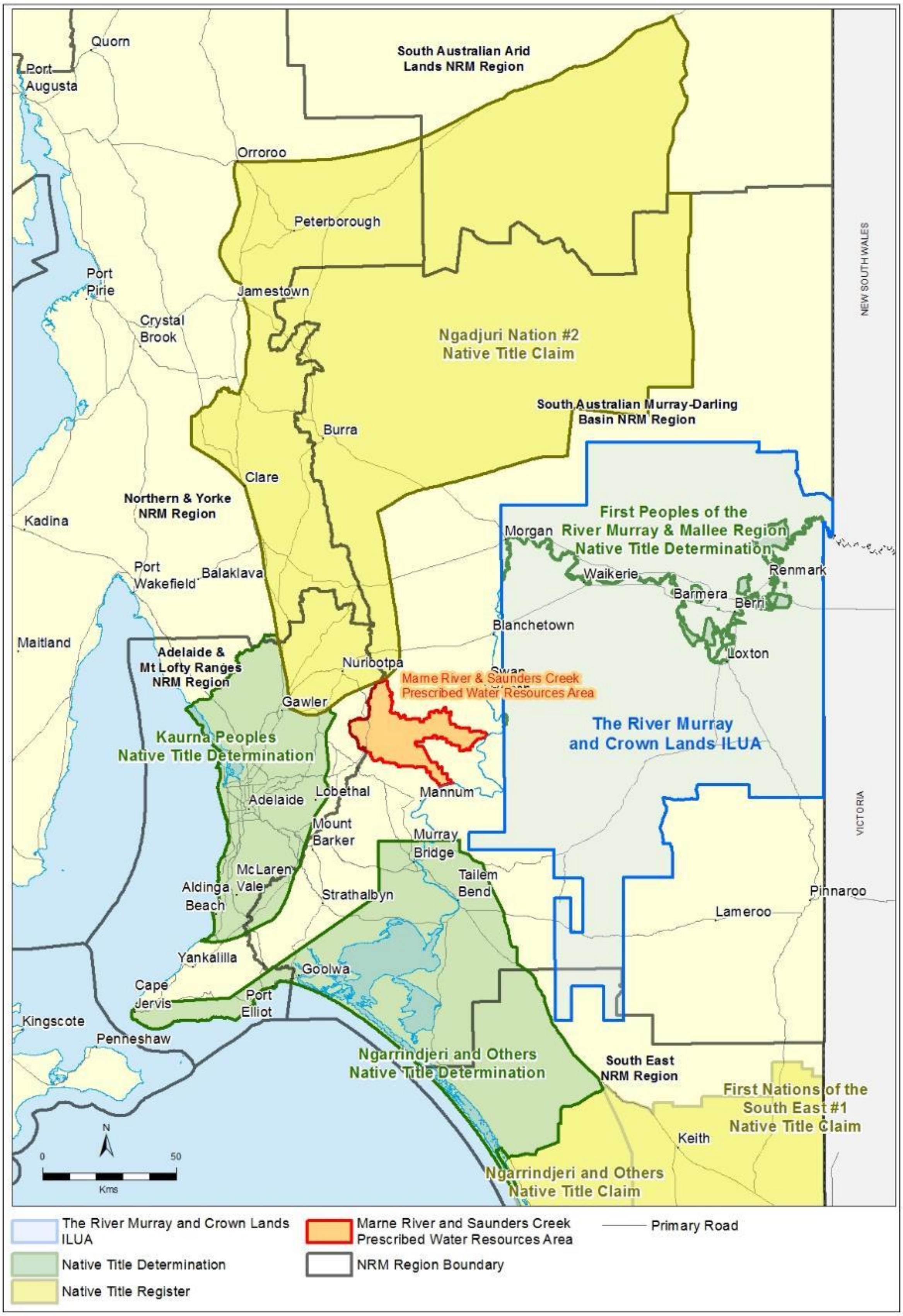


Figure 1A Native title and ILUA areas associated with the surface waters and groundwaters of the SA Murray Darling Basin.

1.2.2 Policy framework

The NRM Act provides two main mechanisms for management of water resources in a water allocation plan, which are:

- allocation and licensing of the taking and use of prescribed water resources for licensed purposes; and
- permitting of water affecting activities (WAAs) such as dam and well construction, construction and excavation in and around watercourses and use of imported water and effluent.

Sections 6 to 8 define the specific principles for achieving the objectives set out in section 1.1. These principles implement the framework of allocation limits and water taking rules identified in section 4.3, as well as other management tools.

1.2.3 Monitoring and evaluation

Section 9 outlines a monitoring and evaluation framework that monitors and assesses the condition of the resources, water-dependent ecosystems and consumptive demand to trigger action if objectives are not met. This information will also improve understanding of supply and demand, which will inform policy development when the Plan is reviewed.

1.3 Allocation of water to existing users

A water allocation plan does not set out the process for allocating water to those who are considered to be existing users prior to the start of the prescription process. Existing users are allocated water under a separate process administered by the Department responsible for administering the NRM Act ('the Department')[1] in accordance with section 164N of the NRM Act.

The entitlements of existing users are considered before other potential licensed use, subject to the sustainable capacity of the water resources and the needs of the environment and non-licensed users. If any water remains available for allocation after the entitlements of existing users have been considered, then that water may be allocated in accordance with the water allocation plan. This Plan does not further discuss the existing user allocation process, except where specific water management principles in the Plan relate to existing user allocations.

1.4 Legislative history of water regulation in the Marne Saunders

Concern over the ability of the Marne and Saunders water resources to continue to meet human and environmental needs led to closer regulation of the water resources from 1999 as follows:

- A Notice of Prohibition (NoP) has been in place on the water resources of the Marne catchment from May 1999 and for the Saunders from February 2002. The NoP provides short-term regulation of use while investigations are undertaken to better assess the capacity of, and risks to, the water resources.
- A Notice of Intent to prescribe the Marne River and Saunders Creek Area was gazetted in January 2002 under the *Water Resources Act 1997*[2] (the WR Act) (*South Australian Government Gazette* 24/1/02 page 382).

[1] The Department that administers the NRM Act ('the Department'). This is the Department for Environment and Water (DEW) as of 22 March 2018. Its former components include the former Department of Water, Land and Biodiversity Conservation (DWLBC) to 30/06/10, the former Department for Water (DFW) from 1/7/10 to 30/6/12 and the former Department of Environment, Water and Natural Resources (DEWNR) from 1/7/12 to 22/3/18. When referring to reports and historical material, this document refers to the department that was in place at that time.

[2] The WR Act was replaced by the NRM Act after the prescription of the water resources of the Marne and Saunders catchments. The transitional provisions of the NRM Act effectively allow the prescription process to continue under the NRM Act.

- The surface water, watercourse water and wells within the Marne River and Saunders Creek PWRA were prescribed on 20 March 2003 (*South Australian Government Gazette* 20/3/03, pages 1111 - 1112 and the boundary described by General Registry Office (GRO) Plan No. 429/2002) under the WR Act.

  Prescription provides for the long term sustainable management of water resources through licensing of the taking and use of prescribed water resources for licensed purposes. A licence is not required for taking water for a range of purposes in the Marne Saunders PWRA, including:
  - domestic use;
  - provision of drinking water for stock that are not subject to intensive farming; and
  - purposes authorised by a notice under section 128 of the NRM Act that apply in the area (e.g. at the date of publication includes fire fighting; public road making; applying chemicals to non-irrigated crops or to control pests; use of up to 1,500 kilolitres per year of roof runoff for commercial (including irrigation), industrial, environmental or recreational purposes; and non-commercial native title rights to take water).
- The surface water, watercourse water and wells within Area A were prescribed on 7 April 2005 (*South Australian Government Gazette* 7/4/05, pages 834 - 836 and the boundary described by GRO Plan No 115/2004) under the WR Act to create the Marne Saunders PWRA as the combination of the former Marne River and Saunders Creek PWRA and Area A (see Figure 1).
- The Catchment Water Management Plan for the River Murray in South Australia was adopted on 12 March 2003, pursuant to section 95 of the WR Act. Chapter 13 of the Catchment Plan contained policies for the control of water affecting activities in parts of the South Australian Murray–Darling Basin, including the Marne Saunders PWRA.
- The Natural Resources Management Plan for the South Australian Murray–Darling Basin Natural Resources Management Region was adopted on 28 April 2009, pursuant to section 80 (3) (a) of the NRM Act. This regional NRM plan replaced the Catchment Water Management Plan for the River Murray in South Australia. Section 2 of volume 3 of the regional NRM Plan includes policies for the control of water affecting activities in parts of the South Australian Murray–Darling Basin, including the Marne Saunders PWRA. According to section 2.1.2, volume 3 of the regional NRM plan:

  "A water allocation plan may set out additional policies that the Board will take into account when considering an application for a permit. The policies in a water allocation plan may be different to the policies in the regional NRM plan. To the extent that a water allocation plan includes different policies, the policies in the regional NRM plan will not apply to that prescribed water resource."
- Amendments to the Plan were made in 2018 and 2019 pursuant to section 89 of the NRM Act, to identify and include the objectives and desired outcomes of Peramangk and Ngadjuri with respect to management of Aboriginal water interests and incorporate their worldviews in the Plan to improve consistency with the Murray–Darling Basin Plan (2019); as well as minor updates to improve consistency with the SA MDB regional NRM plan (2018).

1.5 Aboriginal water interests

For thousands of generations Peramangk, Ngadjuri, Kaurna and Ngarrindjeri nations have cared for the waters and lands of the area of the Adelaide Hills, Plains, Fleurieu Peninsula and lower River Murray. This Country was formed by creation ancestors and it is the ongoing responsibility of current and future generations to care for and protect the waters and lands of their Country today and into the future.

Aboriginal nations' worldview is that water as a living body that is part of the landscape and connected to all living things. Cultural knowledge is founded on an extensive understanding of the relationship between water flow through and across the land, the ecosystems and species which are reliant on this water and the role and responsibility of Aboriginal people in caring for and protecting Country.

For Aboriginal nations, all water is cultural water – this includes water for spiritual, cultural, environmental, social and economic purposes. This is underpinned by the belief that water is life – it provides life to everyone and everything that ever lived and everyone and everything that ever will live. In this way, water is the lifeblood of the landscape and is connected to all the other elements of the landscape, supporting a wide range of spiritual, cultural, environmental, social and economic activities. Water and all of the connected elements must be managed as parts of the same living body of the landscape, to allow it to remain healthy and continue to function and support people to live, as it has for many thousands of generations.

Aboriginal people have expressed a desire for a future that maintains the continuation of their culture upon Country and that continues to give life to their people who live and work in and outside of the region. An important part of this objective that was articulated by all nations consulted with, was that access and use of cultural flows should be enabled through the inclusion and allocation of water for this purpose.

Cultural flows are defined as:
Water entitlements that are legally and beneficially owned by the Indigenous nations and are of sufficient and adequate quantity to improve the spiritual, cultural, environmental, social and economic conditions of those Indigenous nations. This is our inherent right. The provision of cultural flows will benefit Indigenous people in improving health, wellbeing and provides empowerment to be able to care for their country and undertake cultural activities.

This definition of cultural flows was endorsed by representatives from thirty-one Indigenous nations at a joint meeting of the Murray Lower Darling River Indigenous Nations and the Northern Basin Aboriginal Nations - The Echuca Declaration, September 2010.

1.5.1 National Water Initiative and the Basin Plan

The Intergovernmental Agreement on a National Water Initiative[3] includes a commitment to include Aboriginal representation to incorporate Aboriginal social, spiritual and customary objectives and strategies in water planning and to take account of the possible existence of native title rights to water.

The Basin Plan, which provides an overarching plan for water management in the Murray–Darling Basin, requires accredited water resource plans to identify the objectives and outcomes of Aboriginal people related to the management of water resources, and to have regard to Aboriginal values and uses of water as well as cultural flows (MDBA, 2012). Water

[3] An agreement that is a blueprint for water reform between the Commonwealth of Australia and the Governments of New South Wales, Victoria, Queensland, South Australia, the Australian Capital Territory and the Northern Territory

resource plans must also have regard to a range of other matters set out in Section 10.53 of the Basin Plan.

South Australia recognises the importance of, and is committed to seeking and incorporating, Aboriginal interests in the development of water allocation plans. In 2019, amendments under section 89(2) of the NRM Act were made to improve the inclusion of Peramangk and Ngadjuri interests and worldviews in this Plan as a step towards Basin Plan compliance and improved recognition of Aboriginal perspectives. The amendments incorporated into this Plan in consultation with the Peramangk and Ngadjuri nations are a starting point to an ongoing conversation and involvement of Aboriginal nations in water planning.

1.5.2 Recognition of Aboriginal water interests

European colonisation of South Australia significantly disrupted Aboriginal nations' care, control, maintenance and governance of their Country. Water flow and connectivity has been disrupted with obstructions such as dams and weirs being built and water quality and quantity has changed due to extraction. Aboriginal peoples' way of life significantly changed as they were forcibly removed from their Country and their lands and waters were granted to European settlers. This has impacted the ability of Aboriginal people to pass down knowledge of cultural connection, values and practices to the next generation. Nations have had to rebuild their identity though language, Native Title and Aboriginal organisations – today the management of water unites all people, communities and users for a more sustainable future.

1.5.3 Aboriginal cultural objectives

The EMLR water resource plan (DEW, in prep) identifies a number of Aboriginal cultural objectives and outcomes identified by Nations that should be referred to when undertaking water planning. Through further consultation for the amendment of this Plan, Aboriginal nations additionally outlined eight key objectives which represent their collective position on the management of water resources (section 1.1 and Table 1). Incorporating Aboriginal nations' objectives and outcomes into water planning based on cultural values and uses is an iterative process that requires investment over time. The progress that the Marne Saunders water allocation plan has made towards meeting Aboriginal objectives and outcomes that are within scope of the Plan are described in Table 1.

1.5.4 Incorporation of Aboriginal interests in water planning

The process of integrating Aboriginal interests into water management is a complex and ongoing matter. The amendments to this Plan are a preliminary step towards recognising Aboriginal understanding of the relationship between healthy water, lands and all living things. The Plan makes some progress to addressing Aboriginal objectives and outcomes (see Table 1 and sections 1.5.4.1-1.5.4.3). However some objectives (or components of) are outside of the scope of the water allocation plan as set out in section 76 of the NRM Act, which is a statutory instrument that sets out the rules for managing the take and use of prescribed water resources to ensure resource sustainability.

Peramangk and Ngadjuri peoples' knowledge of the relationship between flow, water-dependent ecosystems and sustainable livelihoods is a valuable addition to scientific knowledge and addressing gaps in the understanding of water resources. In relation to water allocation planning this knowledge has only been partially taken into account. Through meaningful engagement and with Aboriginal nations starting to build capacity in water planning, future iterations of this Plan can make further progress to achieving the Aboriginal cultural objectives and outcomes set out in section 1.1, Table 1 and the Eastern Mount Lofty Ranges water resource plan. There is a need for ongoing discussion on how the notion of water use and cultural perspectives can co-exist within the water management regulatory framework to achieve water management outcomes that have integrity and demonstrate respect for Aboriginal and non-Aboriginal communities.

The approach of Aboriginal nations to caring for the Country that all South Australians live in, can be understood through the words of Ngarrindjeri Elder, Tom Trevorrow (deceased):

> *Our traditional management plan was: don't be greedy, don't take any more than you need and respect everything around you. That's the management plan – it's such a simple management plan, but so hard for people to carry out* (Murrundi Ruwe Pangari Ringbalin River Country Spirit Ceremony: Aboriginal Perspectives on River Country, 2010).

1.5.4.1 Protection of Aboriginal cultural heritage

Peramangk and Ngadjuri have identified a desired outcome in the Eastern Mount Lofty Ranges water resource plan that Aboriginal cultural heritage values and sacred water sites are protected and enhanced in the planning and implementation of water resource management activities. The SA MDB NRM Board is addressing this desired outcome in section 8 through:

- Raising awareness of landholder legal obligations in the *Aboriginal Heritage Act 1988*.
- Ensuring compliance with the *Native Title Act 1993* (Cth), determinations of native title and any future Indigenous land use agreements that may be registered.

1.5.4.2 Monitoring and evaluation

The nations have expressed overwhelmingly the need for adequate monitoring and evaluation of the Plan to assess whether its objectives for sustainable water resource management are being achieved. How the Plan will try to achieve this is more specifically discussed in section 9 which sets out monitoring (and reporting) requirements for licensees and some permit holders that are designed to collect information about water demand and use. The Plan also outlines regional-scale monitoring, largely led by agencies such as the SA MDB NRM Board and the Department, while working with other bodies and the community.

Peramangk and Ngadjuri see the monitoring of their lands and waters as an ongoing process, embedded as part of their responsibility to speak for, care for and protect their Country. Through the monitoring, evaluation and reporting process, the Department and the SA MDB NRM Board will aim to:

- Provide opportunities for the involvement of Aboriginal nations in the management, planning and monitoring of water resources.
- Provide opportunities for the capacity and experience building of Aboriginal nations in water resource management.

1.5.4.3 Plan review

The SA MDB NRM Board will review the Plan within ten years of the Minister adopting the Plan, as the recommended timeframe for review of plans. As part of its review, the SA MDB NRM Board will directly consult with the Peramangk and Ngadjuri nations in relation to Aboriginal objectives and desired outcomes and should native title be claimed or an ILUA made over all or any of the Plan area then any native title claimants or holders or Aboriginal parties to an ILUA will be consulted and engaged in accordance with the *Native Title Act 1993* (Cth), the provisions of any ILUA and the principles for engagement in this Plan.

Engagement to date with Ngadjuri has been via the Ngadjuri Nation Aboriginal Corporation (NNAC) Board.

Engagement to date has been with Peramangk via the Mannum Aboriginal Community Association Incorporated (MACAI), a member of Ngarrindjeri Regional Authority. Whilst the Peramangk area is not subject to a native title claim, should one be made in the future then both MACAI and the claimants or holders of native title will be entitled to be consulted and dealt with in the Peramangk area about their respective responsibilities within the Peramangk nation.

Aboriginal engagement

For future review of the Plan there are some guiding documents that should be considered.

South Australia's three water resource plans, including the Eastern Mount Lofty Ranges water resource plan (DEW, in prep), provides six engagement principles to be considered when engaging Aboriginal nations during the review of water allocation plans in the South Australian Murray–Darling Basin. The Peramangk and Ngadjuri nations were engaged according to these principles when developing the material relating to Aboriginal water interests included in the 2019 amendment of this Plan.

Following-on from the engagement principles outlined above, engagement with nations is conducted through various mechanisms based on the needs, interests and capacity of each nation. A key objective of undertaking good engagement is to build on and develop previous engagement principles. Specific engagement mechanisms for the individual nations may vary and it is recognised that some Aboriginal nations also desire to work and be engaged collectively. Collective engagement was undertaken during the amendment of this Plan and the desire by the nations was voiced to continue both collective and individual nation engagement for future water planning and management.

In the event that a native claim or claims are made or that an Indigenous land use agreement is entered over all or part of the Plan, the native title claimants or Aboriginal parties to the ILUA will be consulted in accordance with the *Native Title Act 1993* (Cth), any provisions of an ILUA and the engagement principles set out in this Plan.

Table 1 The progress that this Plan has made towards meeting Aboriginal objectives and outcomes that are within scope of the Plan. Cultural objectives and outcomes identified in the Eastern Mount Lofty Ranges water resource plan (DEW, in prep) that are outside of the scope of this Plan are not referred to within this table.

Source of objectives and outcomes identified as:
[1] Aboriginal cultural objectives listed in section 1.1
[2] Eastern Mount Lofty Ranges water resource plan - Chapter 14 identified objectives
[3] Eastern Mount Lofty Ranges water resource plan - Chapter 14 identified outcomes

Aboriginal cultural objective/outcome	Progress of the Plan towards addressing Aboriginal cultural objective/outcome
To promote awareness and respect for Aboriginal cultural values, perspectives and worldview of water and its critical importance to the health of nations cultural waters and cultural living landscape.[1] The contribution of Aboriginal Nations to caring for Country, including water resources management is valued.[3]	Through the amendment of the Plan, relationships and meaningful engagement with Aboriginal nations have been progressed to establish stronger partnerships between the SA MDB NRM Board and Peramangk and Ngadjuri nations. Awareness of Aboriginal values, perspectives and worldviews have been included in the updated content during the amendment of this Plan along with consideration of how Aboriginal water needs and future water needs can be met being discussed in section 4.1.1 and 4.1.3.3. Amendment of the Plan contributes to fulfilling South Australia’s obligations under Basin-wide plans and legislation.
For the hydrological and ecological condition of the landscape, resemble as closely as possible, those experienced by nations ancestors.[1] To see our lands and waters healthy.[2]	The Plan’s objectives include maintaining water quantity and quality and maintaining (and where possible restoring) water-dependent ecosystems. Section 4.3 outlines the Plan’s management framework for implementing the Plan’s objectives, with key elements including: • Setting surface water consumptive use limits and taking rules to support key parts of the flow pattern that are important to ecosystems (e.g. use limits and requirement to return low flows) (see section 4.3.2). • Setting underground water consumptive use limits to maintain natural flow through aquifers and support dependent ecosystems, by setting aside water to maintain baseflow (underground water input to streams) and throughflow (flow between aquifers) and keeping total outflows (baseflow, throughflow and consumptive use) within resource capacity (see section 4.3.3). • Underground water buffer zones around dependent ecosystems to minimise impacts from trade, new allocations and new wells (see section 4.3.3.1) • Water affecting activity principles to minimise impacts of construction on water-dependent ecosystems and water quality (e.g. protect significant habitat, minimise water quality impacts, allow migration of aquatic organisms) (see section 8)

Table 1 continued

Aboriginal cultural objective/outcome	**Progress of the Plan towards addressing Aboriginal cultural objective/outcome**
Water resources to be managed in a way that supports the ongoing spiritual, cultural, environmental, social and economic needs of current and future generations of Aboriginal nations.[1] To achieve the social and economic outcomes and wellbeing desired by the Nation.[2] To ensure Aboriginal water interests are equitably recognised along with other stakeholders in water resources plans, research and policy.[2] The Aboriginal cultural heritage values and sacred water sites are protected and enhanced in the planning and implementation of water resource management activities.[3]	• An existing section 128 authorisation under the NRM Act regulates the native title right to take and use water by native title holders for personal, domestic, cultural, spiritual or non-commercial communal purposes (see section 4.1.1). • Creating awareness and compliance for the protection of Aboriginal cultural heritage is set out within the Plan (see sections 1.5.4.1 and 8). • The Plan identifies current and future Aboriginal water needs (see sections 4.1.1 and 4.1.3.3).
For adequate monitoring and evaluation to be undertaken to ensure compliance with water management rules and to assess whether objectives are being achieved.[1]	Monitoring and evaluation of the Plan to ensure compliance with water use is discussed in section 9. Undertaking monitoring and evaluation of cultural objectives is discussed in section 1.5.4.2.
To maintain our cultural connections between nations and to the lands and waters and all living things.[2] To establish and maintain strong and productive relationships and partnerships built on mutual respect and agreement-making.[2]	Through consultation for the amendment of this Plan, and review of future Plans, the SA MDB NRM Board will consult with relevant Aboriginal nations and their representative organisations (section 1.5.4.3). Through consultation for the amendment of this Plan in 2019, and the development of the Eastern Mount Lofty Ranges water resource plan (DEW, in prep), nations were engaged collectively with on-Country meetings and workshops. This engagement process further developed relationships between nation representatives and government agency staff.

2 Physical characteristics of the Marne Saunders PWRA

The lands and waters of the Marne Saunders PWRA are the traditional country of Peramangk and Ngadjuri nations who continue to maintain their cultural heritage, economies, languages and traditional laws which are of ongoing importance – further description of these Aboriginal nations' connection to these lands and waters is described in section 1.5.

2.1 Landscape and geology

The information in section 2.1 and 2.2 is generally drawn from MREFTP (2003) and references therein.

The Marne Saunders PWRA spans two major landscape regions: the Mount Lofty Ranges and the Murray Basin. These two distinct parts of the catchment are sometimes referred to as the hills zone (or hills) and plains zone (or plains) respectively and this terminology will be used throughout the Plan (see Figure 1). The Marne Saunders PWRA covers an area of 743 km^2. Table 1A shows how this is divided between the catchments and between the hills and plains zones.

Table 1A Approximate area of the Marne Saunders PWRA lying in the Marne and Saunders catchments and hills and plains zones (all km^2).

Area	Marne	Saunders	Total
Hills	269	99	368
Plains	237	138	375
Total	506	237	743

The hills zone consists of undulating to steep hills formed of rocks of the Kanmantoo Group, including sandstone, siltstone, marble and greywacke with inliers of granite. The rocks have been affected by heat and pressure, and are extensively folded and faulted. The Palmer Fault, at the eastern edge of the Mount Lofty Ranges, defines the eastern limit of the hills zone. The hills zone is raised above the plains zone as a result of uplift of the Mount Lofty Ranges and down-throw of the Murray Basin along the fault line. The Marne River and Saunders Creek systems in the hills zone are undergoing a long-term geological process of adjustment to the lower bed level in the plains zone, resulting in the deep gorges cut by the Marne River and the Saunders Creek in the downstream part of the hills zone.

The plains zone is situated within the Murray Basin, a basin containing unconsolidated sedimentary deposits lying over the same basement rocks that are exposed in the hills zone. The uppermost layer of Quaternary aged deposits includes dunefields, with river and floodplain deposits along the valleys of the Marne River, Saunders Creek and River Murray. Below the Quaternary deposits there are older Tertiary aged deposits of limestone, sands and clays including the Murray Group Limestone, and deeper Renmark Group formations. The topography is relatively flat compared to the hills zone, apart from hills associated with localised outcrops of underlying basement rocks, such as Black Hill, and features associated with watercourses cutting down into the Tertiary sediments. The River Murray is cut down into the Tertiary sedimentary rocks, which are exposed in the red cliffs along the river. The Marne River and Saunders Creek are also cutting down into these rocks, but much more slowly. This results in the relatively steep, narrow valleys along the watercourses from around Black Hill in the Marne and from around Lenger Reserve in the Saunders, down to the junctions with the River Murray.

2.2 Climate

Rainfall is highest at the western edge of the Marne Saunders PWRA, where the annual average rainfall is approximately 800 mm. Rainfall declines towards the east in the rain shadow of the Mount Lofty Ranges, down to approximately 280 mm at the eastern edge (Figure 2).

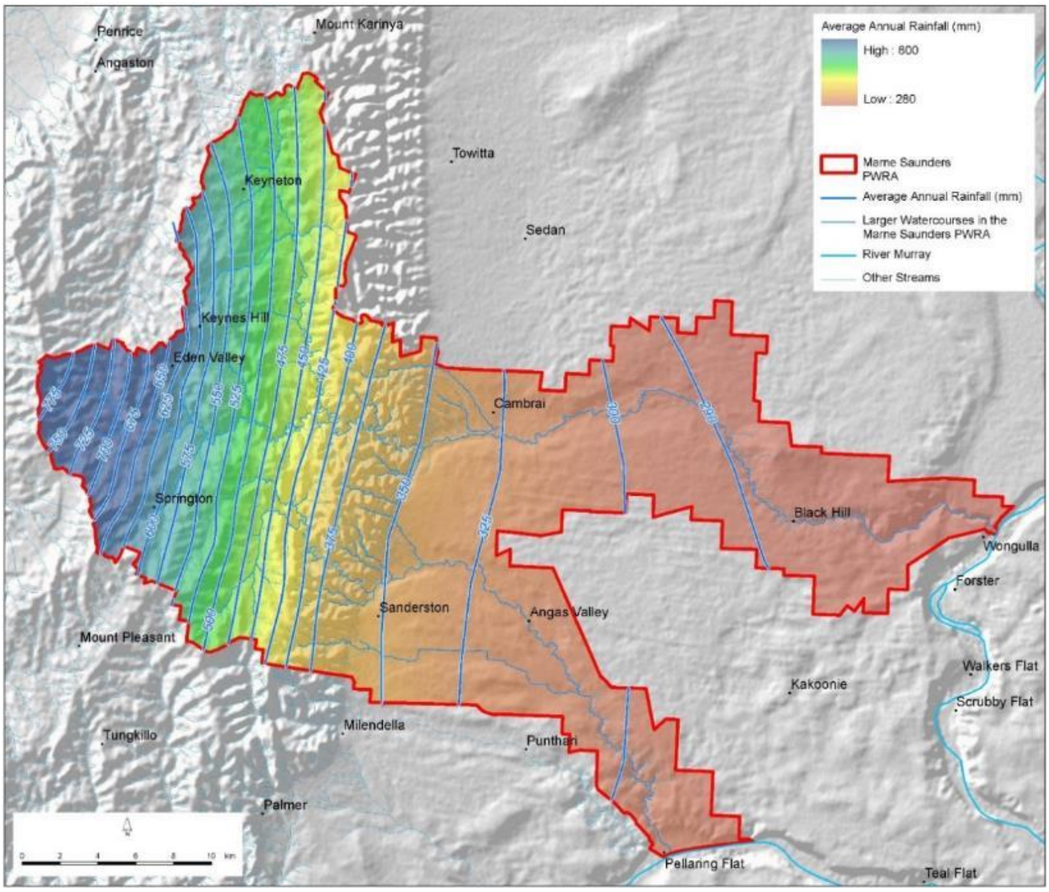


Figure 2 Average annual rainfall bands across the Marne Saunders PWRA.
Data supplied by DWLBC.

Annual rainfall is highly variable, as can be seen from Figure 3 which shows annual rainfall at the Keyneton Bureau of Meteorology rainfall station from 1909 to 2007 as well as the long-term average of 534 mm for this station.

Rainfall generally follows a seasonal pattern, falling largely in winter and spring, although occasional high intensity summer thunderstorms can create flash flooding (Kotz *et al* 2000). Evaporation rates are high, with average monthly evaporation exceeding average rainfall in all months of the year (Kotz *et al*, 2000).

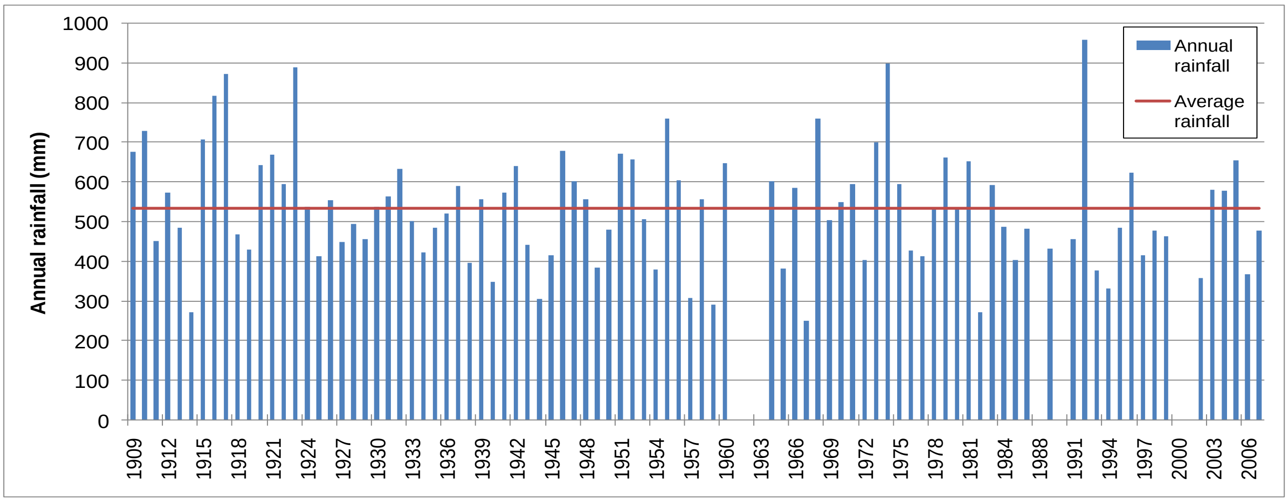


Figure 3 Annual rainfall and long-term average annual rainfall (534 mm) at Keyneton, 1909 - 2007.
Data supplied by Bureau of Meteorology for Station 23725. Data not shown for years with incomplete records.

2.3 Prescribed water resources

Rainfall is the ultimate source of water for the Marne Saunders PWRA, and moves through the landscape through a variety of paths as shown in Figure 4. The majority of rainfall leaves the catchment via evaporation or from transpiration by plants. Part of the rain that falls on the ground runs off the land as surface water and makes its way into watercourses. The Marne River and Saunders Creek begin in the high rainfall hills zone, flowing east down the hills, through gorges and then out onto the plains zone to eventually join the River Murray. Rainfall and streamflow also seep down into the pores and cracks of water-bearing rock and sediment layers known as aquifers to become underground water. Underground water also flows from higher to lower level, with a general movement of underground water from west to east over the Marne Saunders PWRA.

It is important to note that the different water resources in the Marne Saunders PWRA are strongly interlinked (Figure 4). Actions in one resource can influence another, so they need to be managed together. Surface water running over the land enters watercourses and becomes watercourse water. Underground water can also enter the watercourse as “baseflow” via springs and seeps. Flow in the watercourse can seep through the bed and replenish or “recharge” the underground water. This process is especially noticeable in the plains zone, where rainfall is low and streamflow provides the major source of recharge to the parts of the aquifers that lie beneath the watercourse. Water can also move between aquifers.

The movement of water through the landscape can be interrupted by water resource development (including dams, weirs and wells), influencing the volume, water quality and pattern of water availability both locally and at the larger scale.

Further information about characteristics such as supply and movement through each of the prescribed water resources is provided in the rest of this section. The impact of water resource development on the water resources is considered in section 4.2.

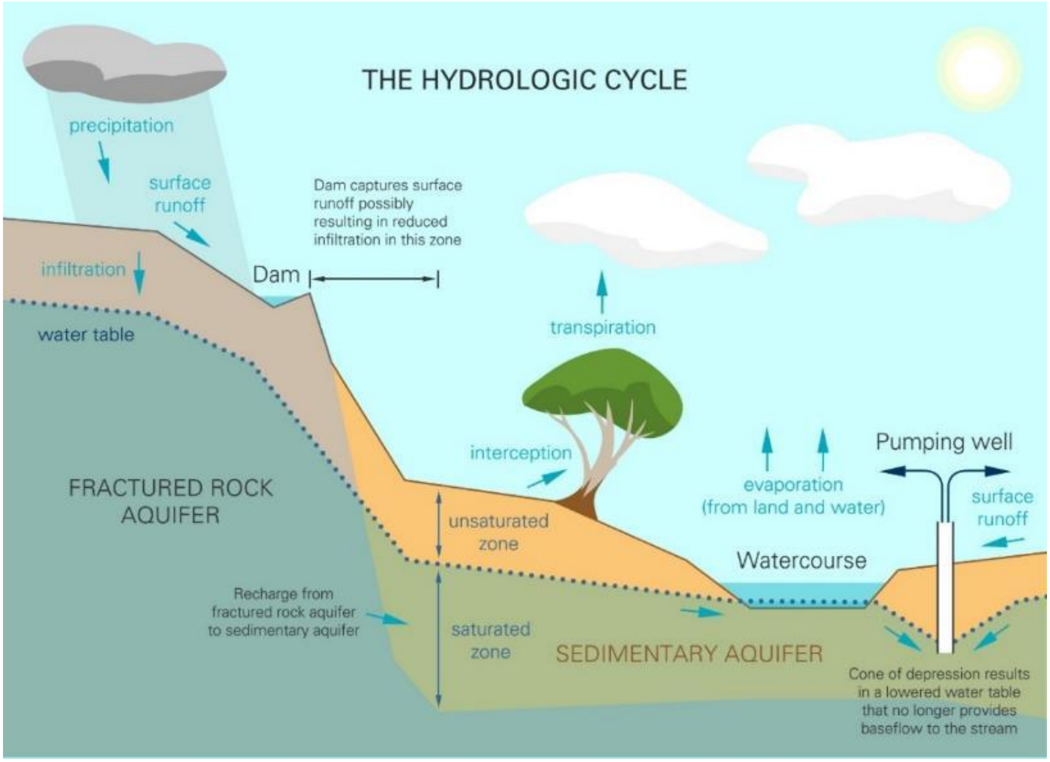


Figure 4 Paths of water movement through the landscape.
Figure courtesy of DWLBC and Ecocreative.

2.3.1 Surface water and watercourse water

The information in this section is largely drawn from Savadamuthu (2002) and Alcorn (2005).

Surface water and watercourse water are considered to be separate water resources in the NRM Act, where surface water is water flowing over land except in a watercourse. However, the two resources are closely linked and it can be difficult to define exactly when surface water becomes watercourse water. Therefore they will be managed together for the purposes of this Plan.

The Marne River and Saunders Creek catchments can be divided on the basis of the hills zone and the plains zone into upper and lower parts of the catchment. The bulk of streamflow is generated in the upper catchments where rainfall is highest. Little runoff occurs in the lower catchments, and most of the streamflow that occurs here has flowed down from the upper catchments. A large proportion of the streamflow in the lower catchments is lost from the watercourse as recharge to the underlying aquifers.

2.3.1.1 Flow and runoff in the upper catchments

The upper catchments can be divided into several major tributaries (see Figure 1). The Upper Marne includes the North Rhine and the Upper Marne (originally known as the South Rhine). The Upper Saunders includes Saunders Creek and One Tree Hill Creek.

The Department operates one flow gauging station in the Marne River catchment, situated about 5 km west of Cambrai near the mouth of the Marne River Gorge, and near the downstream end of the hills (AW4260529 Marne River at Cambrai, replaced in 2001 by A4260605 Marne River at Marne Gorge). Continuous streamflow records are available at this site from 1973 to 1988 and then from 2001.

Flows vary considerably from year to year, reflecting the high degree of annual variability in rainfall. Over the period 1973 to 2007, measured annual flows at the Marne Gorge flow gauging station ranged from over 33,500 ML in 1974 down to 80 ML in 1982 for years with complete flow records (see Figure 5). This monitoring data has been used to construct a surface water model that simulates daily flow based on rainfall, runoff, landscape characteristics and water capture (see section 4.2.1.2 for more information). The model can be used to estimate what flow would have been under current landscape conditions but without water capture by diversion structures like dams. This modelled "no dams" flow is referred to as "adjusted flow". The modelled estimate of average annual adjusted streamflow at the Marne Gorge flow gauging station for 1974 - 2003 is 8,406 ML, and the median is 5,346 ML.

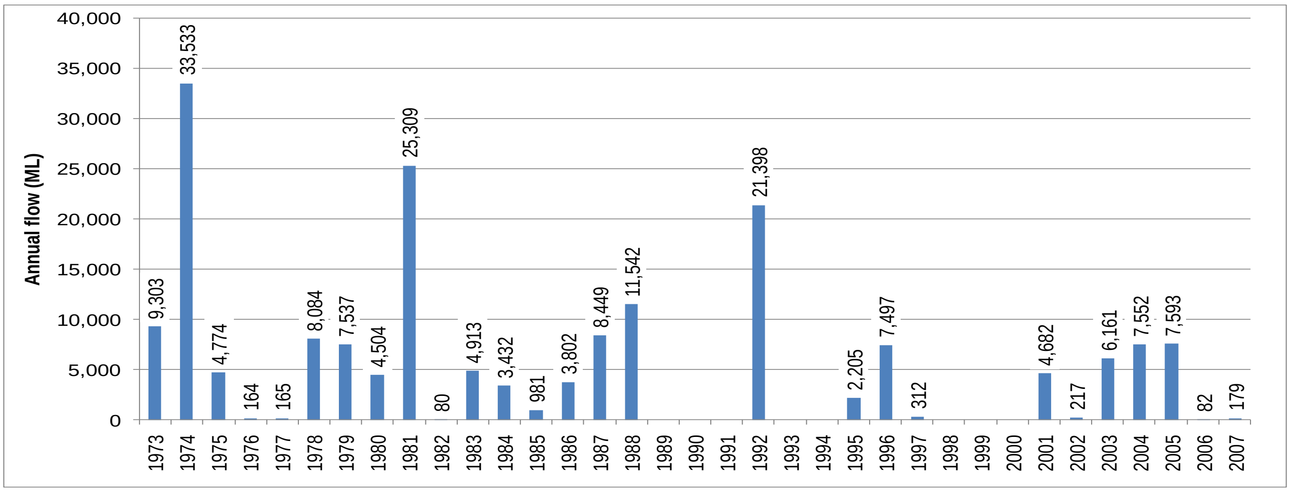


Figure 5 Annual flow measured at the Marne Gorge flow gauging station from 1973 – 2007. Data from Savadamuthu (2002) and DWLBC surface water archive. Data not shown for years with incomplete records.

The depth of average annual runoff from the Upper Marne catchment is 32 mm, which is generally lower than the average depth of runoff for the Mount Lofty Ranges. The percentage of rainfall that becomes runoff increases with higher rainfall, as shown in Figure 6. Once the soil is saturated, a larger proportion of rainfall runs off the land. As a result, a larger proportion of the rainfall becomes runoff in wetter years when there is greater opportunity for the soil to become saturated. This also means that the depth of runoff is higher from wetter areas because the rainfall is higher, and also because a larger proportion of that rainfall runs off the land compared with drier areas.

Flows in the Upper Marne are strongly seasonal, reflecting the seasonal rainfall pattern where the majority of rain falls in winter and spring (see Figure 7), although occasional storm events in the drier seasons may lead to flows. Periods of no flow commonly occur in the drier months. However, water remains in many permanent or semi-permanent pools in the upper catchments throughout the year, providing critical refuge habitat for aquatic organisms (see section 3). Inflow of underground water into the watercourse is likely to be important in maintaining many of these pools (see section 2.3.2.1). Indicative mapping of such dry season pools has been carried out by DWLBC (see Figure 8). This mapping was done using aerial videography linked to a Global Positioning System, captured from a low-flying helicopter in the autumn of 2003 prior to the break-of-season rains.

Flow gauging data is not available for the Saunders Creek. However, surface water modelling for the Upper Saunders, based on runoff characteristics of the Upper Marne and local rainfall, allow streamflow to be estimated (see section 4.2.1.2 and Alcorn (2005)). Modelled average annual adjusted streamflow at the end of the Upper Saunders for the period 1974 - 2003 is 1,003 ML, while the median is 673 ML.

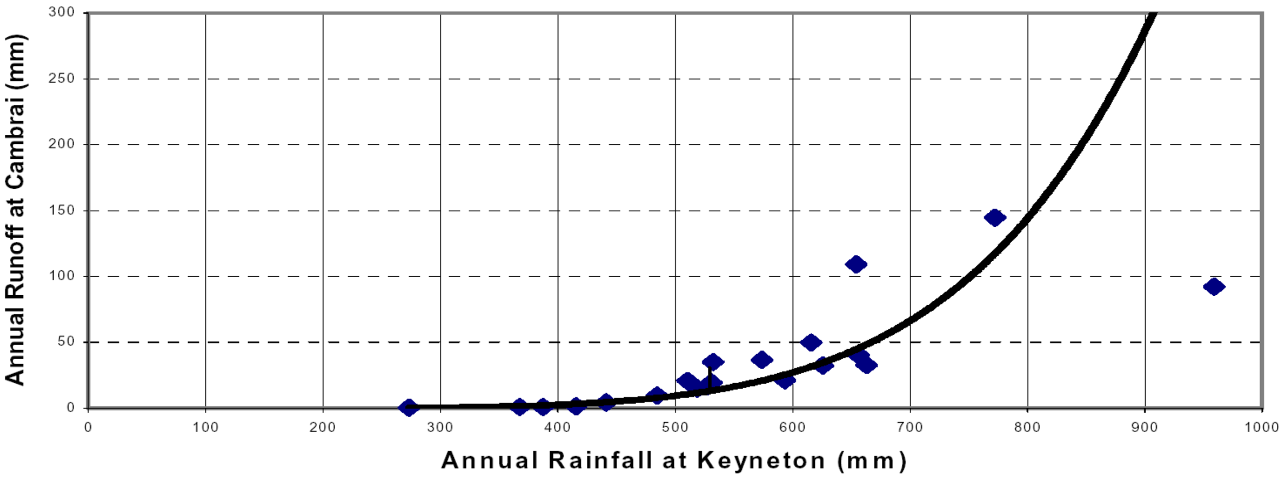
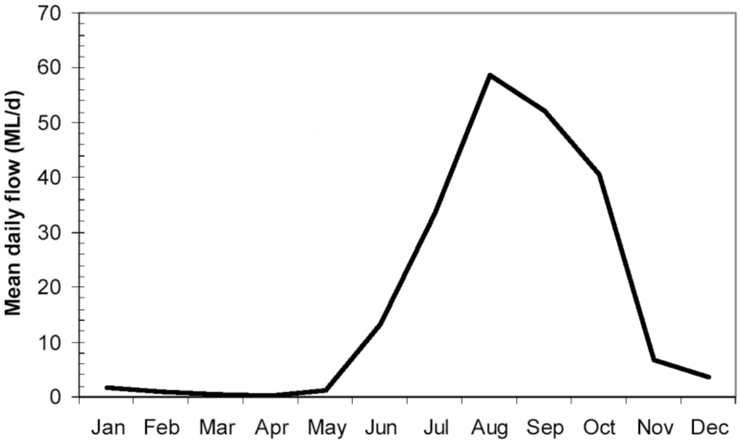


Figure 6 Relationship between annual rainfall at Keyneton and annual runoff depth at the Marne Gorge flow gauging station.
From Savadamuthu (2002).

Figure 7
Modelled average daily adjusted flow by month for the Marne Gorge flow gauging station.
From MREFTP (2003).



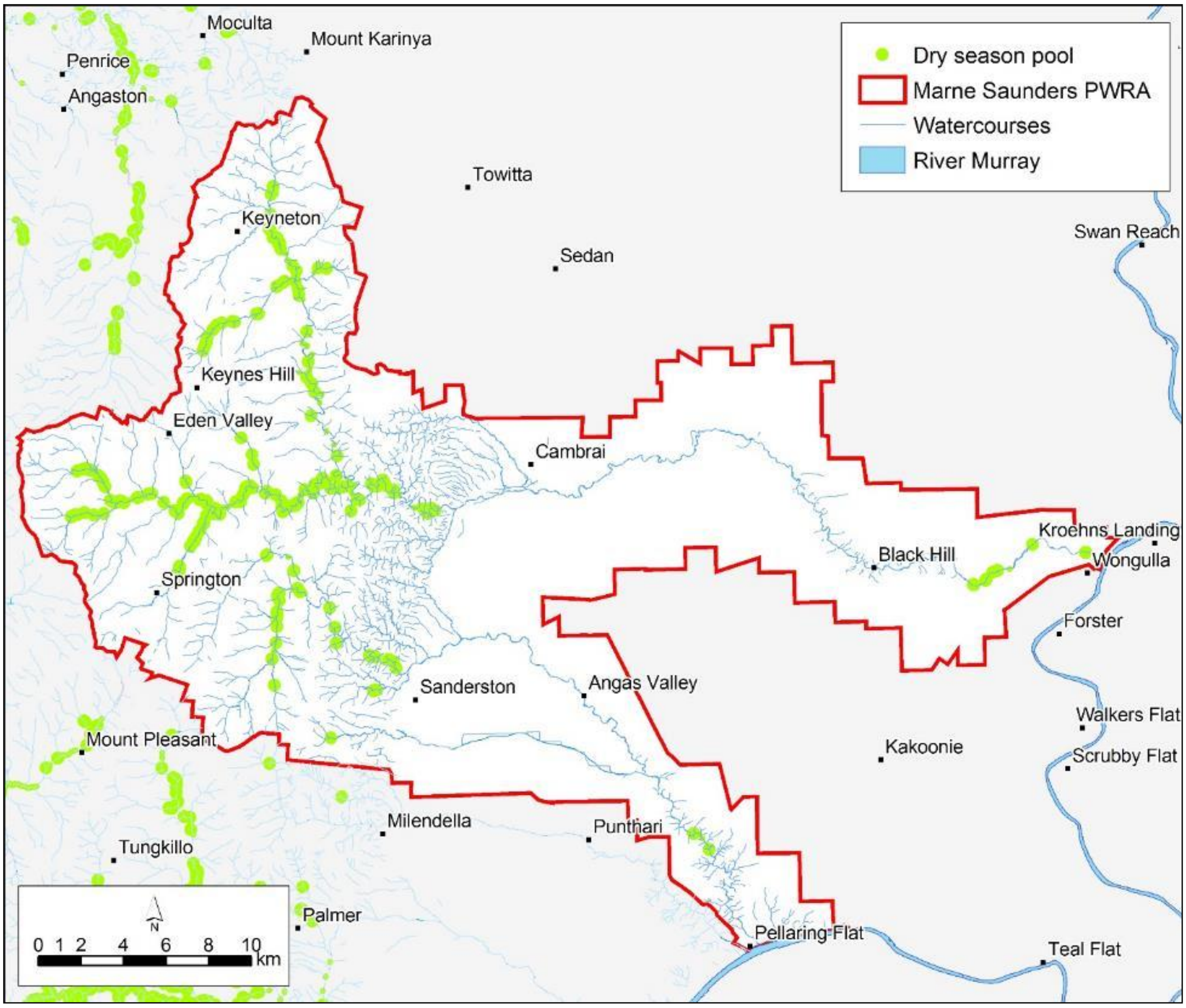


Figure 8 Indicative mapping of dry season pools in the Marne Saunders PWRA.
Data supplied by DWLBC (from aerial videography captured in autumn 2003).

2.3.1.2 Flow and runoff in the lower catchments

There are few watercourses in the lower catchments besides the Marne River and Saunders Creek channels. A few minor tributaries are present, draining from the foothills and also in the incised lower reaches closer to the River Murray (e.g. around Black Hill in the Marne). Rainfall is low and there is little local generation of runoff.

Baseflow from springs provides a key water source in some localised areas. This is particularly important in the Marne River downstream of Black Hill and in the Saunders Creek near Lenger Reserve, where baseflow provides permanent streamflow in an otherwise largely dry environment (see Figure 8).

The bulk of flow in the Lower Marne River and Lower Saunders Creek between the mouths of the gorges and Black Hill (Marne) or Lenger Reserve (Saunders) typically originates in the hills zone. These sections can be described as “losing” watercourses, as surface flows are lost from the watercourse as they percolate into the floodplain sediments, recharging the underground water below.

Water level detectors have been in place along the Lower Marne since 2001 to assess the loss of streamflow along the watercourse. Preliminary data analysis shows that at least 4,000 ML of cumulative flow is required at the Marne Gorge flow gauging station before flow will reach the downstream water level detector site near Black Hill (M. Alcorn, personal communication). Figure 9 shows the attenuation of flow events from the Marne Gorge flow gauging station to downstream water level detectors for July to October 2003. It can be seen that flow does not occur at the water level detector site near Black Hill until mid-September, despite several flow peaks occurring earlier further upstream. The distance that a flow event travels downstream in the lower catchments is likely to depend on a range of factors including the rate of infiltration through the river bed, how wet the river bed is already, and the presence of flow obstructions.

Flow from the Upper Marne to the mouth at the River Murray is now uncommon, having occurred in 1992, 1996 and 2004 in recent times (R. Laucke, personal communication). Flow from the Upper Saunders to the mouth is even more uncommon given the smaller discharge from this area, and it is not known when this last occurred.

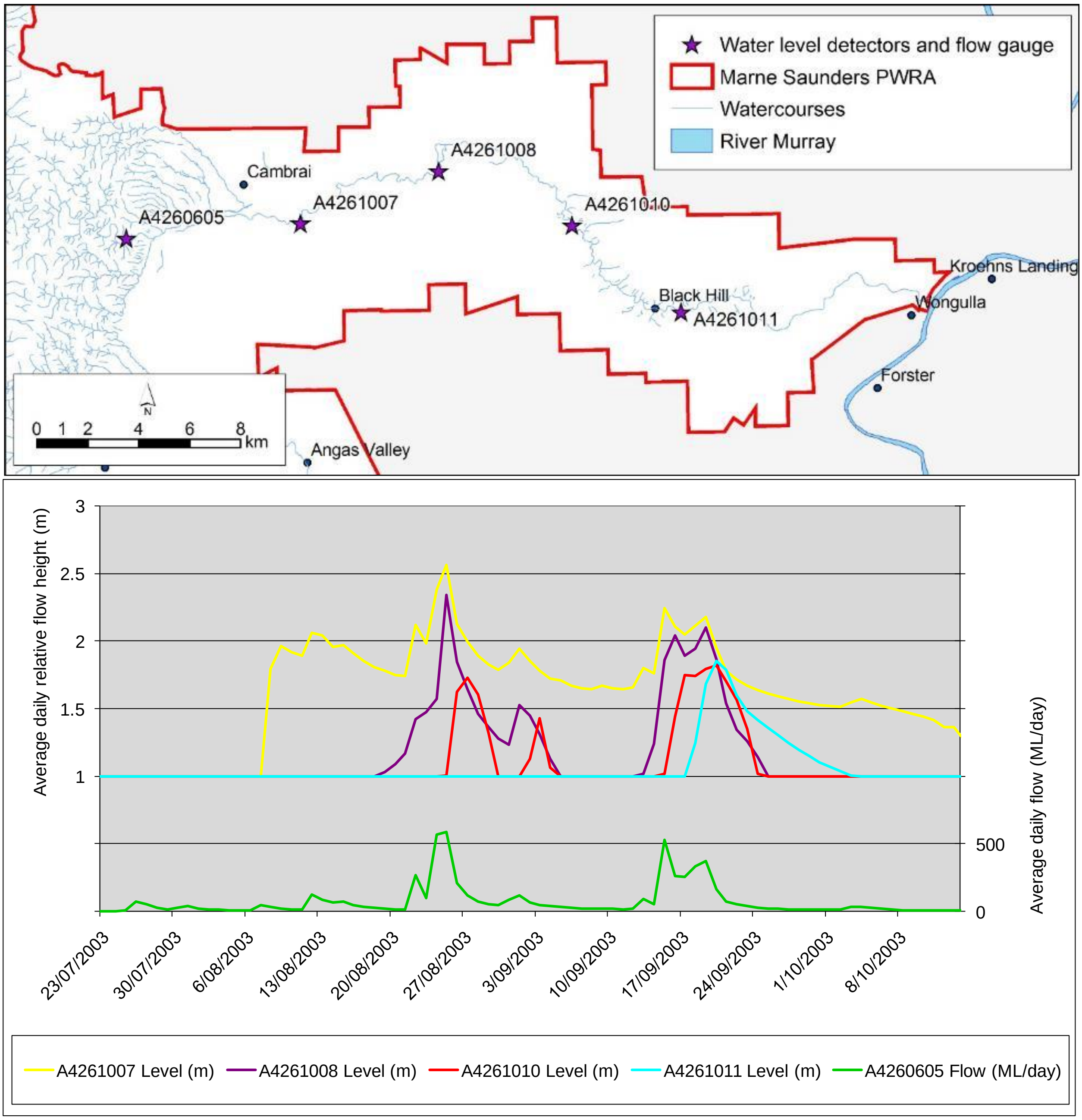


Figure 9 Average daily flow at the Marne Gorge flow gauging station (A4260605, green line on chart) and average daily relative flow height at water level detector sites (A4261007, A4261008, A4261010 and A4261011 on chart) for late July to October 2003.
The map above the chart shows the locations of the Marne Gorge flow gauging station and the water level detector sites. A relative flow height of 1 m is equivalent to zero flow at a water level detector site. Data provided by DWLBC.

2.3.1.3 Surface water and watercourse water quality

Surface water quality data has been collected and analysed under a range of programs in the Marne Saunders PWRA, including:

- Salinity logging at a range of stream flow gauging sites by the Department and SA MDB NRM Board;
- Community programs including Waterwatch and the Community Stream Sampling and Salinity Mapping project supported through the Bureau of Rural Sciences; and
- The Environment Protection Authority's (EPA) state-wide ambient water quality monitoring program, which has included two sites in the Marne catchment.

Salinity

The average stream salinity measured at the Marne Gorge flow gauging station for 1973 – 1997 was 3,302 µS/cm (Jolly *et al* 2000) (equivalent to total dissolved solids of approximately 2,200 mg/L)[4]. However, as discussed below, stream salinity is highly variable over space and time in the Marne Saunders PWRA.

The Australian Drinking Water Guidelines (NHMRC 2004) and the Australian and New Zealand Guidelines for fresh and marine water quality (ANZECC and ARMCANZ 2000) set out recommended salinity tolerances for a range of purposes, with a selection shown below. Values are not shown for irrigated crops, as the salinity tolerance is highly variable depending on the type of crop and soil characteristics. Note that these are general indicative values only.

Drinking water for humans*	500 mg/L
Aquatic ecosystems – lowland rivers**	100 – 5,000 mg/L
Aquatic ecosystems – lakes and wetlands**	300 – 1,000 mg/L
Drinking water for beef cattle***	up to 4,000 mg/L
Drinking water for dairy cattle***	up to 2,500 mg/L
Drinking water for sheep***	up to 5,000 mg/L

* Up to 500 mg/L is considered good quality drinking water based on taste, while up to 1,000 mg/L is acceptable based on taste (NHMRC 2004).

** Default trigger values indicative of slightly disturbed ecosystems in south central Australia – low rainfall areas (ANZECC and ARMCANZ 2000).

*** The stock tolerance values are those given for where no adverse effects on animals are expected. Stock may tolerate higher values without loss of production (ANZECC and ARMCANZ 2000).

Stream salinity in areas such as the Marne and Saunders catchments may be affected by a range of processes including dryland salinity, irrigation-induced salinity, impacts from dams via evaporative concentration and reduction in dilution when fresh runoff is captured. In addition, structures such as dams and roads may affect underground water flow that may force saline underground water into watercourses or to the surface (Dooley and Henschke 2000).

Surface water salinity in the Marne Saunders PWRA is highly variable over space and time. For example, Waterwatch data collected on a single day in June 2008 at a range of sites throughout the Marne catchment varied from 1,090 to 16,490 µS/cm (approximately 730 to 11,050 mg/L), with the highest values recorded in the upper North Rhine (G. Lundstrom, personal communication).

Figure 10 shows average daily salinity and daily discharge at the Marne Gorge flow gauging station from June 2001 to December 2007. It can be seen that salinity varies over time, ranging between 407 – 6,969 µS/cm (approximately 270 – 4,670 mg/L). Low stream salinity is often

[4] Electrical conductivity is a commonly used surrogate measure of salinity. Electrical conductivity (in µS/cm or EC units) has been converted to total dissolved solids (TDS) in mg/L by using a conversion factor of 0.67, as suggested in ANZECC and ARMCANZ 2000, with presented values rounded.

associated with high flow events, although analysis of the salt load discharged from the Marne catchment showed that the highest amount of salt is exported in higher flow years (Jolly *et al* 2000, Hyder Consulting 2007).

The high variability in stream salinity over time means that long-term trends are difficult to determine. Several studies have found that streamflow salinity in the Marne catchment appears to be increasing, although the increases were not considered to be statistically significant (Jolly *et al* 2000, Hyder Consulting 2007).

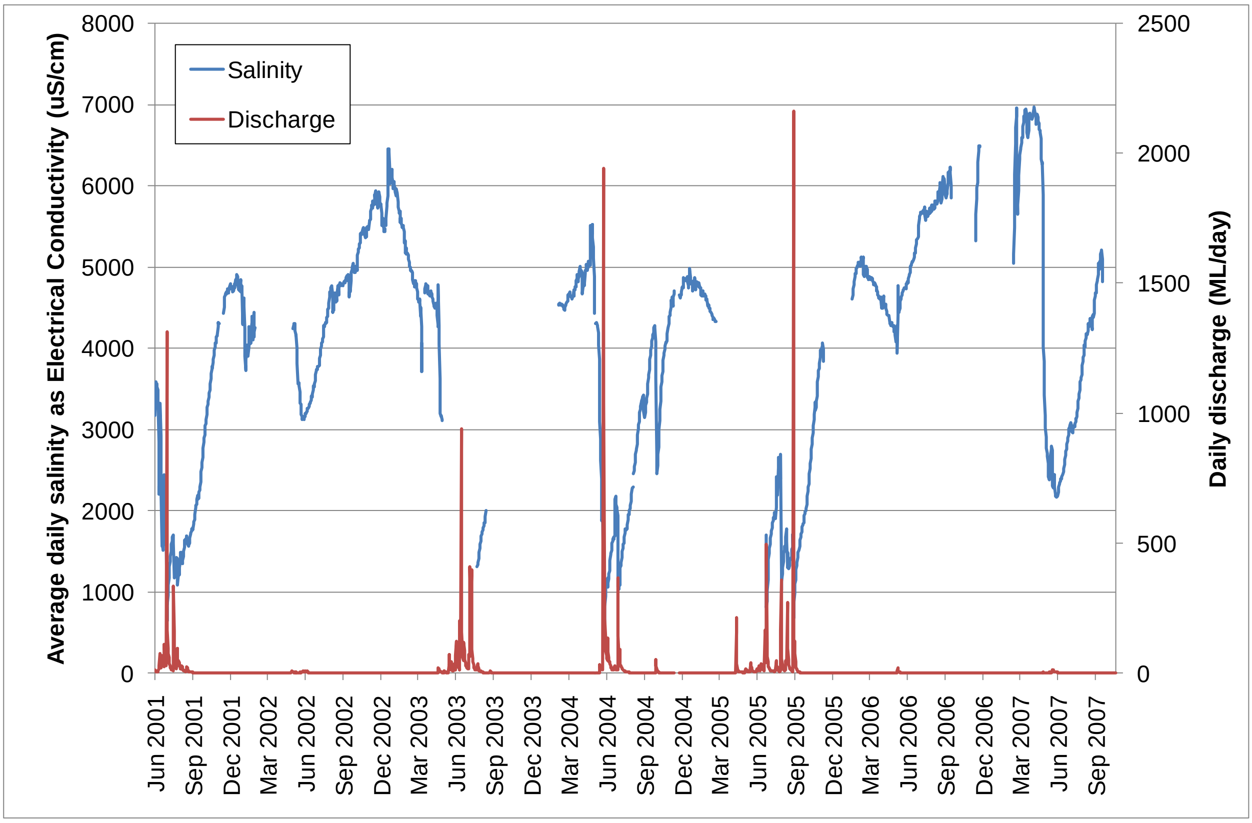


Figure 10 Average daily salinity and discharge over time at the Marne Gorge flow gauging station (A4260605).
Data from DWLBC surface water archive. Gaps show periods where data has not been collected.

Other water quality parameters

Table 2 gives the median and range of values for other water quality parameters measured though the EPA's ambient water quality monitoring site in the Marne River near Cambrai, including key nutrients (nitrogen and phosphorus), pH and turbidity (a measure of water clarity).

The Australian and New Zealand Guidelines for fresh and marine water quality set out default trigger values for different types of physical and chemical stressors in different types of water bodies (ANZECC and ARMCANZ 2000). These default trigger values provide a general indication of levels below which there is a low risk of adverse biological effects. The trigger values for lowland streams in South Australia are given in Table 2, together with the percentage of sampling occasions when these trigger values have been exceeded.

It can be seen that total nitrogen levels commonly exceed the ecosystem trigger values. The total nitrogen concentrations can rise as a result of fertilisers or animal wastes being washed off land during storms (EPA 2009). High nutrient levels may lead to excessive growth of aquatic plants and algae including blue-green algae. This excessive growth may lead to problems including reduction of dissolved oxygen when the plants die and decompose, reduction in recreational amenity, changes in biodiversity and toxic effects in some cases (ANZECC and ARMCANZ 2000).

It is important to note that the default trigger levels provide a general indication only, and don't account for the potentially naturally high levels of water quality parameters.

Table 2 Minimum, median and maximum values for water quality parameters in the Marne River near Cambrai. Table also shows the default trigger values for lowland streams in South Australia (ANZECC and ARMCANZ 2000), and the percentage of sampling occasions where these values have been exceeded.
Data from EPA (2009). Data collected 1995 – 2006 for most parameters.

	Water quality parameter					
	Oxidised nitrogen (mg N /L)	Total nitrogen (mg N /L)	Soluble phosphorus (mg P /L)	Total phosphorus (mg P /L)	pH	Turbidity (NTU)
Minimum	< 0.005	0.43	<0.005	0.014	6.6	0.35
Median	0.01	1.33	0.006	0.045	7.93	4.9
Maximum	1.26	4.46	0.142	0.394	8.7	99
ANZECC trigger value	0.1	1	0.04	0.1	6.5 – 9	50
% occasions where trigger value exceeded	21%	74%	6%	21%	0%	6%

2.3.2 Underground water

The information in this section is drawn from Banks *et al* (2006), Barnett *et al* (2001), Harrington (2004a and 2004b), Yan and Barnett (2001) and Zulfic *et al* (2002).

The two major regions of the Marne Saunders PWRA correspond to different types of aquifers, with fractured rock aquifers found in the hills zone and sedimentary aquifers found in the plains zone. Figure 11 shows a schematic diagram of the relationships between the aquifers and the movement of water through them. As described below, these two aquifer types have different characteristics that influence the movement of water through them, and the yield and quality of water from wells drilled in them.

2.3.2.1 Fractured rock aquifer

The fractured rock aquifer in the hills zone is made up of hard, largely impermeable basement rock where water is stored and moves through joints and fractures in the rock. The movement of water through fractured rock aquifers is largely governed by the size and connection of the water-holding fractures within the rock. The quality of water held in fractures is influenced by the type of rock around it. Fracture size and connectivity and rock type is highly variable over the landscape, which makes behaviour of the aquifer and the wells drilled into it highly variable.

Fractured rock aquifer recharge rates

Water is recharged into the fractured rock aquifer of the Marne Saunders PWRA through percolation of rainfall through the soil profile into the fractures in the rocks. Measuring the rate at which water is recharged into fractured rock aquifers is difficult because of the highly variable nature of the size and connection of fractures.
Sophisticated techniques have been used to measure the recharge rate in the fractured rock aquifer near Eden Valley, as documented in Banks *et al* (2006). This work included techniques such as downhole geophysics, geological fracture mapping, aquifer tests and vertical profiling of underground water chemistry, isotopes and radioactive tracers occurring in the underground water. These techniques provided information on fracture spacing, size and orientation, underground water flow and age of the underground water. The estimated age can be used to make inferences about the recharge rate, with younger ages indicating relatively high recharge rates and older water showing lower recharge rates.

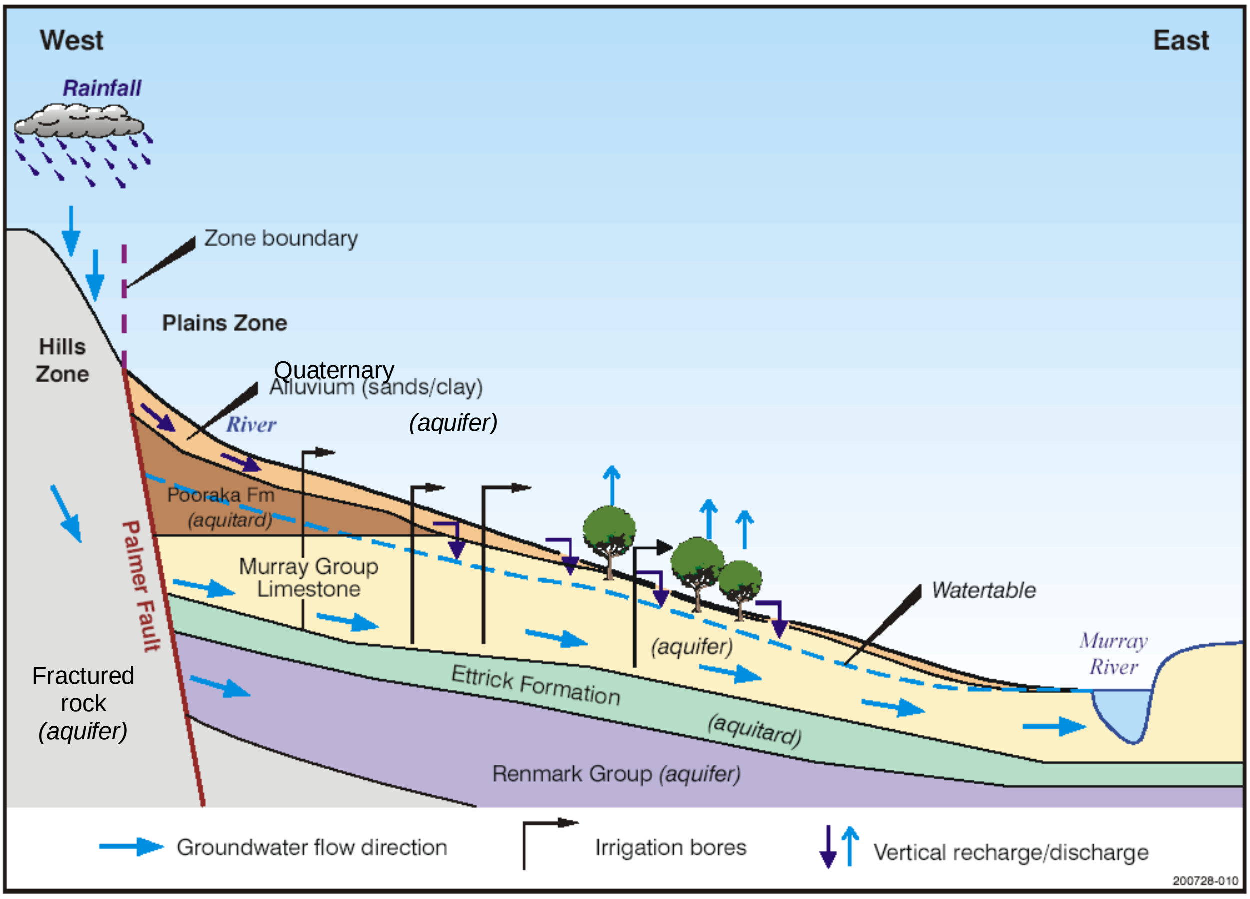


Figure 11 Key aquifers and the movement of underground water through the landscape in the Marne Saunders PWRA.
From Barnett *et al* (2001).

The investigations found two major flow systems at the Eden Valley site, with an upper, younger system to around 50 m depth and an older flow system below. The upper system is made up of sandy clay and weathered siltstone and sandstone, and has an estimated recharge rate of approximately 16 mm per year. The deeper system is composed of unweathered siltstone and sandstone and has an estimated recharge rate of approximately 0.14 - 3 mm per year.

Fractured rock aquifer water movement and discharge

Underground water moves through the fractures from higher points in the landscape towards the lowest points. Watercourses are typically at the lowest point and underground water from the fractured rock aquifer discharges to the watercourses as baseflow. This baseflow can dominate streamflow for much of the year, particularly during summer and autumn and between rainfall events. Analysis of streamflow data for the Marne River and Saunders Creek, using the Lyne and Hollick Filter method (Lyne and Hollick 1979), shows that on average approximately 28% of annual streamflow in the Upper Marne is derived from baseflow and approximately 22% for the Upper Saunders (K. Savadamuthu and M. Alcorn, personal communication). It is likely that baseflow plays an important role in maintaining water in many of the dry season pools identified in Figure 8.

At a larger scale, fractured rock underground water generally moves laterally from the hills zone to the sedimentary aquifers in the plains zone. The average throughflow from the fractured rock aquifer to the sedimentary Murray Group Limestone aquifer for the Marne catchment has been estimated at approximately 950 ML per year on the basis of modelling, although this volume is likely to vary in response to rainfall (Yan and Barnett 2001). This figure has been extrapolated to include the Saunders catchment, giving an estimated average annual discharge from the fractured rock aquifer to the Murray Group Limestone aquifer of approximately 1,625 ML for the Marne Saunders PWRA (S. Barnett, personal communication).

Movement of underground water across the northern, western and southern boundaries of the fractured rock aquifer in the Marne Saunders PWRA has not been measured. It is thought there is likely to be minimal flow across these boundaries, given the topography at the top of the ridge at the northern boundary and the dominant west to east flow direction (T. Wilson, personal communication).

Fractured rock well yield and salinity

The yield of wells drilled in the fractured rock aquifer will largely depend on the number and connectivity of water-holding fractures that the well intercepts. The rocks in the hills zone of the Marne Saunders PWRA are generally tight and impermeable with few open sets of fractures in which underground water can be transmitted. As a result, well yields are mostly low (generally below 2 L/s), apart from isolated occurrences of higher yielding wells south of Springton and near Eden Valley (see Figure 12).

The salinity of underground water depends on rock type and the amount of fresh recharge. Clayey weathering products from the rocks in the hills zone dissolve in the underground water, raising salinity. Salinity varies from 500 – 8,000 mg/L in the fractured rock aquifer in the Marne Saunders PWRA (see Figure 13). There is a broad trend of increasing salinity from west to east, corresponding with decreasing rainfall and hence decreasing recharge.

2.3.2.2 Sedimentary aquifers

Sedimentary aquifers are made up of layers of sediments such as sands, clays, gravels and limestone. The water is stored and moves through the pore spaces between the sediments. There is generally good connection between the pore spaces and water can flow through evenly. This means that water movement in sedimentary aquifers is generally more consistent and predictable than in fractured rock aquifers.

The plains zone is characterised by sedimentary aquifers in unconsolidated or poorly consolidated Murray Basin sediments, lying over the impermeable basement rock that forms the hills zone to the west. Three main aquifers have been identified, which, from shallowest to deepest, are the Quaternary, Murray Group Limestone and Renmark Group aquifers (as shown in Figure 11 and discussed below). The vast majority of water used for consumptive purposes in the plains zone is from the Murray Group Limestone aquifer. As a result, the majority of investigations in the plains zone have been on this aquifer.

2.3.2.3 Quaternary aquifer

The Quaternary aquifer is made up of younger sediments including alluvial silts, sands, clays and gravels of the Marne River and Saunders Creek floodplains. The Quaternary aquifer is about 10 m thick on average. The major sources of recharge to the Quaternary aquifer are likely to be streamflow, local rainfall, and throughflow from adjoining dunes. Recharge rates have not been measured.

Pools persist for some time following streamflow in the Marne River between the Gorge and Cambrai, and it is likely that they are partly sustained by discharge from the Quaternary aquifer. Permanently flowing water is also found in the Marne River downstream of the Black Hill township and in the Saunders Creek around Lenger Reserve (Figure 8). An investigation into the source of the streamflow downstream of Black Hill has shown that discharge from the Quaternary aquifer is an important source of water here, particularly in the months following a flood event (Harrington 2004b). It is likely that the permanent water at Lenger Reserve is also partly sourced from the Quaternary aquifer.

Well yields from the Quaternary aquifer are generally less than 0.5 L/s, with salinities mostly in the range of 1,500 – 2,200 mg/L.

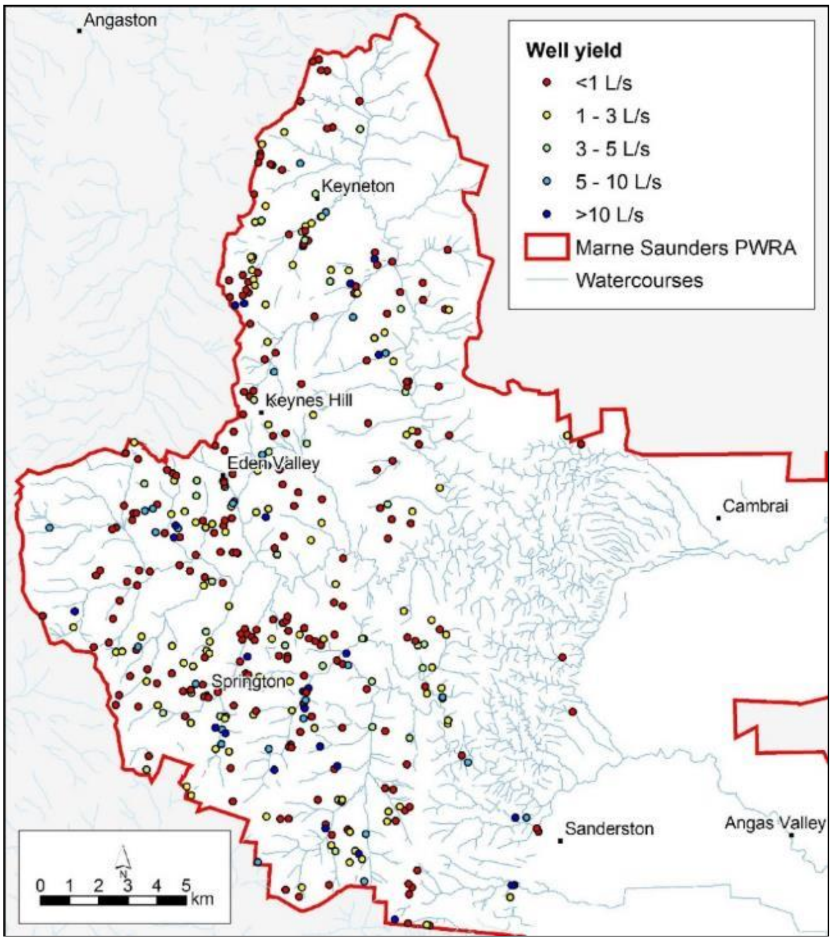


Figure 12
Well yield in the fractured rock aquifer in the Marne Saunders PWRA.

Data from DWLBC Drillhole Enquiry System.

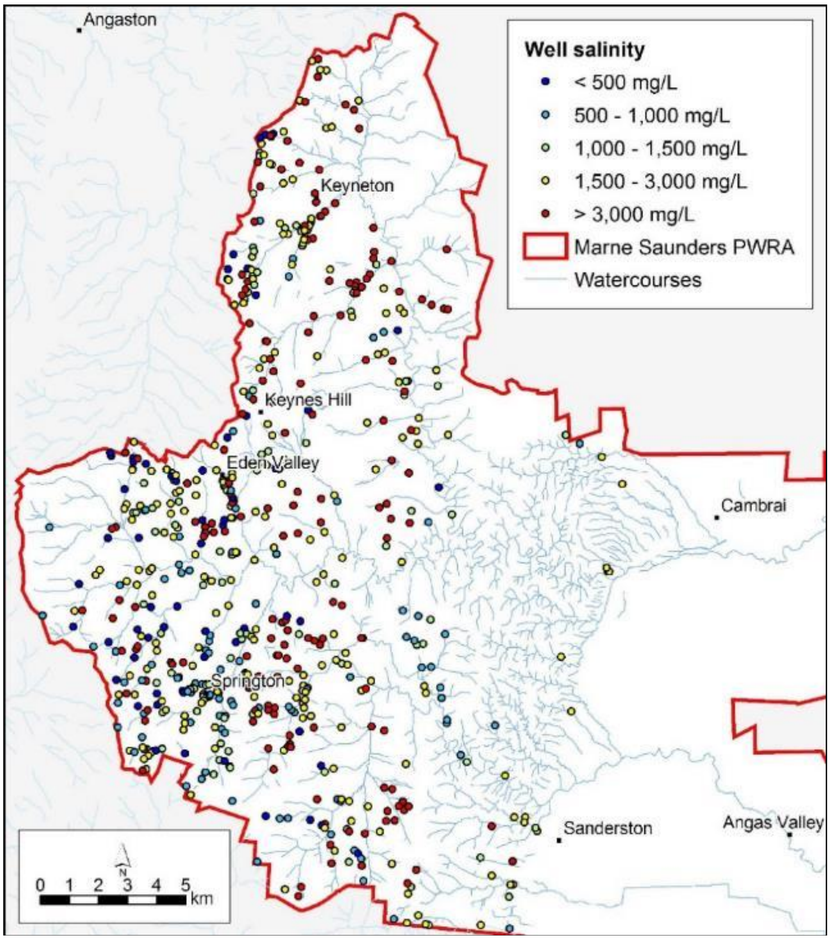


Figure 13
Salinity in wells in the fractured rock aquifer in the Marne Saunders PWRA.

Data from DWLBC Drillhole Enquiry System.

2.3.2.4 Murray Group Limestone aquifer

The Murray Group Limestone (MGL) aquifer is the main aquifer in the plains zone from a consumptive use viewpoint. It can be divided into the confined aquifer and unconfined aquifer as described below.

The part of the MGL aquifer next to the hills zone is confined or disconnected from the surface by the overlying Pooraka formation, which is a thick layer of clay and gravel washed out of the hills zone (see Figure 11). Water in a confined aquifer is held at greater than atmospheric pressure. This pressure causes water level in confined aquifer wells to rise above the surface of the aquifer. Underground water levels may change rapidly in a confined aquifer as a pressure response.

The MGL aquifer becomes unconfined east of Cambrai where the Pooraka formation thins. An unconfined aquifer is not under pressure and is open to receive recharge from the surface. Underground water level changes in unconfined aquifers are typically slower than in confined aquifers.

The MGL aquifer thickness ranges from a few metres in the western part of the Marne Saunders PWRA, where it contacts the underlying basement rocks, to about 50 m at the eastern margin of the area.

Murray Group Limestone aquifer recharge

The main source of recharge to the confined MGL aquifer is thought to be lateral throughflow from the fractured rock aquifer, as described in section 2.3.2.1. The thick clay of the overlying Pooraka formation largely separates the confined MGL aquifer from recharge from local rainfall and streamflow.

The Pooraka formation thins downstream of Cambrai and streamflow from the Marne River percolates through the stream bed to become the major source of recharge to this unconfined part of the MGL aquifer. Monitoring data shows a strong relationship between streamflow and water level in the unconfined MGL aquifer beneath the Marne River. The amount of recharge from streamflow decreases with distance downstream and also with distance laterally away from the Marne River. The timing and quantity of streamflow is driven by rainfall and water extraction in the hills zone, demonstrating the close links between surface water, watercourse water and underground water. Annual streamflow provides the upper bounds of annual recharge to the unconfined MGL aquifer, which is highly variable from year to year as discussed in section 2.3.1.1.

Further from the Marne River, the main source of recharge to the unconfined aquifer is infiltration from local rainfall. Annual recharge here is thought to be of the order of 1 mm per year.

Streamflow in the Lower Saunders catchment is much less than in the Lower Marne catchment (see section 2.3.1.1). Therefore the main source of recharge to the MGL unconfined aquifer in the Saunders catchment is likely to be local rainfall in most years when flow is minimal.

Murray Group Limestone aquifer water movement and discharge

Underground water flow direction is generally from the hills zones in the west to the lowest point at the River Murray in the east. The watertable gradient is steep. The extension of the Morgan Fault, which strikes NE - SW several kilometres west of the River Murray, acts as a permeability barrier to underground water flow from west to east. Underground watertable elevations are about 40 m Australian Height Datum (AHD) to the west of the Fault, but are less than 5 m AHD to the east of the fault near the river (S. Barnett, personal communication).

An important type of natural surface discharge from the MGL aquifer is extraction of underground water by the River Red Gums that line the watercourses. Estimates of water use by River Red Gums in the area are variable but significant, ranging from just under 500 ML per year to 2,900 ML per year (Tucker 2001, Yan and Barnett 2001).

Another important type of natural surface discharge from the MGL aquifer is discharge from springs into the watercourse downstream of Black Hill and around Lenger Reserve. An investigation of the sources of flow at the Black Hill Springs indicated that the MGL aquifer is the primary source, where the regional watertable in the MGL aquifer is forced to flow over impermeable basement rock protruding through the limestone (Harrington 2004b). This investigation also proposed a conceptual model of surface water-underground water interactions in the area, where the rate and location of discharge to the watercourse is driven by local underground water level as well as the gradient of the regional underground water table. Therefore the investigation concluded that the location of discharge is likely to be influenced by streamflow (driven in turn by rainfall and extraction), and extraction of underground water both locally and further up the water table gradient. Long-term measurements of discharge at the Black Hill Springs are not available, but a water level detector has been installed in the area to provide data in the future.

Murray Group Limestone aquifer well yield and salinity

Well yields of up to 25 L/s have been recorded in individual wells, with the majority falling in the range of 5 - 15 L/s in the Marne catchment. Yield in the MGL aquifer in the Saunders catchment is highest in the western portion near the hills zone at 1 - 3 L/s, dropping down to generally less than 1 L/s towards the east (see Figure 14).

The majority of wells in the vicinity of the Marne River and the western parts of watercourses of the plains zone have a salinity of around 1,000 - 2,000 mg/L due to the relatively high recharge of fresher stream water. Salinity generally increases above 2,000 mg/L away from the watercourses where the recharge rate is lower (see Figure 15).

2.3.2.5 Renmark Group aquifer

The Renmark Group aquifer occurs below the Murray Group Limestone, consisting of fine to medium-grained sands with bands of carbonaceous clays and lignites. Deposits are discontinuous, because their distribution is restricted to pockets in the undulating basement rock that lies beneath. This formation is a confined aquifer, separated from the Murray Group Limestone by the low permeability Ettrick Formation. The depth from the surface to the Renmark Group aquifer ranges from 20 m near Kongolia and Black Hill to more than 70 m near the hills zone. There is little consumptive use of water from this aquifer, as the overlying Murray Group Limestone aquifer is more easily accessible and provides water of better quality and more reliable yields. As a result, this aquifer is not well studied.

The major source of recharge is thought to be lateral throughflow from the fractured rock aquifer of the hills zone. The recharge rate has not been measured. Flow direction is most likely to be from west to east. Of the few wells drilled in the Renmark Group aquifer, yields are generally 0.5 - 5 L/s, and salinity is from 1,000 to over 7,000 mg/L with the fresher pockets occurring near the western margins of the plains zone.

2.4 Other water sources in the Marne Saunders PWRA

Water is used from non-prescribed sources in the Marne Saunders PWRA including reticulated supply (mains water and off-peak water) and some limited re-use of wastewater.

Reticulated water is supplied to Keyneton, Springton, Eden Valley and Cambrai and this mains water is also available along the pipe routes leading to these towns. Mains water is largely used for domestic supply and commercial use within the towns, although there is also some limited use for irrigation, industrial and stock purposes.

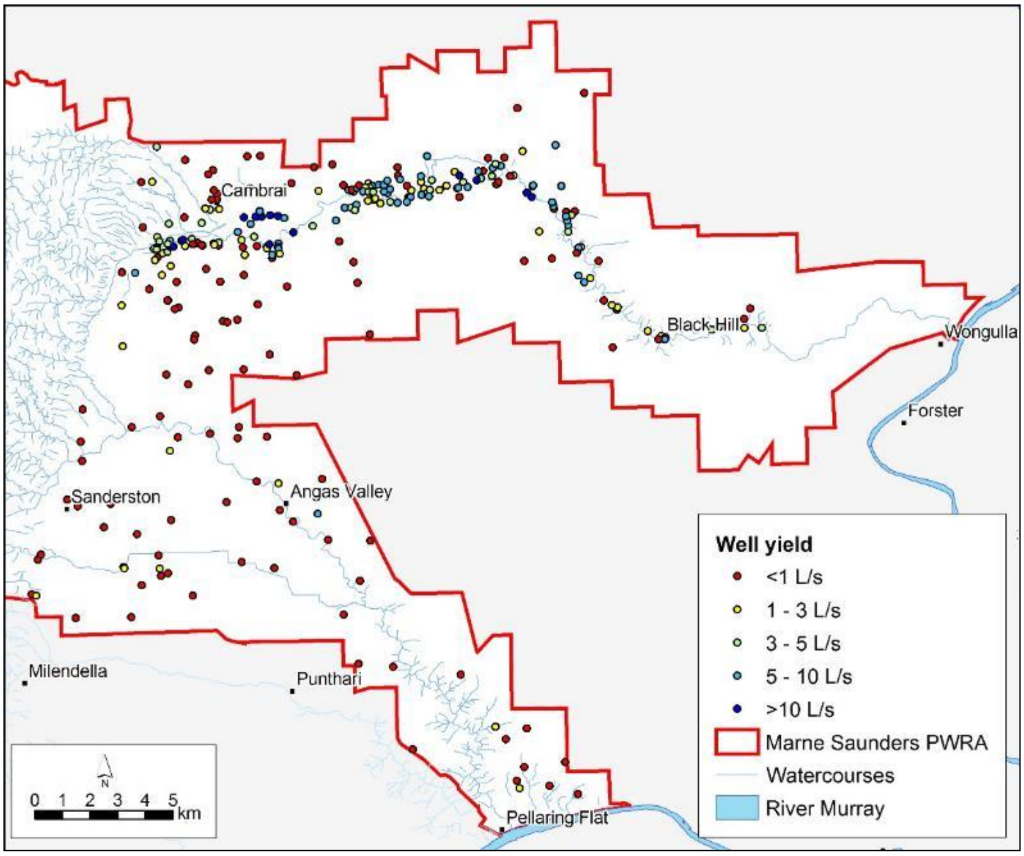


Figure 14 Well yield in the Murray Group Limestone aquifer in the Marne Saunders PWRA. From Barnett *et al* (2001), Zulfic *et al* (2002) and Drillhole Enquiry System.

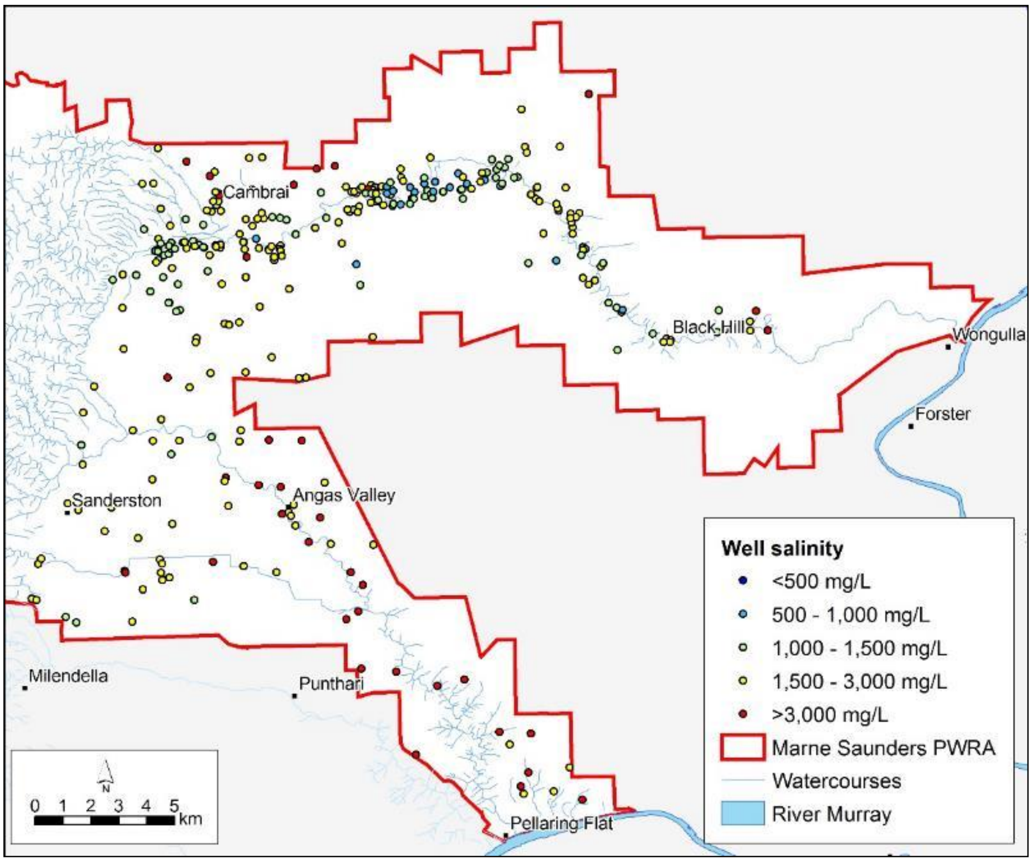


Figure 15 Salinity in wells in the Murray Group Limestone aquifer in the Marne Saunders PWRA. From Barnett *et al* (2001), Zulfic *et al* (2002) and Drillhole Enquiry System.

The water mains are also used to supply “off-peak” water, which is water allocated to River Murray licensees that can be accessed from April to October. Up to approximately 200 ML of off-peak water is supplied in the Marne Saunders PWRA, largely for irrigation, and it is understood that this is the maximum supply able to be provided through the current infrastructure.

3 Needs of water-dependent ecosystems

The Marne Saunders PWRA supports a range of water-dependent ecosystems. Water-dependent ecosystems have been defined as “those parts of the environment, the species composition and natural ecological processes of which are determined by the permanent or temporary presence of flowing or standing water” (ARMCANZ & ANZECC 1996). They include watercourses, riparian zones, wetlands, floodplains, estuaries, cave and aquifer ecosystems, and may depend on surface-, watercourse- and/or underground water.

Water-dependent ecosystems depend on a pattern or regime of water flow or level. This regime can be described in terms of seasonality, timing, frequency, duration, magnitude, depth and rate of change. Appropriate water quality is also important to sustain water-dependent ecosystems.

Water provides a medium for water-dependent organisms to live and breed in and around. The water regime also structures habitats by driving processes such as erosion and sedimentation, and by influencing water quality through processes like flushing. The structure and functioning of water-dependent ecosystems is strongly driven by the water regime that they experience. Changes in important elements of the water regime are likely to lead to changes in condition and composition of water-dependent ecosystems. The water regime needed to sustain the ecological values of ecosystems, including their processes and biological diversity, at a low level of risk is termed environmental water requirements (EWRs) according to the State NRM Plan. Section 3 describes the environmental water requirements of the Marne Saunders PWRA.

Section 4.2.3 outlines the impact of current water resource development on water-dependent ecosystems, and assesses whether the environmental water requirements are currently being met. According to the State NRM Plan, environmental water provisions (EWPs) are “those parts of environmental water requirements that can be met at any given time. This is what can be provided at that time with consideration of existing users’ rights, social and economic impacts”. Environmental water provisions for the Marne Saunders PWRA are described in sections 4.3.2.1 and 4.3.3.1.

The Peramangk and Ngadjuri have deep knowledge of the connectivity of underground water and surface water sources on their lands and waters. Through respectful partnership, this knowledge could assist in addressing knowledge gaps and assessment of the needs of water-dependent ecosystems in the region, which is further discussed in section 1.5. Aboriginal nations refer to freshwater wetlands as ‘nurseries’ in recognition of the important role these areas play in providing food and shelter for many types of animals, birds and fish (ngartjis). Submerged plants in these nursery areas are critical for food and shelter for animals and their young. The nurseries are regarded as the lungs of the system that cleanse the body (land) (DEWNR, 2017).

A decline in the ecological condition of the surface and underground water systems can also be understood as a threat to Aboriginal people’s health and wellbeing. In this way, Aboriginal nations support the intent of the Plan to sustainably manage this part of Country.

3.1 Determination of environmental water requirements

The environmental water requirements for the Marne Saunders PWRA have been identified using a number of steps outlined below and further described in this section:

- Divide the area into environmental reaches that represent similar habitats and landscape processes (section 3.2).
- Identify ecological assets (species or communities) and their condition in each reach (section 3.3).
- Develop a conceptual model for each reach that identifies key ecological drivers of habitat and organisms, particularly in terms of water regime as well as other issues affecting water-dependent ecosystems (not specifically outlined in this Plan, although some information is

provided in sections 3.2 and 3.3. See MREFTP 2003 and Doeg and van der Wielen 2007 for details).
- Set environmental objectives for each ecological asset (section 3.4.1).
- Identify the environmental water requirements of each asset by identifying the ecological processes required to meet the objectives, and the parts of the water regime linked to each ecological process. Each environmental water requirement is expressed in terms of flow bands (zero flows through to high flows), and seasonality, duration and frequency of flow events where possible (section 3.4.2).
- Summarise environmental water requirements as a qualitative description of the flow bands needed in different flow seasons for each reach, by combining the environmental water requirements of the ecological assets found in each reach (section 3.5).
- Quantify the environmental water requirements by identifying flow statistics or metrics that represent the ecologically important parts of the water regime. Examples of flow metrics include the duration of the period of zero flow in the low flow season, frequency of high flow events in the high flow season (section 3.6).
- Provide a mechanism to allow assessment of relative environmental stress of different water management scenarios on the water regime. This is achieved comparing the value of each flow metric under a modelled management scenario with the value under natural conditions. Limits were set on the deviation from natural values, with higher deviation corresponding to higher levels of environmental stress (section 3.6).

The study on environmental water requirements of the Marne catchment (MREFTP 2003) used a technical panel of ecologists, geomorphologists, hydrologists and hydrogeologists to carry out the steps above. Members of the panel collected new information on types and distribution of ecological assets and landscape characteristics. The subsequent study for the Saunders catchment (Doeg and van der Wielen 2007) used existing data and built on the concepts developed for the Marne catchment.

The information presented in this section is largely drawn from these two studies (MREFTP 2003, and Doeg and van der Wielen 2007). Additional information is also included from other studies on native fish (e.g. Hammer 2006, Hammer 2007a, Hammer 2007b) and studies on underground water described in section 2.3.2.

3.2 Environmental reaches

The catchments were divided into 13 environmental reaches, where each reach represents a different major “ecological unit” in the Marne Saunders PWRA. Each reach contains a distinct group of habitats and ecosystems, and has relatively consistent characteristics within the reach in terms of hydrology, geology, stream shape and processes. Figure 16 shows the reaches. Each reach type is described below in terms of stream form, habitat types and key aspects of the water regime. The environmental water requirements reports provide more information on the reaches, including identification of other processes influencing water-dependent habitat type and quality in the reaches (e.g. erosion, stock access, vegetation clearance, flow barriers etc) (MREFTP 2003, and Doeg and van der Wielen 2007).

Reach M1 – Marne headwaters

The Marne headwaters are ephemeral drainage lines and minor streams in the high rainfall area at the top of the Marne catchment. The streamflow moves quickly through the reach, with very little permanent water or areas of in-stream habitat that retain water for long periods. There are some exceptions such as Boehm’s Spring, where discharge of underground water supports water-dependent ecosystems.

The headwaters provide a large part of the flow for the rest of the catchment, and as a result, dams tend to be concentrated here.

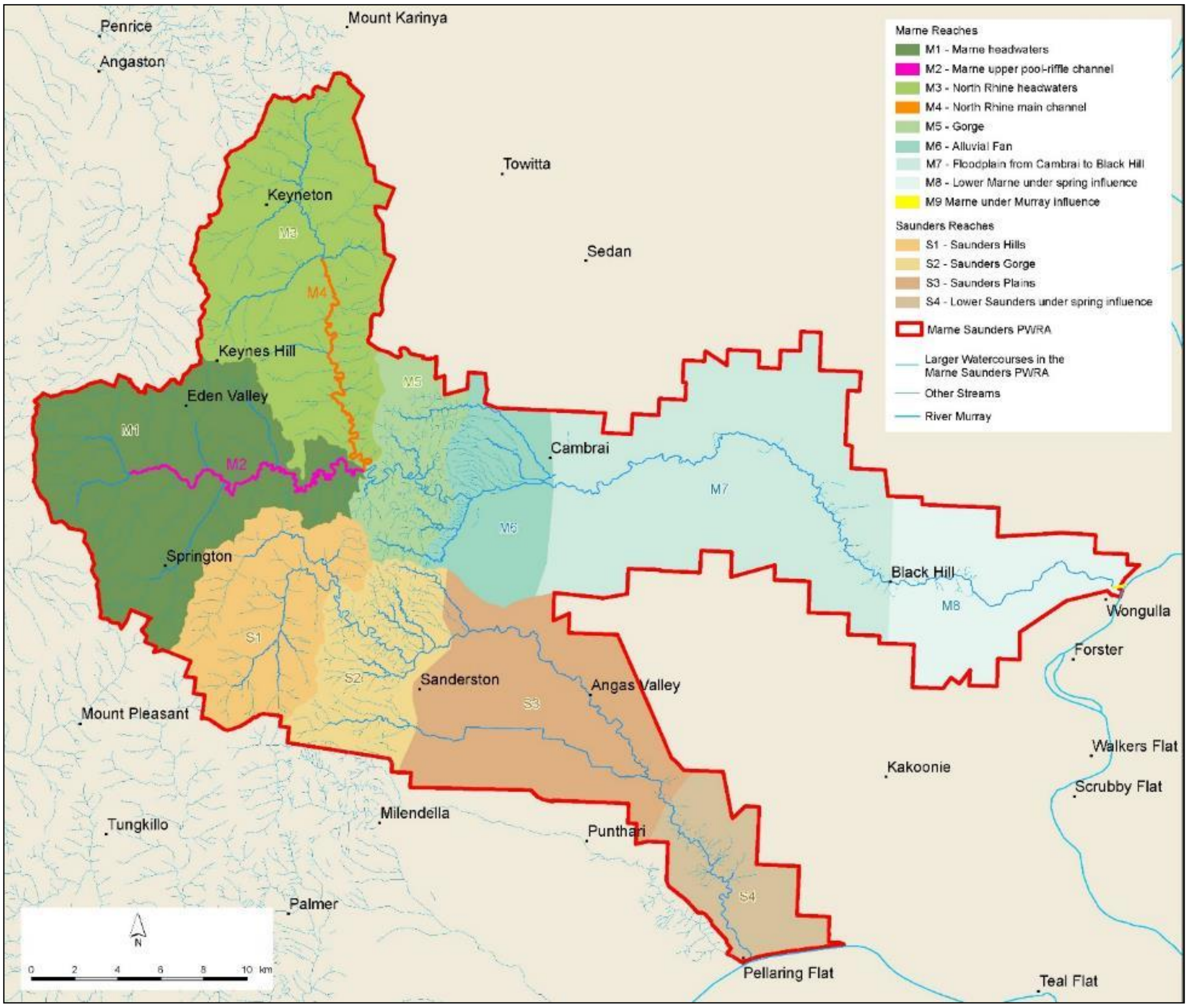


Figure 16 Environmental reaches defined for the Marne Saunders PWRA.
Adapted from MREFTP 2003, and Doeg and van der Wielen 2007.

Reach M2 – Upper Marne pool-riffle channel

Water from the small headwater streams of the Marne feed together to form the main Upper Marne channel. The main channel is made up of a series of sandy bottomed pools joined by gravel riffles (sections of broken running water) during periods of flow, with small pockets of floodplains. Floods and high flow events shape the channel here and in the other reaches, creating and maintaining different habitats by scouring pools and washing out accumulated silt in riffles. Aquatic and riparian vegetation also influences habitat here, and in other reaches in the catchment. The vegetation provides habitat, and also influences erosion processes, for example by trapping sediment. Bedrock outcrops and woody debris like sticks and logs add to the diversity of habitats available.

As described in section 2.3.1.1, flow in the upper catchment is strongly rainfall dependent and seasonal, with an important component of flow provided by baseflow from underground water. When flow stops, the riffles dry up and the main channel becomes a string of permanent pools that are often sustained by baseflow from underground water (see Figure 8).

The pools provide a key refuge during periods of low or no flow for plants and animals that depend on the presence of water. Over the dry period, these pools decrease in volume through evaporation, increase in temperature and decrease in dissolved oxygen levels. These changes mean that the stress on the plants and animals living there increases over time. The occasional short flow events during this time (freshes) are important to top up the pools and refresh water quality, increasing the likelihood of survival of biota over this period.

Reach M3 – North Rhine headwaters

The headwaters of the North Rhine, the major tributary of the Marne, are similar to the Marne headwaters (reach M1). It consists of ephemeral drainage lines, grassy depressions, gullies and minor streams with very little aquatic habitat. Rainfall is generally lower and dryland salinity is more extensive in the North Rhine compared with the Upper Marne, leading to higher salinity in the stream when it flows. Like the Marne headwaters, the North Rhine headwaters provide the major source of flow for the main channel and downstream parts of the catchment.

Reach M4 – North Rhine main channel

The headwaters of the North Rhine flow into the main channel, which passes through a broad valley before joining with the Upper Marne just before the gorge reach. The North Rhine main channel is similar to the Upper Marne, being made up of strings of sandy pools and gravelly riffles with minor floodplains with a similar flow pattern. However, there are fewer deep, permanent pools and the water salinity is generally higher compared with the Upper Marne.

Reach M5 – Marne Gorge

The Marne River breaks out of the hills onto the plains through a steep, narrow rocky gorge which concentrates the water's energy during high flows. There are different habitats in and around the stream, including pools, riffles, rock bars and slower moving flood channels. The fast moving, high energy flows scour out much of the finer sediment, so the aquatic habitats often have a bed of bedrock, boulders, cobbles and gravels, with some sandy and gravelly bars and small floodplain pockets. The complex channel structure and variable levels of flow interact to create habitats that range from permanently wet, to a mix of wet and dry, to largely dry. Disturbance by high flows helps to maintain diversity by scouring out silt, opening new patches for plants to grow and preventing dominance by a single species.

There are some permanent pools that are likely to be sustained by baseflow from underground water. The steep walls provide shade for the stream which is likely to reduce evaporation and help sustain these pools.

Reach M6 – Marne Alluvial Fan

As the Marne River leaves the confines of the gorge, the water spreads out and loses energy, depositing the sediment eroded from the upper catchment. This alluvial fan of sediment creates the thick layers of clays and silts that prevent streamflow from seeping down to recharge the Murray Group Limestone aquifer in this area (see section 2.3.2.4). The Marne River here has a main channel with numerous smaller flood channels. The bed has a mixture of sand-gravel shallow pools and cobbled riffles, with logs providing important in-stream habitat.

Few areas of permanent water exist in this reach, although some pools retain water for significant periods after flow ceases.

Reach M7 – Floodplain from Cambrai to Black Hill

Beyond the alluvial fan, the Marne River becomes a small, winding, low gradient sandy channel in a broad floodplain, lined with River Red Gums. The channel is usually dry with no permanent water, as there is little rainfall and most of the streamflow from the upper catchment soaks through the river bed to recharge the underlying aquifers (see sections 2.3.1.2 and 2.3.2.2). Large woody debris is likely to provide important habitat when the channel flows, and play a role in shaping other habitats in the channel by influencing the pattern of sediment erosion by flow.

Floods from high rainfall events in the hills occasionally break out of the channel and spread over the floodplain, providing much-needed water to floodplain vegetation, carrying seeds and stimulating germination of River Red Gums.

This reach also includes the Marne Valley Conservation Park, a River Red Gum floodplain forest containing temporary lagoons that fill during flood events.

Reach M8 – Lower Marne under spring influence

Around the township of Black Hill, the Marne River begins to carve into the limestone of the River Murray floodplain, creating a narrow valley with numerous small gullies feeding into the valley. The underground water discharges to the surface (see section 2.3.2.4) to create a series of unique permanently flowing, spring-fed pools joined by shallower flowing runs that provide a highly significant aquatic habitat in an otherwise dry environment. The discharge of underground water to provide permanent cool, clear flow is critical to sustain these habitats between the rare flood events that make it this far down the Marne River.

Reach M9 – Marne under Murray influence

The Marne River joins the River Murray at Wongulla. The open area around the Marne mouth is now permanently backfilled by murky water from the River Murray. The Marne mouth used to contain a deep, clear, spring-fed wetland that supported a diverse range of plants and animals. Sediments deposited during the floods of the 1990s and drying up of the springs has led to the former wetland becoming a dense bed of reeds with a small, often dry channel running through to the open area backfilled by the River Murray. Occasional floods from the Marne provide flushes to this wetland, but otherwise the water regime here is largely determined by the flow level in the River Murray.

Reach S1 – Saunders Hills

The Saunders Hills reach extends from the headwaters to the head of the Saunders Gorge. It includes headwater drainage lines and tributaries feeding into the main channels of One Tree Hill Creek and the Reen Valley. The river valley in the reach is variable, with broader floodplains alternating with confined steep sided valley slopes. The gradient is generally low, so the main channel has a low energy channel dominated by sequences of silty and sandy pools connected by shallow long gravel or sand runs when flowing.

The headwater drainage lines and tributaries are similar in nature and flow pattern to the headwater reaches of the Marne, where flow passes through quickly. In-stream habitat is generally found in the main channel sections, where the sequences of pools and runs are similar to the pool-riffle main channels in the Marne. However, the flow in the Saunders catchment is lower than in the Marne, and there can be extensive periods of no flow. Permanent pools are less common than in the Marne catchment (see Figure 8).

Reach S2 – Saunders Gorge

The Saunders Creek flows out of the hills through a steep, rocky gorge that falls 160 metres over approximately 7 kilometres. When flowing, it is a fast moving, high energy stream running over a bedrock, boulder and cobble bed with some gravel and sand bars and small floodplain pockets. There are many small local tributaries either feeding into the Saunders Creek, or making their own way down to the plains. During the dry season, the watercourse contracts back to the spring-fed pools scattered in the Saunders Creek and its tributaries in the reach.

Reach S3 – Saunders Plains

Across the plains area, the Saunders Creek has a small sandy bed lined with River Red Gums, with an extensive floodplain. The gradient is very low and there are few local tributaries. Local rainfall is very low, and on the rare occasions that there is flow in this reach, it is largely generated from the upstream reaches. As described in section 2.3.1.2, the Saunders Creek is a losing stream in this reach, where much of the flow seeps through the bed to recharge the underlying aquifers. There is no permanent surface water and no persistent in-stream habitat.

Reach S4 – Lower Saunders under spring influence

For a small section of the lower Saunders Creek catchment, the creek enters another small valley section where the creek descends from its own floodplain to the floodplain of the River Murray. The valley is carved into the Murray Group Limestone, with the depth of incision increasing downstream. There are numerous small gullies running down into the valley. In the mid section of this reach, there is a series of permanent pools fed by baseflow from the underground water, joined by short runs. This reach is highly significant in the context of the Saunders catchment as it contains the majority of the truly permanent aquatic habitat in the entire catchment.

3.3 Ecological assets

Ecological assets have been identified for each reach, focusing on fish, macro-invertebrates and plants. These groups have been selected as indicators of environmental water requirements for the broader water-dependent ecosystems. They are generally highly dependent on water and are generally not able to opportunistically move to other areas which may provide better aquatic habitats when conditions are poor in their resident catchments. A summary of the type and distribution of these groups is given below.

3.3.1 Fish

Data on the fish fauna of the Marne Saunders PWRA has been collected from museum records, recollections from landholders and several studies of fish in the area. A total of 19 native and 3 introduced fish species occur, or have occurred, in the Marne Saunders PWRA, of which 10 native species are now believed to have disappeared locally (Table 3).

Table 3 Fish species recorded from the Marne River catchment.
Status:
Vul: Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth)
P: protected under *Fisheries Management Act 2007*
* believed to have locally disappeared

Species	Common Name	Status
Native species		
Ambassis agassizii	Chanda Perch	P*
Craterocephalus stercusmuscarum fulvus	Fly-specked Hardyhead	
Craterocephalus fluviatilis	Murray Hardyhead	Vul*
Gadopsis marmoratus	River Blackfish	P
Galaxias maculatus	Common Galaxias	*
Galaxias olidus	Mountain Galaxias	
Hypseleotris spp.	Carp Gudgeon	
Maccullochella peelii	Murray Cod	Vul*
Macquaria ambigua	Callop	*
Macquaria colonorum	Estuary Perch	*
Melanotaenia fluviatilis	Crimson-spotted Rainbowfish	
Mogurnda adspersa	Purple-spotted Gudgeon	P*
Nemetalosa erebi	Bony Bream	
Philypnodon sp.	Dwarf Flatheaded Gudgeon	
Philypnodon grandiceps	Flatheaded Gudgeon	
Pseudaphritis uruvillii	Congolli	*
Pseudogobius olorum	Western Blue Spot Goby	*
Retropinna semoni	Australian Smelt	
Tandanus	Catfish	P*
Introduced species		
Gambusia holbrooki	Gambusia or Plague Minnow	
Cyprinus carpio	Carp	
Carassius auratus	Goldfish	

Mountain Galaxias is the only species that has been found in the Upper Marne (reach M2 and M5) during recent surveys, occasionally appearing in the North Rhine (reach M4) after large flow events allow recolonisation (Hammer 2007a). No native fish have been found in the Upper Saunders yet (reach S1 and S2), although survey efforts have been less intense there than in the Upper Marne. Given the similarities in habitat with the Upper Marne, it is possible that small native fish occur in reaches S1 and S2.

The only other reaches where native fish have been recently found are the permanently flowing spring fed reaches of the Lower Marne (M8) and Lower Saunders (S4), and the Marne under Murray influence (M9) where backfilling from the Murray provides permanent aquatic habitat. The Black Hill Springs of reach M8 support a highly significant population of River Blackfish, one of four remaining populations in the South Australian Murray–Darling Basin of this formerly widespread species (Hammer 2004). The springs also support Mountain Galaxias, Carp Gudgeon, Dwarf Flathead Gudgeon and the introduced Gambusia (or Plague Minnow) and Carp.

The Marne mouth wetland (reach M9) supports a diverse fish fauna typical of River Murray wetlands, including gudgeons, Smelt, Hardyhead and Bony Bream. The spring fed pools in reach S4 support Carp Gudgeons, an important population in the context of the catchment.

The species shown in Table 3 as having disappeared from the area were previously found in reaches M8 and M9, with the most recent observations of their presence made in the 1950s - 1980s. These species include some that migrate between fresh and marine habitats for different parts of their lifecycle (diadromous species, including Congolli and Common Galaxias) and it is likely that the fresh flows from the Upper Marne to the wetland at the mouth would have provided an attractant flow for these species.

The fish distribution of the Marne Saunders PWRA reflects different habitat types. Mountain Galaxias and River Blackfish are only found in flowing streams like those found seasonally in reaches M2 and M4 and permanently in reach M8. The gudgeons are primarily stream dwellers, while the remaining species are wetland species.

3.3.2 Macro-invertebrates

Aquatic macro-invertebrates have been collected from 14 sites in the Marne catchment (including all reaches except M7 and M9) and two sites in the Saunders catchment (in reaches S1 and S2). One site near Cambrai has been sampled regularly since 1994 - 1995 as part of the Environment Protection Authority's ambient monitoring program.

Macro-invertebrates have been found on all sampling occasions, except when sampling was prevented by the site being dry. Different macro-invertebrate communities tend to be found in pools compared with riffles and so these habitats are sampled separately. The majority of samples have been collected from pools, as riffles have commonly not been present during sampling which typically occurs in Autumn and Spring.

Over 190 species of macro-invertebrates have been recorded from the Marne catchment and 83 from the Saunders catchments. Commonly found species include round worms (Nematoda), aquatic worms (Oligochaeta), scuds *(Austrochiltonia australis)*, isopods *(Heterias pusilla*), springtails (Hypogastruridae), non-biting midges (*Procladius*, *Paramerina, Cricotopus, Tanytarsus, Cornynoneura, Parakiefferiella* and *Chironomus*), water boatmen *(Micronecta*), predacious diving beetles (Dytiscidae), water mites *(Oribatida* spp.) and backswimmers *(Anisops*). All of these are typical of slow flowing or still waters, which are the main habitats of the Marne River and Saunders Creek in Spring and Autumn when flows are low or stopped.

A number of species were recorded that could be considered of conservation significance in the catchment. They include:

- a water scavenger beetle *Sternolophus marginicollis*, from the Marne River south of Cambrai (reach M6);
- a whirligig beetle *Dineutis australis*, from the North Rhine River;
- a diving beetle *Necterosoma penicillatum*, from the North Rhine River;
- a species of non-biting midge *Kiefferulus martini*, from Boehm's Spring (reach M1);

- six genera of water bugs from the families Hebridae (velvet water bugs), Naucoridae (creeping water bugs), Saldidae (shore bugs), Mesoveliidae (large water striders), Nepidae (needle bugs) and Hydrometridae (water measurers), all collected in the Marne River; and
- one species of caddis fly *Orphninotrichia maculata*, from the lower Marne River at Vicki's Spring (reach M8).

These species are considered to be rare or uncommon in South Australian streams and have only been recorded from a few other sites in the State.

Very few riffles were sampled within the catchment. When sampling of riffles did occur, most of them contained macro-invertebrates that are considered to be dependent on flowing water, such as the families Hydropsychidae (caddis flies), Simuliidae (black flies), Gripoterygidae (stonefly larvae) and some genera of Chironomidae (non-biting midge larvae).

Many of the species collected have a fully aquatic lifecycle and so are dependent on water being present in order to survive (e.g. flatworms, nematodes, snails, worms, mites, scuds, freshwater shrimp and springtails). In addition, direct connectivity between habitats through flowing water is required in order to colonise new habitats in the catchment as they occur (e.g. dry pools that refill with rain). Therefore, reductions in hydrological connectivity and frequent and extended drying of habitats such as riffles may restrict the composition of macro-invertebrate assemblages. Other macro-invertebrate species found in the area have an aerial adult phase in their life cycle. These species can colonise new areas as adults, even without direct connectivity.

The Australian River Assessment System assessment methodology provides a way of assessing the condition of macro-invertebrate communities in comparison with "reference condition". Reference condition represents what would be expected at the least disturbed sites within the local landscape. The agricultural landscapes in South Australia have all been subjected to some degree of disturbance. Therefore macro-invertebrate communities in reference condition in the Marne Saunders PWRA could be said to be in no worse condition than communities at reference sites in agricultural landscapes in South Australia, but this does not necessarily mean they are in undisturbed, natural condition. The ten sites sampled in the Marne catchment in 2001 - 2002 were found to be in reference condition or better, while the two sites sampled in the Saunders catchment in 1994 - 1995 were in reference condition or slightly impaired from reference condition.

Almost all of the sampling of macro-invertebrates in the Marne Saunders PWRA has focused on species found in water above the stream bed. However, macro-invertebrates and other organisms are also known to live within the flow that occurs within and below the streambed (hyporheic fauna) and also within aquifers (stygofauna). Streambeds and aquifers are likely to provide important habitats in the Marne Saunders PWRA, given the ephemeral nature of the surface water habitat. Recent limited sampling of these habitats has found hyporheic invertebrates, including some species that only live in this habitat (R. Leijs, personal communication, 2008).

3.3.3 Vegetation

Systematic surveying of vegetation has not been undertaken in the Marne Saunders PWRA, although information is available from state biological survey data, herbarium records and from species recorded at 38 sites visited during the Marne environmental water requirements project.

A total of 74 plant taxa have been recorded from riparian (streamside) and in-stream habitats in the Marne catchment and 46 from the Saunders. A significant number of these are introduced, with 20 recorded in the Marne catchment and 10 in the Saunders catchment. A number of species found in the Marne Saunders PWRA are considered to be of particular conservation significance in the Murray region (Lang and Kraehenbuehl, 2000), including:

- *Baumea arthrophylla* (Swamp Twig-rush) Rare
- *Baumea juncea* (Bare Twig-rush) Rare
- *Isolepis australiensis* (a club-rush) Rare
- *Isolepis fluitans* (Floating Club-rush) Threatened
- *Isolepis inundata* (Swamp Club-rush) Threatened
- *Isolepis nodosa* (Knobby Club-rush) Uncommon
- *Samolus repens* (Creeping Brookweed) Rare
- *Schoenoplectus pungens* (Spiky Club-rush) Uncommon
- *Vallisneria americana* (Ribbon Weed) Uncommon

The water-dependent vegetation of the Marne Saunders PWRA can be broadly grouped into in-stream (generally on the creek bed and banks) and riparian (generally on top of banks and floodplain) communities, although some species are likely to be found in both environments. Riparian communities commonly have an overstorey of trees and/or woody shrubs and an understorey of shrubs, herbs and/or grasses. River Red Gums (*Eucalyptus camaldulensis*) are found along the creeks in all reaches, together with other woody shrubs in some reaches like Short-leaf Honey Myrtle (*Melaleuca brevifolia*). River Red Gums are scattered more broadly on the floodplain of the Lower Marne (reach M7), including a significant floodplain forest and temporary wetlands in the Marne Valley Conservation Park. Small patches of River Box (*Eucalyptus largiflorens*) woodland are found higher on the floodplain in reach S4 and M9. Lignum (*Muehlenbeckia florulenta)* and samphire (*Halosarcia* and *Sarcocornia* species*)* shrublands are also associated with the River Murray floodplain at the mouth.

In-stream vegetation is dominated by reed-like plants (e.g. bulrushes (*Typha* species), Common Reed (*Phragmites australis*), sedges (*Cyperus* species), rushes (*Juncus* species), Marsh Club-Rush (*Bolboschoenus caldwelli*), spike rushes (*Eleocharis* species) and club-rushes (*Isolepis* species)) and some herbaceous species (e.g. Swamp Crassula (*Crassula helmsii*) and Creeping Monkey Flower (*Mimulus repens*)). More aquatic herbs and submerged plants are associated with pool habitats in reaches M2, M3, M4, M6, M8, M9, S1, S2 and S4 (e.g. Water Ribbons (*Triglochin procerum*), water milfoils (*Myriophyllum* species) and charophytes). The highest diversity in the Upper Marne was found in reaches M2 and M4 where the pools are more permanent and widespread. The Saunders Hills (reach S1) was the most diverse reach in the Saunders. The permanent, stable water levels of the Marne mouth wetland (reach M9) supported the highest diversity of truly submerged aquatic species, including Curly Pondweed (*Potamogeton crispus*), Fennel Pondweed (*Potamogeton pectinatus*) and Ribbon Weed (*Vallisneria americana*).

In-stream vegetation was generally most limited in reaches M1, M7 and S3, except for protected areas like Boehm's Spring at the top of M1 and the Marne Valley Conservation Park in M7. In-stream vegetation in M3 and M4 (along the North Rhine) was often dominated by salt-tolerant species.

The high energy gorge environments of reaches M5 and S2 have fewer herbaceous species due to the rocky substrate and scouring by high energy flows. The Marne Gorge was noted as having a high level of diversity over space. The diverse shape of the channel and range of flow levels in this reach allows plants with different water requirements to grow at different points on the elevation gradient (e.g. lower wetter habitats through to higher, drier habitats) within a relatively small channel area.

The highest diversity in the Marne catchment was found at the Black Hill Springs (reach M8) where the permanently flowing water and wide range of habitats (still and flowing water, amphibious and floodplain habitats) support the widest range of species.

Native vegetation has been extensively cleared or disturbed in the Marne Saunders PWRA. The current presence and distribution of water-dependent plants is driven by factors such as vegetation clearance, land management, stock impacts and invasion by exotic species in addition to the water regime. For example, a survey of 90 km of watercourses in the Upper Marne found that less than 2% of the surveyed watercourses had remnant vegetation in moderate to good condition, and 78% of the riparian vegetation was recorded as severely modified, dominated by exotic pasture grasses and scattered trees and/or native or exotic shrubs (Kotz *et al* 2000).

3.3.4 Other native water-dependent animals

A number of other water-dependent animals have been recorded from the Marne Saunders PWRA, including frogs (6 species), water-dependent reptiles (Red-bellied Black Snake (*Pseudechis porphyriacus*) and anecdotal observations of tortoises), water-dependent mammals (anecdotal observations of water rats (*Hydromys chrysogaster*)) and a range of water-dependent birds (30 species).

3.3.5 Key environmental assets

The permanently flowing spring-fed reaches of M8 and S4 in the Lower Marne and Saunders have been identified as key environmental assets of particular significance. The permanent flow of cool, clear water allows these habitats to support species that are uncommon within the South Australian Murray Darling Basin (in the case of the Black Hill Springs at M8) or within the catchment (in the case of the springs in the Lower Saunders at S4). Therefore these important assets need particular protection from the impacts of water resource development and water affecting activities under this Plan.

3.4 Objectives and environmental water requirements for assets

3.4.1 Setting environmental objectives

The next step in the process of determining environmental water requirements is to set environmental objectives for the identified ecological assets. The environmental objectives define the purpose for any environmental water requirement. An environmental objective is a general statement of the desired future condition of the particular ecological assets in the particular area, compared to the current condition. These environmental objectives can deal with the desired condition of individual species (such as a particular fish species, or a specific aquatic or riparian plant species), or might include an entire community (such as all migratory fish or a plant community).

Examples of environmental objectives are given below:

- maintain a self-sustaining population of River Blackfish in a particular river reach.
- restore the aquatic macro-invertebrate community in a particular river or reach.
- rehabilitate River Red Gum woodland communities in a particular floodplain.

The terminology of an environmental objective is important, as it expresses the desired condition of the asset in relation to the current state. The direction of an objective is usually expressed in terms of one of the targets given below.

- **Maintain –** keep the condition of the resource in its current state. This is usually used if the condition is healthy, but may be appropriate if the condition is declining and there is no way of improving it.
- **Restore** – move the condition of the resource back to natural conditions.
- **Rehabilitate –** move the condition of the resource to some better condition, but which is lower than or different to natural.

Where either the current composition or condition is unknown, objectives can be stated in terms of “**provide** conditions suitable for potential or predicted biota”.

It needs to be recognised that environmental objectives are not necessarily achievable or maintainable solely through environmental water provisions. For example, even if sufficient water is available for a self-sustaining population of River Blackfish, this goal may not be achieved if the water is polluted or habitats are destroyed. However, environmental water provisions are important as the water regime is the key driver for watercourse processes and thus certain water regime components must be provided in order to achieve the environmental objective.

The environmental objectives for the assets in each reach of the Marne Saunders PWRA are given in Table 4.

Table 4 Environmental objectives for assets in each reach.

Asset	Environmental objective
Reach M1 – Marne headwaters	
Water quality	• Restore or rehabilitate water quality delivered from the reach to downstream.
Geomorphology and significant features	• Maintain Boehm's Spring. • Maintain or rehabilitate channel shape and structure.
Reach M2 – Upper Marne pool-riffle channel	
Mountain Galaxias	• Maintain or restore a self-sustaining population of Mountain Galaxias.
Macro-invertebrate community composition	• Maintain macro-invertebrate community at reference condition in refuge areas. • Restore macro-invertebrate community to droughted areas.
In-stream plant community	• Maintain a high diversity aquatic plant community including *Myriophyllum*, *Mimulus* and *Triglochin* species. • Restore aquatic plant community to droughted areas.
Riparian plant community	• Restore riparian plant community.
Geomorphology	• Maintain channel shape and structure.
Reach M3 – North Rhine headwaters	
Riparian plant community	• Restore riparian plant community.
Water quality	• Restore or rehabilitate water quality delivered from the reach to downstream, particularly salinity (if current levels are determined to be unnatural).
Geomorphology	• Maintain or rehabilitate channel shape and structure.
Reach M4 – North Rhine main channel	
Mountain Galaxias	• Restore a self-sustaining population of Mountain Galaxias.
Macro-invertebrate community composition	• Maintain macro-invertebrate community at reference condition.
In-stream plant community	• Maintain *Triglochin* dominated pools.
Riparian plant community	• Restore riparian vegetation community.
Geomorphology	• Maintain channel shape and structure.
Reach M5 – Marne Gorge	
Mountain Galaxias	• Maintain or restore a self-sustaining population of Mountain Galaxias.
Macro-invertebrate community composition	• Maintain macro-invertebrate community at reference condition.
In-stream plant community	• Maintain high diversity aquatic plant community.
Riparian plant community	• Maintain high diversity riparian plant community.
Geomorphology and significant features	• Maintain gorge channel shape, substrate type and structure.
Reach M6 – Marne Alluvial Fan	
Macro-invertebrate community composition	• Maintain macro-invertebrate community at reference condition.

Asset	Environmental objective
In-stream plant community	• Maintain or restore submerged vegetation community.
Riparian plant community	• Rehabilitate riparian River Red Gum community.
Geomorphology	• Maintain channel shape and structure.
Reach M7 – Floodplain from Cambrai to Black Hill	
In-stream plant community	• Restore aquatic plant community to temporary wetlands in Marne Valley Conservation Park.
Riparian plant community	• Rehabilitate riparian River Red Gum community. • Maintain viable River Red Gum floodplain community in Marne Valley Conservation Park.
Geomorphology and significant features	• Maintain channel shape and structure. • Rehabilitate transmission of water through the reach. • Maintain or restore floodplain wetlands in Marne Valley Conservation Park.
Reach M8 – Lower Marne under spring influence	
River Blackfish	• Maintain a self-sustaining population of River Blackfish. • Restore a self-sustaining population of River Blackfish (to springs in the reach that have dried out).
Lower Marne fish community	• Maintain diversity, demographics and composition of lower Marne fish community.
Macro-invertebrate community composition	• Maintain macro-invertebrate community at reference condition.
In-stream plant community	• Maintain a high diversity aquatic plant community including *Phragmites* and *Typha* runs, without allowing dominance of the habitat (e.g. maintain areas of open water and varied sediment topography).
Geomorphology	• Maintain channel shape and structure.
Reach M9 – Marne under Murray influence	
Lower Marne fish community	• Maintain diversity and composition of lower Marne fish community. • Restore community of diadromous fish species.
Macro-invertebrate community composition	• Maintain macro-invertebrate community at reference condition.
In-stream plant community	• Maintain a high diversity aquatic plant community, without allowing dominance of the habitat (e.g. maintain areas of open water).
Geomorphology	• Maintain channel shape and structure.
Reach S1– Saunders Hills	
Small native fish community	• Provide suitable flow and habitat conditions for the maintenance of small native fish community.
Macro-invertebrate community composition	• Maintain macro-invertebrate community at reference condition for edges.
In-stream plant community	• Provide suitable flow and habitat conditions for the maintenance of in-stream plant community.
Riparian plant community	• Maintain or enhance riparian and floodplain River Red Gum and Honey Myrtle community.
Geomorphology	• Maintain channel shape and structure.
Reach S2 – Saunders Gorge	
Small native fish community	• Provide suitable flow and habitat conditions for the maintenance of small native fish community.
Macro-invertebrate community composition	• Maintain macro-invertebrate community at reference condition for edges. • Restore macro-invertebrate community to reference condition for riffles.
In-stream plant community	• Provide suitable flow and habitat conditions for the maintenance of in-stream plant community.
Riparian plant community	• Maintain or enhance the riparian River Red Gum and Honey Myrtle community.
Geomorphology and significant features	• Maintain gorge channel shape, substrate type and structure.

Table 4 continued

Reach S3 – Saunders Plains	
Riparian plant community	• Maintain or enhance the riparian River Red Gum community.
Geomorphology	• Maintain channel shape and structure. • Rehabilitate transmission of water through reach.
Reach S4 – Lower Saunders under spring influence	
Carp Gudgeon	• Maintain a self-sustaining population of Carp Gudgeon.
Macro-invertebrate community composition	• Provide suitable flow and habitat conditions for the maintenance of permanent flow macro-invertebrate community.
In-stream plant community	• Provide suitable flow and habitat conditions for the maintenance of in-stream plant community.
Riparian plant community	• Maintain or enhance the riparian River Red Gum and Honey Myrtle community.
Geomorphology	• Maintain channel shape and structure.

3.4.2 Identifying water requirements to achieve environmental objectives

An environmental objective for a living organism can only be achieved if certain ecological processes occur in the catchment. These can be:

- **habitat processes** such as maintaining a particular stream bed condition (e.g. particle size) that will provide a suitable physical environment for the species or community;
- **biological processes** (such as spawning, recruitment, migration, germination etc) associated with the asset that are important for the maintenance of a population; or
- **ecosystem processes** (such as the entrainment of leaf litter from the banks as part of catchment carbon cycling) that *indirectly* assist in achieving the objective.

Each of these processes can be linked to water-related events and flow components that need to be present for each of these processes to occur. It is these water-related events and flow components that make up the environmental water requirements of the living organism (or, more specifically, the environmental water requirements to achieve the environmental objective for that living organism).

In the case of environmental objectives for physical features and habitats, flows are important as drivers of processes that determine the characteristics of the physical features, such as erosion, sediment transport and deposition.

These water-related events and flow components can generally be described in terms of:

- the season in which they should occur; and
- the magnitude of the event, which can be described in terms of different levels called flow bands, as well as duration and frequency of the event.

Flow seasons and flow bands are described below.

3.4.2.1 Flow seasons

Many of the flow requirements that trigger events, particularly biological processes, can be tied to particular “flow seasons” during the year. These seasons do not refer to traditional seasons like summer, autumn, winter or spring, but rather to seasons based on the natural flow distribution during the year. These can be identified as four flow seasons, which are:

- **low flow season** - with generally constant low flows – or no flow - with infrequent shorter periods of high flow following rainfall;
- **high flow season** - with higher baseflow and frequent periods of much higher flows; and
- two **transitional flow seasons** - consisting of months between the low flow and high flow seasons, where low flows change to high flows and vice versa.

Analysis of the “natural” flow pattern of the Marne and Saunders shows that the flow seasons correspond to calendar months as outlined below.

- Low flow season — January, February, March, April, May
- Transitional flow season (low to high) — June, July
- High flow season — August, September, October
- Transitional flow season (high to low) — November, December

"Natural" flow refers to adjusted flow from the modelled no dams scenario. See section 4.2.1.2 for more information on flow modelling.

3.4.2.2 Flow bands

Within the natural flow seasons, the Environmental Water Requirements to be determined are described in terms of a number of different flow components as described below.

- Cease-to-Flows – when no flows are recorded in the channel. During these periods, the stream may contract to a series of pools or ponds, or may dry out completely.
- Low flows (low flow season) – the minimum flow that maintains water flowing through the channel, keeping in-stream habitats wet and pools full. The permanence of flow in a stream is a product of the combination of low flows and cease-to-flows as well as channel shape.
- Freshes (low flow season) – refers to small and short duration high flow events that last for one to several days as a result of localised rainfall during the low flow season.
- Low flows (transitional and high flow seasons) – the persistent increase in baseflow that occurs with the onset of the wet season (beginning in the transitional flow season (low to high), lasting through to the end of the transitional flow season (high to low)).
- Freshes (transitional and high flow season) – long, sustained increases in flow during the transitional and high flow season as a result of heavy rainfall events. These may last for a number of weeks, but are still contained within the channel.
- High flows (or bankfull flows) – flows that fill the channel, but do not spill onto the floodplain (can occur any time but more commonly are associated with the high flow season).
- High overbank flows – higher flows than the bankfull flows that spill out of the channel onto the floodplain (can occur any time but commonly are associated with the high flow season).

3.4.2.3 Environmental water requirements for each type of asset

The environmental water requirements of each type of asset in the Marne Saunders PWRA are shown in Table 5 to Table 7. These tables show the habitat, biological and ecosystem processes required to achieve the environmental objectives for each type of living asset, together with the water requirements that need to be present to allow these processes to occur in terms of flow seasons and flow components. For some assets, the environmental objectives and linked environmental water requirements are the same or similar in several reaches, so have been grouped by asset for the sake of simplicity.

The environmental water requirements for non-living assets such as water quality and geomorphology are covered by the processes relating to water quality and channel shape that are required to meet the environmental objectives for living assets.

Table 5 Environmental water requirements to meet objectives for vegetation.

Asset and reach: In-stream plant communities in the Upper Marne, North Rhine, Upper Saunders, gorges and alluvial fan (Reaches M2, M4, M5, M6, S1 and S2)	
Environmental objectives: • Maintain a high diversity aquatic plant community (Reaches M2, M4 and M5) • Restore aquatic plant communities to droughted areas (Reach M2) • Maintain or restore submerged vegetation community in the alluvial fan (Reach M6) • Provide suitable flow and habitat conditions for the maintenance of in-stream plant communities (Reach S1 and S2).	
Habitat processes	***Water requirements***
Habitat availability	• Zero flows and low flows at a frequency and duration that provide persistence of water in pools throughout the year[5]
Water quality in pools	• Freshes during the low flow season that refill pools or refresh water quality
Habitat quality	• Freshes and high flows that prevent sedimentation of pools throughout the year
Habitat diversity	• High flows that occur at a frequency and duration to maintain a diversity of habitats and create new habitats by disturbance
Deep pool structure in Reaches M2, M4, S1 and S2.	• High channel forming flows that occur at a frequency and duration to maintain channel form
Biodiversity processes	***Water requirements***
Spread of seed or propagules	• Freshes or high flows that move seed & propagules between pools

Asset and reach: In-stream plant communities in the Lower Marne and Lower Saunders (Reaches M8, M9 and S4)	
Environmental objectives: • Maintain a high diversity aquatic plant community, without allowing dominance of the habitat (Reaches M8 and M9) • Provide suitable flow and habitat conditions for the maintenance of in-stream plant community (Reach S4)	
Habitat processes	***Water requirements***
Habitat availability	• Permanent water in pools throughout the year
Habitat diversity	• High flows that occur at a frequency and duration to maintain a diversity of habitats, create new habitats by disturbance and prevent excessive sedimentation
Deep pool structure in the lower Marne River	• High channel forming flows that occur at a frequency and duration to maintain channel form
Biodiversity processes	***Water requirements***
Spread of seed or propagules	• Freshes or high flows that move seed & propagules between pools

[5] "Persistence" means that water must be retained in pools somewhere in the reach throughout each year, not necessarily in every pool, and not even necessarily in the same pool from year to year. However, it needs to be recognised that the ecological function of persistent natural pools cannot be replaced by permanent un-natural pools.

<table>
<tr><th colspan="2">Asset and reach: Riparian plant communities in the Upper Marne, North Rhine and Upper Saunders and gorges (Reaches M2, M3, M4, M5, S1 and S2)</th></tr>
<tr><td colspan="2">Environmental objectives:
Restore riparian plant communities in the Upper Marne and North Rhine (Reaches M2, M3 and M4)
Maintain high diversity riparian plant communities in the Marne Gorge (Reach M5)
Maintain or enhance riparian and floodplain River Red Gum and Honey Myrtle communities (Reaches S1 and S2)</td></tr>
<tr><td>Habitat processes</td><td>Water requirements</td></tr>
<tr><td>Inundation of riparian zone in the Marne Gorge</td><td>Variable overbank flows that maintain a mosaic of water regimes</td></tr>
<tr><td>Water source in the Upper Marne and North Rhine sub-catchments</td><td>Zero flows and low flows at a frequency and duration that provide water in pools throughout the year
Freshes during the low flow season that refill pools or refresh water quality
Overbank flows or occasional freshes during the low flow season to replenish riparian soil moisture</td></tr>
<tr><td>Biodiversity processes</td><td>Water requirements</td></tr>
<tr><td>Recruitment</td><td>High overbank flows that occur at a frequency and duration to regularly flood River Red Gum habitats and support recruitment of new individuals to reproductive adults</td></tr>
</table>

<table>
<tr><th colspan="2">Asset and reach: Riparian and floodplain River Red Gum communities in the Lower Marne and Lower Saunders (Reaches M6, M7, S3 and S4)</th></tr>
<tr><td colspan="2">Environmental objectives:
Rehabilitate riparian and floodplain River Red Gum communities (Reaches M6 and M7)
Maintain viable River Red Gum floodplain community in Marne Valley Conservation Park (Reach M7)
Maintain or enhance riparian and floodplain River Red Gum and Honey Myrtle communities (Reaches S3 and S4)</td></tr>
<tr><td>Habitat processes</td><td>Water requirements</td></tr>
<tr><td>Water source</td><td>Underground water level within reach of tree roots
High in-channel and high overbank flows that replenish local underground water sources
High overbank flows that occur at a frequency and duration to regularly flood the Marne Valley Conservation Park</td></tr>
<tr><td>Biodiversity processes</td><td>Water requirements</td></tr>
<tr><td>Recruitment</td><td>High overbank flows that occur at a frequency and duration to regularly flood River Red Gum habitats and support recruitment of new individuals to reproductive adults</td></tr>
</table>

Table 6 Environmental water requirements to meet objectives for fish.

Asset and reach: Mountain Galaxias in the Upper Marne, North Rhine and Marne Gorge (Reaches M2, M4 and M5)	
Environmental objective: • Maintain or restore self-sustaining populations of Mountain Galaxias in the Upper Marne pool-riffle channel, North Rhine main channel and Marne Gorge reaches	
Habitat processes	***Water requirements***
Habitat availability	• Zero flows and low flows at a frequency and duration that provide persistence of water in pools throughout the year. Freshes during the low flow season that refill pools are also important
Water quality	• Freshes during the low flow season that refresh water quality
Deep pool structure in the upper Marne sub-catchment	• Bankfull channel forming flows that occur at a frequency and duration to maintain channel form in the Upper Marne
Habitat quality	• Freshes and high flows that prevent sedimentation of pools throughout the year
Clean substrate for egg deposition following spawning	• Freshes during the low flow season and transitional flow season (low to high)
Biodiversity processes	***Water requirements***
Recolonisation of vacant habitats and mixing of extant populations	• Occasional freshes that allow movement between pools over relatively short distances, particularly in the late low flow season and transitional flow season (low to high) • Sustained high flows that allow movement between pools over relatively long distances during transitional and high flow seasons
Spawning trigger	• Increase in flows over transitional flow season (low to high)

Asset and reach: River Blackfish in the Lower Marne (Reach M8)	
Environmental objective: • Maintain or Restore self-sustaining populations of River Blackfish in the lower Marne under spring influence reach	
Habitat processes	***Water requirements***
Habitat availability	• Zero flows and low flows at a frequency and duration that provide permanent water in pools throughout the year
Habitat diversity (prevent encroachment of vegetation)	• High flows that occur at a frequency and duration to prevent vegetation encroachment
Deep pool structure in the lower Marne sub-catchment	• High channel forming flows that occur at a frequency and duration to maintain channel form
Biodiversity processes	***Water requirements***
Recolonisation of vacant habitats and mixing of extant populations	• Low flows or occasional freshes that allow movement between pools over relatively short distances

Asset and reach: Fish communities in the lower Marne (Reaches M8 and M9)	
Environmental objectives: • Maintain diversity, demographics and composition of the lower Marne fish community • Restore community of diadromous fish species	
Habitat processes	***Water requirements***
Habitat availability	• Zero flows and low flows at a frequency and duration that provide permanent water in pools throughout the year
Habitat diversity (prevent encroachment of vegetation)	• High flows that occur at a frequency and duration to prevent vegetation encroachment
Deep pool structure in the lower Marne sub-catchment	• High channel forming flows that occur at a frequency and duration to maintain channel form

Asset and reach: Fish communities in the lower Marne continued	
Biodiversity processes	***Water requirements***
Recolonisation of vacant habitats and mixing of extant populations	• Low flows or occasional freshes that allow movement between pools over relatively short distances
Attractant flows for diadromous fish species from the River Murray	• High flows at the natural time of year for diadromous fish

Asset and reach: Small native fish in the Upper Saunders and Gorge (Reaches S1 and S2)	
Environmental objectives: • Provide suitable flow and habitat conditions for the maintenance of small native fish communities	
Habitat processes	***Water requirements***
Available habitat	• Zero flows and low flows at a frequency and duration that provide persistent water in pools throughout the year
Available habitat	• High flows to maintain channel form and pool structure (Reach S1 only), mainly occurring in the high flow season
Habitat quality	• Freshes and high flows that prevent sedimentation of pools throughout the year
Adequate water quality	• Occasional freshes in the low flow season that mix and refresh pool quality
Clean substrate for egg deposition	• Freshes during the late low flow season and transitional flow season (low to high) leading up to breeding
Presence of habitat diversity	• High flows that prevent vegetation encroachment into pools, mainly occurring in the high flow season
Biodiversity processes	***Water requirements***
Spawning trigger	• Increase in flows over transitional flow season (low to high)
Mixing and spread of populations	• Occasional freshes that allow movement between pools over relatively short distances, particularly in the late low flow season or transitional flow season (low to high) leading up to breeding

Asset and reach: Carp Gudgeon in lower Saunders under spring influence (Reach S4)	
Environmental objectives: • Maintain a self-sustaining population of Carp Gudgeon in Saunders Creek (Reach S4)	
Habitat processes	***Water requirements***
Available habitat	• Low flows provide permanent water in pools throughout the year (i.e. no zero flows)
Available habitat	• High flows to maintain channel form and pool structure, mainly occurring in the high flow season
Habitat quality	• Freshes and high flows that prevent sedimentation of pools throughout the year
Adequate water quality	• Low flows provide permanent flowing water in pools throughout the year (i.e. no zero flows) • Occasional freshes in the low flow season that mix and refresh pool quality
Clean substrate for egg deposition	• Freshes during spring and summer (the transitional flow season (high to low) and low flow season)
Presence of habitat diversity	• High flows that prevent vegetation encroachment into pools, mainly occurring in the high flow season
Biodiversity processes	***Water requirements***
Mixing and spread of populations	• Occasional freshes that allow movement between pools over relatively short distances, particularly in the low flow season during breeding

Table 7 Environmental water requirements to meet objectives for macro-invertebrates.

Asset and reach: Aquatic macro-invertebrates in the Upper Marne and Upper Saunders main channels (Reach M2, M4 and S1)	
Environmental objectives: • Maintain macro-invertebrate communities at reference condition • Restore macro-invertebrate communities to droughted areas	
Habitat processes	***Water requirements***
Habitat availability	• Zero flows and low flows at a frequency and duration that provide persistence of water in pools throughout the year • Regular flows across riffles throughout the year, with some extended periods of flow
Water quality in pools	• Freshes during the low flow season that refill pools or refresh water quality
Habitat diversity and quality	• Freshes that clean sediment from riffle substrate • Freshes and high flows that prevent sedimentation of pools throughout the year
Deep pool structure	• High channel forming flows that occur at a frequency and duration to maintain channel form and deep pool structure
Biodiversity processes	***Water requirements***
Recolonisation of vacant habitats and mixing of extant populations	• Low flows or occasional freshes that allow movement between pools by fully aquatic species over relatively short distances
Ecosystem processes	***Water requirements***
Delivery of riparian organic material to streams	• High overbank flows, mainly occurring in the high flow season

Asset and reach: Aquatic macro-invertebrates in the Marne Gorge and Alluvial Fan (Reach M5 and M6) and Saunders Gorge (S2)	
Environmental objectives: • Maintain macro-invertebrate community at reference condition • Restore macro-invertebrate community to reference condition for riffle habitats (Reach S2)	
Habitat processes	***Water requirements***
Habitat availability	• Zero flows and low flows at a frequency and duration that provide persistence of water in pools throughout the year • Regular flows across riffles throughout the year, with some extended periods of flow
Water quality in pools	• Freshes during the low flow season that refill pools or refresh water quality
Habitat diversity and quality	• High flows that occur at a frequency and duration to maintain pool habitat structure • Freshes that clean sediment from riffle substrate
Pool/riffle structure	• High channel forming flows that occur at a frequency and duration to maintain channel form
Biodiversity processes	***Water requirements***
Recolonisation of vacant habitats and mixing of extant populations	• Low flows or occasional freshes that allow movement between pools and riffles by fully aquatic species over relatively short distances
Ecosystem processes	***Water requirements***
Delivery of riparian organic material to streams	• High overbank flows, mainly occurring in the high flow season

Asset and reach: Aquatic macro-invertebrates in the Lower Marne and Lower Saunders (Reach M8, M9 and S4)	
Environmental objectives: • Maintain macro-invertebrate community at reference condition (Reaches M8 and M9) • Provide suitable flow and habitat conditions for the maintenance of permanent flow macro-invertebrate community (Reach S4)	
Habitat processes	***Water requirements***
Habitat availability	• Permanent water in pools throughout the year
Habitat diversity (prevent encroachment of vegetation)	• High flows that occur at a frequency and duration to prevent vegetation encroachment
Deep pool structure	• High channel forming flows that occur at a frequency and duration to maintain channel form
Biodiversity processes	***Water requirements***
Recolonisation of vacant habitats and mixing of extant populations	• Low flows or occasional freshes that allow movement between pools by fully aquatic species over relatively short distances

Significant features

Water requirements for the wetlands in the Marne Valley Conservation Park (Reach M7) in terms of the aquatic plant community and the geomorphology of the wetlands are covered by the requirements for the floodplain River Red Gum community.

Water requirements for the protection of the structure of the Marne and Saunders Gorges (Reaches M5 and S2) are covered by the very high flows for a number of biodiversity assets in the gorges (fish, macro-invertebrates, riparian plants).

No specific water requirements can be derived for the protection of Boehm's Spring (Reach M1) as the flora and fauna of the spring has not been adequately surveyed. However, as it is at the head of the catchment, the best management would be to prevent any local activity that would have an impact on the natural water regime or water quality of the spring.

3.5 Environmental water requirements for each reach

The next step is to describe the total environmental water requirements of each environmental reach. A summary of water requirements can be compiled for each reach by combining the environmental water requirements for each of the assets found there, as shown in Table 8. This table also shows the likely key water source(s) for each requirement in terms of runoff (surface water and/or watercourse water), baseflow (underground water discharged to the surface and/or watercourse) and/or underground water.

Many of the specific flow requirements are common to a number of assets. For example, high flows that maintain pool structure are important for a range of assets including fish, macro-invertebrates and in-stream plant communities. Table 8 summarises the environmental water requirements of each reach by each flow requirement that maintains a certain process. This means that a number of environmental objectives within a reach may be achieved by the same environmental water provision.

Table 8 Summary of environmental water requirements for each reach.

Environmental water requirements	Key source
Summary of environmental water requirements for Reach M1	
No specific environmental water requirements are proposed for Reach M1 (upper Marne headwaters) due to current lack of in-stream or flow dependent assets. One objective for the reach is to rehabilitate the channel shape and structure. It is assumed this process will occur by delivering additional water allocated for downstream ecological assets. Another objective for the reach is to ensure the delivery of high quality water to downstream reaches. This is primarily a product of local land-use management (e.g. chemicals and sediment management).	Runoff
However, Boehm's Spring is a significant ecological asset within the reach and should be managed so that any local activity does not alter the natural water regime or water quality of the springs.	Baseflow
Summary of environmental water requirements for Reach M2	
Zero flows and low flows at a frequency and duration that provide water in pools throughout the year.	Runoff, baseflow
Regular flows across riffles throughout the year, with some extended periods of flow.	Runoff, baseflow
Freshes during the low flow season that refill pools or refresh water quality.	Runoff
Low flows or occasional freshes that allow macro-invertebrate movement between pools and riffles by fully aquatic species over relatively short distances.	Runoff, baseflow
Freshes that allow fish movement between pools over relatively short distances, particularly in the late low flow season or transitional flow season (low to high).	Runoff
Freshes that clean sediment from riffle substrate during low flow season and transitional flow season (low to high) for cleaning substrate for fish egg deposition, and throughout the year to improve habitat quality for macro-invertebrates.	Runoff
Freshes or high flows that move seeds or propagules between pools.	Runoff
Freshes or high flows that prevent sedimentation of pools throughout the year.	Runoff
Increase in flows over transitional flow season (low to high) as a fish spawning trigger.	Runoff, baseflow
High flows that allow fish movement between pools over relatively long distances.	Runoff
High flows that occur at a frequency and duration to maintain pool habitat structure.	Runoff
High flows that occur at a frequency and duration to maintain a diversity of habitats, create new habitats by disturbance and prevent excessive sedimentation.	Runoff
High channel forming flows that occur at a frequency and duration to maintain channel form.	Runoff
High overbank flows to deliver riparian organic material, mainly occurring in the high flow season.	Runoff
High overbank flows to regularly flood River Red Gum habitats to support recruitment of new individuals, mainly occurring in the high flow season.	Runoff
Summary of environmental water requirements for Reach M3	
No specific environmental water requirements are proposed for Reach M3 (upper North Rhine headwaters) due to current lack of flow dependent assets. One objective for the reach is to rehabilitate the channel shape and structure. It is assumed this process will occur by delivering additional water allocated for downstream ecological assets. Another objective for the reach is to ensure the delivery of high quality water to downstream reaches. This is primarily a product of local land-use management (e.g. sediments and salinity management).	Runoff
Summary of environmental water requirements for Reach M4	
Zero flows and low flows at a frequency and duration that provide water in pools throughout the year.	Runoff, baseflow
Regular flows across riffles throughout the year, with some extended periods of flow.	Runoff, baseflow
Freshes during the low flow season that refill pools or refresh water quality.	Runoff
Low flows or occasional freshes that allow macro-invertebrate movement between pools and riffles by fully aquatic species over relatively short distances.	Runoff, baseflow
Freshes that allow fish movement between pools over relatively short distances, particularly in the late low flow season or transitional flow season (low to high).	Runoff
Freshes that clean sediment from riffle substrate during low flow season and transitional flow season (low to high) for cleaning substrate for fish egg deposition, and throughout the year to improve habitat quality for macro-invertebrates.	Runoff

Environmental water requirements	Key source
Summary of environmental water requirements for Reach M4 continued	
Freshes or high flows that move seeds or propagules between pools.	Runoff
Freshes or high flows that prevent sedimentation of pools throughout the year.	Runoff
Increase in flows over transitional flow season (low to high) as a fish spawning trigger.	Runoff, baseflow
Medium flows or freshes that replenish riparian soil moisture during low flow periods.	Runoff, baseflow
High flows that allow fish movement between pools over relatively long distances.	Runoff
High flows that occur at a frequency and duration to maintain pool habitat structure.	Runoff
High flows that occur at a frequency and duration to maintain a diversity of habitats, create new habitats by disturbance and prevent excessive sedimentation.	Runoff
High channel forming flows that occur at a frequency and duration to maintain channel form.	Runoff
High overbank flows to deliver riparian organic material, mainly occurring in the high flow season.	Runoff
High overbank flows to regularly flood River Red Gum habitats to support recruitment of new individuals, mainly occurring in the high flow season.	Runoff
Summary of environmental water requirements for Reach M5	
Zero flows and low flows at a frequency and duration that provide water in pools throughout the year.	Runoff, baseflow
Regular flows across riffles throughout the year, with some extended periods of flow.	Runoff, baseflow
Freshes during the low flow season that refill pools or refresh water quality.	Runoff
Low flows or occasional freshes that allow macro-invertebrate movement between pools and riffles by fully aquatic species over relatively short distances.	Runoff, baseflow
Freshes that allow fish movement between pools over relatively short distances, particularly in the late low flow season or transitional flow season (low to high).	Runoff
Freshes that clean sediment from riffle substrate during low flow season and transitional flow season (low to high) for cleaning substrate for fish egg deposition, and throughout the year to improve habitat quality for macro-invertebrates.	Runoff
Freshes or high flows that move seeds or propagules between pools.	Runoff
Freshes or high flows that prevent sedimentation of pools throughout the year.	Runoff
Increase in flows over transitional flow season (low to high) as a fish spawning trigger.	Runoff, baseflow
High flows that allow fish movement between pools over relatively long distances.	Runoff
Variable high and overbank flows that differentially inundate the riparian zone.	Runoff, baseflow
High flows that occur at a frequency and duration to maintain pool habitat structure.	Runoff
High channel forming flows that occur at a frequency and duration to maintain channel form.	Runoff
High overbank flows to deliver riparian organic material, mainly in the high flow season.	Runoff
High overbank flows to regularly flood River Red Gum habitats to support recruitment of new individuals, mainly occurring in the high flow season.	Runoff
Summary of environmental water requirements for Reach M6	
Zero flows and low flows at a frequency and duration that provide water in pools throughout the year.	Runoff, baseflow
Regular flows across riffles throughout the year, with some extended periods of flow.	Runoff, baseflow
Low flows or occasional freshes that allow macro-invertebrate movement between pools and riffles by fully aquatic species over relatively short distances.	Runoff, baseflow
Freshes during the low flow season that refill pools or refresh water quality.	Runoff
Freshes that clean sediment from riffle substrate to improve habitat quality.	Runoff
Medium flows or freshes that replenish riparian soil moisture during low flow periods.	Runoff, baseflow
High flows that occur at a frequency and duration to maintain pool habitat structure.	Runoff
High channel forming flows that occur at a frequency & duration to maintain channel form.	Runoff
High and overbank flows that replenish local underground water sources.	Runoff
High overbank flows that occur at a frequency and duration to regularly flood River Red Gums.	Runoff

Table 8 continued

Environmental water requirements	**Key source**
Summary of environmental water requirements for Reach M7	
Underground water level within reach of tree roots.	Underground water
Medium flows or freshes that replenish riparian soil moisture during low flow periods.	Runoff, baseflow
High and overbank flows that replenish local underground water sources.	Runoff
High and overbank flows that occur at a frequency and duration to regularly flood the Marne Valley Conservation Park.	Runoff
High and overbank flows that occur at a frequency and duration to regularly flood River Red Gum habitats.	Runoff
Summary of environmental water requirements for Reach M8	
Water in pools throughout the year.	Baseflow, runoff
Low flows or occasional freshes that allows movement of fish and macro-invertebrates between pools over relatively short distances.	Baseflow, runoff
Freshes or high flows that move seeds or propagules between pools.	Runoff
High flows that occur at a frequency and duration to prevent vegetation encroachment.	Runoff
High flows that occur at a frequency and duration to maintain a diversity of habitats, create new habitats by disturbance and prevent excessive sedimentation.	Runoff
High channel forming flows that occur at a frequency and duration to maintain channel form.	Runoff
Summary of environmental water requirements for Reach M9	
Water in pools throughout the year.	Runoff, baseflow, Murray
Low flows or occasional freshes that allows movement of fish and macro-invertebrate between pools over relatively short distances.	Runoff, baseflow, Murray
Freshes or high flows that move seeds or propagules between pools.	Runoff
High flows that occur at a frequency and duration to prevent vegetation encroachment.	Runoff
High flows that occur at a frequency and duration to maintain a diversity of habitats, create new Habitats by disturbance and prevent excessive sedimentation.	Runoff
High channel forming flows that occur at a frequency and duration to maintain channel form.	Runoff
High flows at natural time of year for diadromous fish.	Runoff
Summary of environmental water requirements for Reach S1	
Zero flows and low flows at a frequency and duration that provide persistent water in pools throughout the year.	Runoff, baseflow
Freshes, mainly in the low flow season, that refill pools or refresh water quality.	Runoff
Freshes during the low flow season to clean substrates for fish egg deposition.	Runoff
Freshes that allow fish movement between pools over relatively short distances, particularly in the late low flow season or transitional flow season (low to high).	Runoff
Freshes throughout the year that allow macro-invertebrate movement between pools over short distances.	Runoff
Increase in flows between the Low and high flow seasons to trigger fish spawning.	Runoff, baseflow
Freshes or high flows in Spring/Summer that move seeds or propagules between pools.	Runoff
Freshes or high flows that prevent sedimentation of pools throughout the year.	Runoff
High flows to prevent domination by few plant species, through encroachment, mainly occurring in the high flow season.	Runoff
High channel forming flows to maintain channel form and pool structure, mainly occurring in the high flow season.	Runoff
High overbank flows to regularly flood River Red Gum habitats to support recruitment of new individuals, mainly occurring in the high flow season.	Runoff
High overbank flows to deliver riparian organic material, mainly occurring in the high flow season.	Runoff

Environmental water requirements	Key source
Summary of environmental water requirements for Reach S2	
Zero flows and low flows at a frequency and duration that provide persistent water in pools throughout the year.	Runoff, baseflow
Low flows that provide regular and extended flows across riffles throughout the year.	Runoff, baseflow
Freshes throughout the year that clean sediment from riffle substrate.	Runoff
Freshes, mainly in the low flow season, that refill pools or refresh water quality.	Runoff
Freshes during the low flow season to clean substrates for fish egg deposition.	Runoff
Freshes that allow fish movement between pools over relatively short distances, particularly in the late low flow season or transitional flow season (low to high).	Runoff
Freshes throughout the year that allow macro-invertebrate movement between pools and riffles over short distances.	Runoff
Increase in flows between the low and high flow seasons to trigger fish spawning.	Runoff, baseflow
Freshes or high flows in Spring/Summer that move seeds or propagules between pools.	Runoff
Freshes or high flows that prevent sedimentation of pools throughout the year.	Runoff
High flows to prevent domination by few plant species, through encroachment, mainly occurring in the high flow season.	Runoff
High overbank flows to regularly flood River Red Gum habitats to support recruitment of new individuals, mainly occurring in the high flow season.	Runoff
High overbank flows to deliver riparian organic material, mainly occurring in the high flow season.	Runoff
Summary of environmental water requirements for Reach S3	
Medium or high flows that replenish local underground water sources.	Runoff
High overbank flows to regularly flood River Red Gum habitats to support recruitment of new individuals, mainly occurring in the high flow season.	Runoff
Summary of environmental water requirements for Reach S4	
Low flows that provide permanent water in pools throughout the year (i.e. no zero flow events).	Baseflow, runoff
Freshes that refresh water quality, particularly in the low flow season.	Runoff
Freshes that allow movement of fish and macro-invertebrates between pools over relatively short distances, particularly in the low flow season during Carp Gudgeon breeding.	Runoff
Freshes or high flows in Spring/summer that move seeds or propagules between pools.	Runoff
Freshes during spring and summer (the transitional flow season (high to low) and the low flow season), that clean substrate for Carp Gudgeon egg deposition.	Runoff
High flows to prevent domination by few plant species, through encroachment, mainly occurring in the high flow season.	Runoff
High channel forming flows to maintain channel form and pool structure, mainly occurring in the high flow season.	Runoff
High overbank flows to regularly flood River Red Gum habitats to support recruitment of new individuals, mainly occurring in the high flow season.	Runoff

3.6 Representing environmental water requirements as flow metrics

The environmental water requirements of the Marne Saunders PWRA cover a range of flow bands and water levels in different flow seasons, as outlined above. It is important to note that this analysis does not simply advocate the natural flow regime as the environmental water requirements for the area. The environmental objectives can still be met provided that the identified flow events occur at a frequency and duration that maintains the linked processes. The natural flow regime will best achieve these frequencies and durations, but flow can deviate from natural (e.g. fewer events or shorter durations) without significantly altering the environmental benefits of the flows.

Specific thresholds linked to particular events have not yet been identified in the Marne Saunders PWRA, and cannot be determined for any single stream without extensive data and study. However, it is important to represent the environmental water requirements in a quantitative manner, so that the effectiveness of different management approaches for providing water for the environment can be assessed and compared.

The approach that has been taken to quantify the environmental water requirements in the Marne Saunders PWRA is to identify a range of surrogate flow statistics or metrics that can be related to the important environmental water requirements. The long-term average value of these flow metrics can be compared under "natural" (adjusted flow from the modelled no dams scenario) and current conditions, or with modelled flow resulting from a given management approach ("test case" conditions). The deviation of these surrogate flow metrics under current or test-case conditions from the "natural" values gives information on the degree of environmental stress caused by the change, with higher deviation from "natural" associated with higher environmental stress. This deviation from "natural" can therefore be used to assess the ability of the flow metric to meet the requirements for any environmental objective.

This section outlines the flow metrics that were identified and how the level of environmental stress under a given set of conditions can be assessed. This metric-based approach focuses on surface flow measures, which incorporates baseflow to some extent. The requirements for underground water are poorly understood and are thought to relate largely to maintaining the underground water level within reach of vegetation.

3.6.1 Identification of ecologically important flow metrics

A number of key hydrological variables or flow metrics associated with the environmental objectives have been identified for each flow season. They capture important flow properties (volume, pattern, variability and connectivity) for each season with understandable and simply calculated parameters. These flow metrics are outlined below by flow season.

3.6.1.1 Low flow season (January-May)

In the low flow season, almost all the identified environmental water requirements are related to maintaining the persistence of water in pools. This is primarily related to the frequency and duration of zero flows, the frequency and duration of freshes and the presence of low flow periods. Surrogate measures for these environmental water requirements are shown in Table 9.

Table 9 Selected key flow metrics in the low flow season.

Low flow season	Rationale
Average daily flow	A measure of total seasonal volume.
Median daily flow	A surrogate measure of low flows.
80^{th} percentile flow	A surrogate measure of low flows.
Zero flows – number of events per 100 years	A measure of how often pools become isolated. A measure of 0.1 ML/day is used as effectively zero flow.
Zero flows – median duration of individual spell events	A measure of how long pools are isolated. Increases in zero flow durations increase stress on the system.
Freshes – number of events per 100 years	A measure of refreshing pools and flushing sediment. A surrogate measure for freshes has been defined as flows over the median daily flow in the low flow season.
Freshes – median duration of individual spell events	A measure of refreshing pools and flushing sediment.

3.6.1.2 Transitional flow seasons (June-July and November-December)

In the transitional flow season (low to high), the major identified environmental water requirements relate to the seasonal increase in baseflow and the frequency and duration of freshes (for Mountain Galaxias breeding, migration and egg deposition site condition). While natural zero flows still occur in these seasons, measures are needed to determine whether the frequency or duration of these components have changed.

In the transitional flow season (high to low), it is important that zero flows are not introduced too early, related to the seasonal decrease in baseflow. Freshes are important to fill pools in preparation for the on-coming low flow season.

Surrogate measures for these environmental water requirements are shown in Table 10.

Table 10 Selected key flow metrics in the transitional flow seasons.

Transitional flow seasons (both)	Rationale
Average daily flow	A measure of total seasonal volume. Also a surrogate measure of seasonal increase/decrease in baseflow.
Median daily flow	A surrogate measure of seasonal increase/decrease in baseflow.
Zero flows – number of events per 100 years	A measure of changes in low flows and how often pools become isolated. A measure of 0.1 ML/day is used as effectively zero flow.
Zero flows – median duration of individual spell events	A measure of how long pools are isolated. Increases in zero flow durations increase stress on the system.
Freshes - number of events per 100 years	Surrogate measures of longitudinal connectivity, breeding triggers and sediment flushing. A surrogate measure for freshes has been defined as flows over the median daily flow in the transitional flow season.
Freshes – median duration of individual spell events	Surrogate measures of longitudinal connectivity, breeding triggers and sediment flushing.

3.6.1.3 High flow season (August – October)

Environmental water requirements in the high flow season are mainly concerned with providing persistence of water, providing for longitudinal connectivity (for fish, macro-invertebrate and plant seed re-distribution) producing disturbance (up to bankfull flows maintaining channel form), and overbank flows (carbon cycling). Specifically, the variability of flows in the gorges is important for riparian vegetation maintenance. Surrogate measures for these environmental water requirements are shown in Table 11.

Table 11 Selected key flow metrics in the high flow season.

High flow season	Rationale
Average daily flow	A surrogate measure for total seasonal volume.
Median daily flow	A surrogate measure of water persistence and longitudinal connectivity.
Coefficient of Variation (Cv)	A measure of flow variability.
Freshes - number of events per 100 years	Surrogate measures of longitudinal connectivity and low level disturbance. A surrogate measure for freshes has been defined as flows over the median daily flow in the high flow season.
Freshes – median duration of individual spell events	
High flows - number of events per 100 years	Surrogate measures for bankfull and overbank flows relating to lateral connectivity and disturbance flows. A surrogate measure is defined as the frequency and duration of flows over the 10th percentile exceedence flow.
High flows – median duration of individual spell events	Surrogate measures for bankfull and overbank flows relating to lateral connectivity and disturbance flows.

3.6.2 Assessment of environmental stress through flow deviation analysis

The level of environmental stress resulting from test case conditions can be assessed by comparing the long-term average value for each of the flow metrics under those conditions with the value for that metric under “natural” flows (adjusted flows from the modelled no dams scenario). The percentage change between the flow metric value for “natural” and test case conditions is transformed into a rating between 0 and 3, in accordance with Table 12.

For example, if the median duration of zero flow events in the low flow season is 50 days under natural conditions and 100 days under current conditions, then the percentage difference from current to natural is 200%. This percentage difference has a rating of 2 according to Table 12.

It is necessary for Table 12 to provide for both a decrease in the value of a test case flow metric compared to "natural" as well as an increase. For example, when dams are constructed it is common that the duration of freshes during the low flow season decreases while the duration of zero flow increases as the majority of runoff is trapped in dams during this period.

Table 12 Rating system used to assess reductions and increases in key flow metrics.

Test case metric value as a % of "natural" metric value		Rating
Decrease	**Increase**	
90-100	100-149	0
70-89	150-199	1
50-69	200-399	2
<50	=>400	3

These ratings can be equated to the degree of environmental stress caused by the change, and hence the ability of the flow metric to meet the requirements for any environmental objective. In general, a rating of 0 would imply very low stress, a rating of 1 would imply low stress, a rating of 2 would imply moderate stress and a rating of 3 would imply high stress. The environmental objectives are unlikely to be met when most of the relevant flow metrics have a rating of 3. Conversely, the environmental objectives are likely to be met where all of the relevant flow metrics have a rating of 0 or 1.

These surrogate measures for quantifying environmental water requirements are used in section 4.2.3 to identify key impacts of current water resource development on environmental water requirements, and in section 4.3.2 to set environmental water provisions and to identify an acceptable water management regime that meets these provisions.

3.7 Environmental water quality requirements

Water quality plays an important role in determining the nature and condition of water-dependent ecosystems. Water quality issues of particular local significance include dissolved oxygen, salinity, temperature, suspended solids and nutrients.

Water quality is linked with water regime in many complex ways, and water quality objectives are often included as implicit components of flow regimes. For example, cool baseflows may maintain water temperature within ecosystem tolerance; high flows move organic matter from banks, riparian areas and floodplain into channels; and freshes flowing through riffles increase oxygen concentrations in pools and dilute salts. A significant number of the processes and associated water requirements in Table 5, Table 6 and Table 7 are linked to such water quality requirements.

Specific targets for environmental water quality parameters have not been identified for the Marne Saunders PWRA, besides the process requirements and linked water requirements to meet the objectives in Table 5, Table 6 and Table 7. In the absence of knowledge of specific tolerances and requirements of local water-dependent ecosystems, the default trigger values in the Australian and New Zealand Guidelines for fresh and marine water quality (ANZECC and ARMCANZ 2000) or the water quality criteria for freshwater aquatic ecosystems given in the *Environment Protection (Water Quality) Policy 2003* provide a good indication of water quality requirements. It is important to note that these trigger values and water quality criteria have been set as a broad scale reference and may not reflect natural water quality values for a local area, such as catchments that are naturally saline or rich in some metals due to local geology. It is likely that water-dependent ecosystems will have adapted to tolerate the local water quality in areas where values naturally exceed these criteria. Therefore it is not considered necessary to improve water quality to meet these standards in such cases, unless required for specific circumstances such as creation of new refuges for threatened species when their original habitat cannot be restored.

4 Capacity of the resources to meet demands

This part of the Plan covers three main areas:

- Demand for water for human uses, including consumptive use (section 4.1).
- An assessment of the capacity of the water resources to meet current demands (including consumptive use and environmental needs) and the responses of the water resources to the current level of consumptive demand (section 4.2).
- Development of a new water resource management framework to be implemented through the prescription process, and an assessment of the capacity of the water resources to meet demands under the new framework (section 4.3).

4.1 Demand for water

Demand for water can be broadly divided into the categories of environmental and other non-consumptive needs and values, and consumptive use. Environmental water requirements are described in section 3. Other non-consumptive needs and values may include mitigating pollution, public health (for example, limiting noxious algal blooms), cultural values across the community, recreation, fisheries, tourism, navigation and amenity values. These non-consumptive water needs and their associated water requirements have not been quantified in the Marne Saunders PWRA at this point.

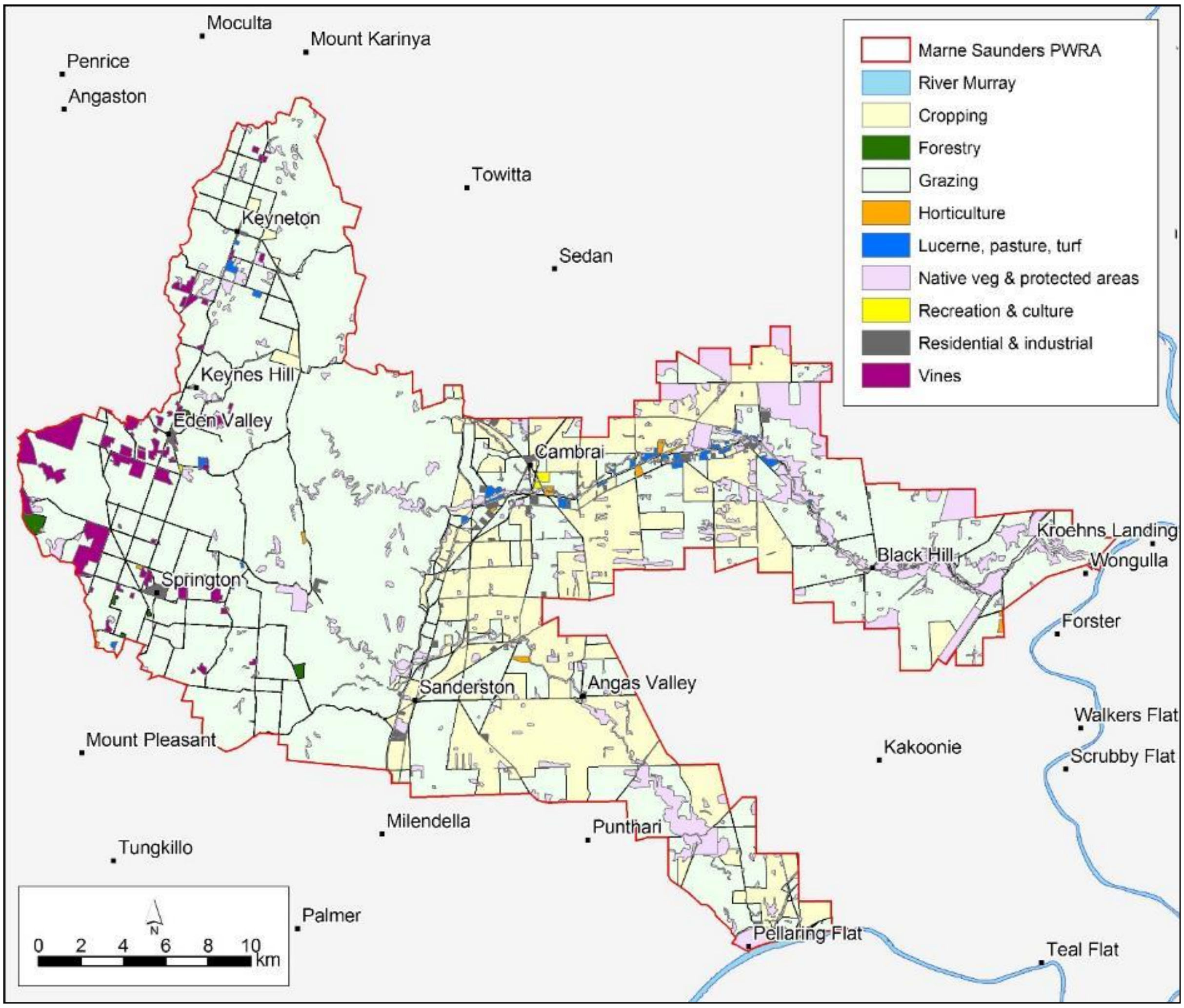


Figure 17 Major land use over the Marne Saunders PWRA.
Data grouped from 2003 Bureau of Rural Sciences' Land Use and management mapping of South Australia (see Keane 2003).

Water is used for a range of consumptive purposes in the Marne Saunders PWRA, which can be split into:

- non-licensed purposes (see section 1.4 – includes domestic use, drinking water for non-intensive stock, public road making, fire fighting, applying chemicals to non-irrigated crops or to control pests, use of roof runoff of less than the gazetted threshold volume, taking water via creation or maintenance of small artificial waterbodies that aren't used to capture or store water for use; and exercise of the native title rights by Native Title holders to use the natural water resources of the native title determined area for personal, domestic, cultural, spiritual or non-commercial communal needs providing the taking does not involve stopping, impeding or diverting the flow of water from a watercourse; and
- licensed purposes (everything besides non-licensed purposes, including irrigation, industrial use, intensive animal production and recreational use).

Figure 17 shows the major types of land use in the Marne Saunders PWRA, giving an indication of the broad distribution of many of the water consuming activities in the area. It can be seen that the majority of the area is used for grazing or cropping.

This section:

- provides an overview of the current range and size of key water-consuming purposes in the Marne Saunders PWRA;
- estimates the likely amount of water required for the annual current demand where available; and
- discusses probable future demand for consumptive use of water, generally over the life of this Plan.

4.1.1 Aboriginal water needs

Aboriginal water needs span the categories of water needs described above, including the different forms of water demand described in sections 4.1.2 and 4.1.3.

Aboriginal nations have a deep cultural and spiritual connection with traditional country, including the flora, fauna and other resources it provides. Water is extremely important to the way of life, supporting many different aspects of society and governance. From an Aboriginal perspective, historic and contemporary values and uses are seen as one, they do not need to be separated as they form part of Aboriginal identity. Aboriginal cultural objectives and outcomes discussed in section 1.5.3 are founded on Aboriginal cultural values and uses.

Through ongoing engagement in water planning with Peramangk and Ngadjuri nations, Aboriginal values and uses in relation to water have been discussed to include:

- Economy, trade and travel
- Storytelling and identity
- Healing, health and well-being
- Ceremonies and lore
- Hunting, fishing and collection of bush food, medicine and resources
- Drinking and preparation of food
- Bathing, swimming and other recreational enjoyment
- Supporting flora, fauna and culturally significant species and the landscape
- Protecting important cultural heritage sites and objects
- Forming relationships and understanding through reconciliation, education and awareness
- Supporting life – water as the lifeblood of the living body that is the landscape

Aboriginal nations call for environmentally sustainable management of the lands and water of their traditional country. Good health of water resources and the landscape as a whole living body has been identified by nations as critically important to achieving their Aboriginal cultural objectives and providing Aboriginal water needs into the future. A decline in the condition of water resources and the water-dependent ecosystems and species of the Marne Saunders PWRA impacts on many of the values and uses of water of Aboriginal people, and through their connection to Country, can also be understood as a threat to Aboriginal people's health and wellbeing.

An important part of Aboriginal water needs is a sufficient quantity and quality of water to support Aboriginal values and uses. Through consultation during the amendment of this Plan, Aboriginal nations stated that they would like to see the water resources of the Marne Saunders PWRA protected and restored to function as it did for previous generations and support all aspects of life.

Water needs based on Aboriginal values and uses are not limited to the water authorised under section 128 of the NRM Act that is taken in exercise of native title rights. The provisions in this Plan that aim to maintain water quantity and quality may help to support some other Aboriginal values and uses, particularly in relation to supporting flora, fauna and the landscape (see Table 1). Until the consultation was undertaken that resulted in amendment to the Plan in 2019, Aboriginal values and uses had not been considered as part of the water licensing process in the Marne Saunders to date.

4.1.2 Non-licensed water needs

4.1.2.1 Stock and domestic water needs

Stock and domestic water needs make up the majority of non-licensed demand for water. Stock and domestic water is taken from a range of sources:

- mains water supplied to the townships of Springton, Eden Valley, Keyneton and Cambrai and along the mains line between these towns;
- rainwater;
- dams, watercourses and springs; and
- wells (including bores and windmills that extract underground water).

Current and future stock and domestic water requirements from these different water resources have been estimated using a range of information, including land use and land capability mapping, aerial photography, published information on stock water requirements and domestic consumption for different purposes, and a voluntary mail survey conducted by the Marne Saunders Water Resources Planning Committee (SA MDB NRMB 2010).

Domestic water requirements

It is assumed that the majority of water use in the townships will be mains water, and so domestic water use in the townships has not been estimated. On the basis of the information sources outlined above, the total domestic water requirement outside of the townships is estimated at 205 ML per year for approximately 720 households. This volume is split between the different resources for the hills and plains zones as shown in Table 13. Rainwater is the primary source of domestic water outside the townships, particularly within the house. This is supplemented by underground water (particularly on the plains where rainfall is low) and dam water (only in the hills), generally for garden watering and for purposes such as toilet flushing and laundry.

Table 13 Estimated domestic water needs by water resource and hills/plains (in ML per year). From SA MDB NRMB (2010). Values are rounded.

	Mains	Rainwater	Dam	Well	Watercourse	Total
Hills	19	62	20	24	2	**127**
Plains	4	29	0	41	4	**79**
Total	**23**	**91**	**20**	**65**	**6**	**205**

Estimated future domestic water needs have been incorporated into the estimates of domestic water requirements. The future domestic requirements are based on projected population increases in the Barossa and Mid Murray Council regions, scaled to the area and different types of residential opportunities of the Marne Saunders PWRA. The majority of this development is expected in the hills zone (Clarke 2008).

Stock water requirements

Provision of drinking water for stock that are not intensively kept does not require a licence. A licence is required for providing drinking water for intensively kept stock (e.g. piggeries, feedlots) and use of water for other purposes related to stock. This section only relates to the estimated requirements for drinking water for non-intensively kept stock.

The total stock drinking water requirement for the Marne Saunders PWRA is estimated at 508 ML per year for approximately 58,800 hectares of grazing land. This volume is split between the different resources for the hills and plains as shown in Table 14. The reliance on different water resources is again driven by availability, with wells providing the major source on the low rainfall plains, and dams and watercourses supplying most stock water in the wetter hills.

These estimates of stock water requirements are expected to reflect future requirements for this purpose as they are based on land that is or is likely to be able to be grazed, and its carrying capacity for moderate to good production rates (SA MDB NRMB 2010). The demand for stock water use is expected to remain relatively stable, although drought and changing commodity prices may change the balance between cropping and grazing over time. In the hills zone, there is potential for land use change to develop food groups for the growing gourmet Barossa fine food industry. Branded lamb sheep grazing is a primary industry that has high potential as a local fine food product. An increase in this industry may increase stock numbers in some parts of the catchment (Clarke 2008).

Table 14 Estimated stock drinking water needs (in ML per year) by water resource and hills/plains.
From SA MDB NRMB (2010). Values are rounded.

	Mains	Rainwater	Dam	Well	Watercourse	Other	Total
Hills	28	6	179	70	73	0	**356**
Plains	7	1	1	135	2	6	**152**
Total	**35**	**7**	**180**	**205**	**75**	**6**	**508**

Additional water capture for stock and domestic purposes

The estimated volume required for stock and domestic needs taken from dams does not include an allowance for evaporation and seepage or for storage of more than one year's supply.

It is important to note that stock and domestic dams will capture a volume of water related to the size of the dam, the volume of runoff generated from the catchment area upstream of the dam, the amount of water intercepted by other upstream dams and water diversions, and losses from the dam via use, evaporation and seepage. Therefore the figures in Table 13 and Table 14 are indicative of the theoretical requirement for stock and domestic water needs only, and do not necessarily reflect the amount of water actually taken from the surface water resource for this purpose.

However, for water taken from wells and watercourses, it is reasonable to assume that the amount taken will reflect the stock and domestic requirements, given the costs associated with pumping and storage vessels, or because of direct extraction for the purpose in the case of stock access to watercourses.

4.1.2.2 Other non-licensed water needs

The volume used for applying chemicals to broad acre crops on the plains zone of the Marne Saunders PWRA has been estimated at 6.5 ML per annum. This estimate was obtained via a DWLBC telephone survey (K. Walton, personal communication, 6 February 2004).
The volume of water used for other non-licensed purposes (including public road making, fire fighting, applying chemicals to other non-irrigated crops or to control pests, roof runoff of less than the threshold volume for purposes other than stock and domestic use) is likely to be small and in the case of public road making and fire fighting, highly variable from year to year. This volume has not been estimated for the purposes of this Plan.

4.1.3 Current licensed water needs

4.1.3.1 Estimated licensed water demand

The current likely demand for water for licensed purposes is estimated in this section as the total volume of reasonable requirements of existing users in the Marne Saunders PWRA. These reasonable requirements are estimated on the basis of the theoretical water requirements for the sizes and types of enterprises that existing users are entitled to, as defined in accordance with section 36 of the WR Act[6]. This demand includes requirements of users taking water during the establishment period (6 May 1996 to 24 January 2002), as well as eligible prospective users that demonstrated significant commitment towards prior to 24 January 2002, which is when the Notice of Intent to Prescribe the Marne Saunders Water Resources came into force. Section 4.1.3.3 discusses future licensed water demand.

It is important to note that figures presented in this section only represent the theoretical needs of the entitled types and sizes of enterprises of existing users, and do not include any of the other considerations to be made when determining the ultimate size of allocations to existing users in the Marne Saunders PWRA. Allocations to existing users need to be based on the capacity of the resource and not just these theoretical needs.

Table 15 shows the approximate demand for water for licensed purposes by purpose of use, and split between the hills and plains zones. These figures have generally been calculated using maximum theoretical requirement rates for the different enterprises.

Net irrigation requirements were determined by Rural Solutions SA (M. Skewes, personal communication), using the methodology of Allen *et al* (1998) and incorporating local information on climate and practices. This methodology makes a number of assumptions, including growth for full production potential (with some exceptions like high quality wine grapes), non-restricting soil water and fertility conditions, and a disease free crop.

Table 16 shows the same demand split by water resource. Where existing users take water from more than one resource, they have been asked to nominate a fixed split of their total entitlement between the resources under the existing user allocation process.

4.1.3.2 Licensed water use

Section 4.1.3.1 gives information on estimated water demand for licensed purposes, based purely on theoretical water requirements for types and sizes of enterprises. It is useful to compare this demand with the volume that has been measured to be taken for these purposes in the area over the last few years.

[6] The WR Act has been replaced by the NRM Act. However, the prescription process in the Marne Saunders PWRA was started under the WR Act and so applications to be considered as an existing user are made under section 36 of the WR Act. The process for allocating water to existing users is outlined in the Natural Resources Management Act (Marne Saunders Prescribed Water Resources Area Reduction to Water Access Entitlements) Regulations 2009, and the issuing of licences will occur under the provisions of the NRM Act.

Table 15 Approximate theoretical water demand for licensed purposes by enterprise type and split between hills and plains zones (in ML/year).
Grand totals are the sum of the industrial, intensive animal keeping and irrigation totals. Figures are rounded. Data is best available at publication, supplied by DWLBC.

Group	Enterprise	Demand (ML/year)		
		Hills	Plains	Total
Industrial[1]		25	5	30
Intensive animal keeping[2]		126	53	179
Irrigation	Fodder and trees	6	14	20
	Fruit, vegetables and nuts	112	22	134
	Lucerne (hay and pasture)	1,183	1,725	2,908
	Native produce	18	57	75
	Olives	124	931	1,055
	Pasture	197	28	225
	Wine grapes	2,274	1	2,275
	Other[3]	40	630	670
	Irrigation total	3,954	3,408	7,362
Grand totals		**4,105**	**3,466**	**7,571**

[1] Industrial uses include wineries, quarries, dairy washdown and food processing
[2] Intensive animal keeping includes piggeries, chickens (layers and broilers) and rabbits
[3] Other irrigated crops include turf, recreational use (ovals etc), cereal, garden and nursery

Table 16 Approximate theoretical water demand for licensed purposes by water resource (in ML/year). Figures are rounded. Data is best available at the time, supplied by DWLBC.

Water resource	Demand (ML/year)
Watercourse	266
Surface water	2,051
Fractured rock aquifer	1,900
Murray Group Limestone aquifer	3,354
Total	**7,571**

Water users that have been authorised to take water under the Notice of Restriction have been required to meter the volume taken for licensed purposes from their wells, dams and watercourses. Metered usage from the different water resources is given for 2002/03 to 2004/05 in Figure 18. It can be seen that metered usage is considerably less than the theoretical demand from these resources presented in Table 16, with usage being around a quarter to a half of the theoretical demand. This difference is likely to be due to a number of factors, including:

- limitations on the ability of users to access water (limited by dam capacity, runoff from the area upstream of the dam, interception by upstream users, and losses to evaporation and seepage; or by well yield, water quality and interference from other users);
- production and practices on the ground not meeting the assumptions of the methodology of Allen *et al* (1998) for determining theoretical crop requirements (e.g. not growing for maximum production, limited by soil factors, nutrition etc);
- some of the theoretical demand is for future development that existing users are entitled to but have not yet implemented (although this is a small proportion of the demand based on current information);
- use of alternative water sources such as mains water;
- not all sources used for licensed purposes are metered; and
- artificial inflation of the demand from the fractured rock aquifer by conjunctive users of both surface water and fractured rock aquifer underground water. Many conjunctive users

preferentially use their fresher surface water and only rely on water from the saltier fractured rock aquifer during droughts. Existing users may have nominated a higher proportion of their entitlement to come from the fractured rock aquifer than is used during average years in order to ensure they have sufficient water from this resource during droughts when their dam is dry.

However, some metered usage may also be used for non-licensed purposes. For example, metered water taken from a well may then go to both a stock trough and to provide irrigation.

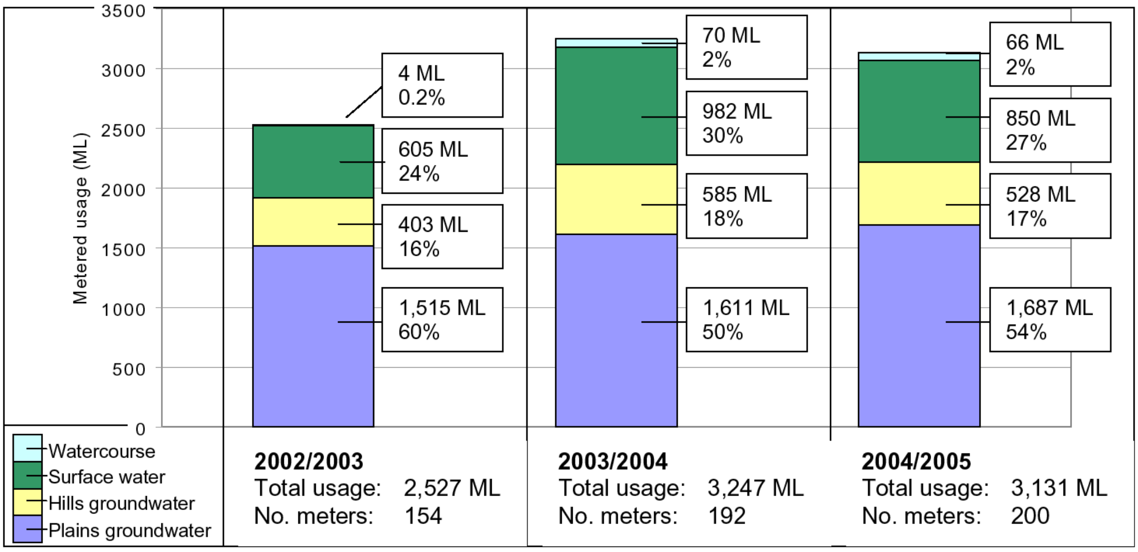


Figure 18 Metered usage from different water resources for 2002/03 to 2004/05.
Usage is measured from July to June in the following year. Data supplied by DWLBC.

4.1.3.3 Future licensed water needs

This section outlines the expected future water demands in the Marne Saunders PWRA. The Plan establishes the management arrangements and limits for extraction of water within the Marne Saunders PWRA and any future increase in water demand and water affecting activities will need to be accommodated within these management arrangements.

The following information is drawn from Clarke (2008).

The Barossa region of South Australia, which overlaps the Marne Saunders PWRA, is famous for its premium quality wines and fine food. It has been forecast that future expansion of the region's high value grapes will only occur in small parcels. Although there is land capability for expansion, this will be restricted by the ability to access a secure water supply. There is also potential for land use change from irrigated pasture to olive and fruit orchards, and opportunities for small provincial horticultural food production within the hills zone to develop food groups for the growing gourmet Barossa fine food industry.

No major expansion or the establishment of large areas of primary production has been predicted for the plains zone. Irrigated lucerne, pasture and olives (collectively the highest present water users on the plains) are not expected to increase, although water trading may move water between different enterprises.

The mixture of intensive livestock industries such as piggeries and poultry is changing. Piggeries are declining as current production is expensive and the industry competes with cheaper imports, while poultry in the area is forecast to grow by one to two properties over the next ten years.

There is potential for growth in the wine manufacturing industry with the development of small wineries to produce boutique wines. Water demand will depend on the relative amounts of crushing and processing. The Wine Industry Impact Review forecasted that in 2011, 601,600 tonnes of grapes will be crushed or processed in the Barossa region (Barossa and Light Regional Development Board, 2004). Based on the percentage of the Marne Saunders PWRA within the Barossa region, there is potential for 4,429 tonnes per year to be crushed and processed within the Marne Saunders PWRA. Based on the average water demand of 2 - 5 kL/tonne for crushing and processing, water demand could increase to approximately 22 ML per year for this purpose. However, large scale industrial development is not forecast for this area as intensive industry is not considered consistent with the character of the region and due to lack of suitable service roads.

Future Aboriginal water needs

Peramangk and Ngadjuri nations want a future that maintains the continuation of their culture upon their traditional country and that continues to give life to their people who live and work in and outside of the region. Water is an important part of this.

Section 4.1.1 outlines Aboriginal values and uses associated with water. If these needs (or components of them) are not being met through existing arrangements, then these unmet needs should be given consideration when future amendments of this Plan are contemplated or required.

The aspirations of Aboriginal nations to re-establish the economic benefits that flow from their Country into their communities and institutions have been articulated at workshop discussions. Aboriginal nations recognise new industries are here to stay and seek to share the economic benefits from Country. Future water needs of Peramangk and Ngadjuri nations may include licences to take water for commercial purposes within the existing water licensing provisions of the NRM Act.

4.2 Capacity of the resource to meet current demands

Section 4.2 gives an assessment of the capacity of the water resources to meet current demands. The current level of water resource development is a reflection of the total current demand for consumptive use. The impact of current water resource development on the behaviour of the water resources is outlined in sections 4.2.1 (surface water and watercourse water) and 4.2.2 (underground water). Section 4.2.3 examines the impact of this development on the water demands of water-dependent ecosystems. This assessment shows what components of demand are currently being affected, and therefore provides direction on what issues need to be addressed when developing a framework for long-term sustainable management.

4.2.1 Effects of water resource development - surface water and watercourse water

4.2.1.1 Water resource development

There are approximately 960 dams in the Marne Saunders PWRA with a total capacity of approximately 3,790 ML. This volume has been estimated by DWLBC from a combination of sources, including measurements from aerial photography (from 2005) and where available, dam wall heights and surveys of dams provided by landholders. Table 17 gives the breakdown of this total capacity between dams used for licensed purposes and other dams, and between the catchments.

Table 17 Total approximate dam capacity (in ML) in the Marne Saunders PWRA, broken down by catchment and purpose of use.
Data supplied by DWLBC (October 2009). Values are rounded.

	Marne	Saunders	Total
Licensed use	1,869	257	2,126
Non-licensed use only	1,356	296	1,652
Total	3,225	553	3,778

The dam capacity is not evenly spread over the area as shown in Figure 19. For example, 344 ML or 62% of the total dam capacity in the Saunders catchment is concentrated in the upper part of the One Tree Hill sub-catchment in an area of about 11.2 km^2, giving a dam capacity density of 31.6 ML/km^2. However, in the adjacent lower rainfall Reen Valley sub-catchment, the dam capacity density is significantly lower at 7.4 ML/km^2 (Alcorn 2005). There are very few dams in the plains zone.

The total dam capacity in 1991 in the Marne was estimated at 1,123 ML (Savadamuthu 2002). Dam capacity has not increased significantly since 1999 when the Notice of Restriction was placed in the area, meaning that dam capacity almost tripled in less than 10 years. There are currently approximately 15 watercourse diversion points (e.g. pumps and weirs) where the water is used for licensed purposes. The number of watercourse diversion points for non-licensed use is not known.

4.2.1.2 Impact of surface water and watercourse water resource development

It is important to note that the impact of dams on the water resources, users and the environment is not limited to the volume extracted from dams and watercourses. Dams trap all of the runoff from the upstream catchment area until they fill and spill. The presence of the dam as a physical barrier to water movement and the capacity of the dam have a key influence on the volume and pattern of downstream flow. The level of usage, evaporation and seepage from the dam will also affect how soon the dam fills and spills. Therefore it is important that the policy framework for sustainable water allocation takes both dam capacity and usage into consideration for all dams, including those used for licensed and non-licensed purposes.

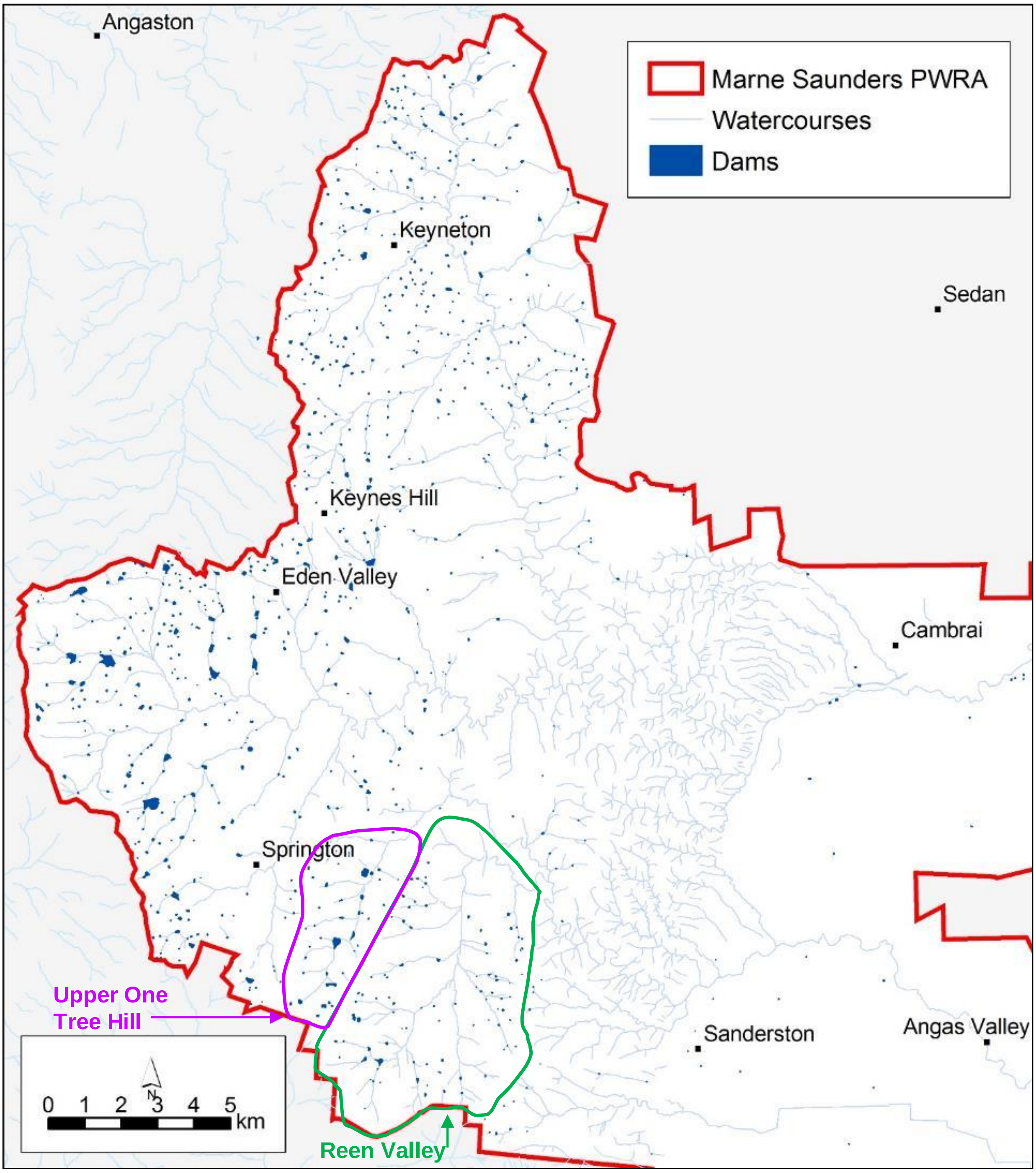


Figure 19 Dams in the Marne Saunders PWRA, indicating the Upper One Tree Hill and Reen Valley sub-catchments.
Data provided by DWLBC (based on 2005 aerial photography).

It is difficult to separate the impacts of year to year variation in climate from the impacts of water resource development when examining flow monitoring data. Modelling that simulates flow in response to climate and incorporates the effects of water resource development can be used to separate these two factors. Such flow modelling data can be used to examine the impacts of water resource development on the volume and pattern of flow in the Marne Saunders PWRA.

Modelling of surface water and watercourse water

Surface water models for the Marne and Saunders catchments have been developed by DWLBC, as described in Savadamuthu (2002) and Alcorn (2005). In summary, the models simulate daily flow throughout the upper catchments and are able to represent the pattern of dams over the landscape (including location, dam capacity, usage and pattern of water capture) as well as parameters of the water cycle including runoff, infiltration and evaporation. The catchment is represented as a series of nodes of catchment areas and dams that are connected on the basis of the drainage pattern.

The Marne model has been calibrated to average daily streamflow at the Marne Gorge flow gauging station. The catchment characteristics of the Marne catchment have then been applied to the ungauged Saunders catchment. The models only operate to the end of the hills zone, because downstream of this point the watercourses lose significant flow to the underlying aquifers. The pattern of this loss over space and time has not been sufficiently measured and cannot be adequately modelled yet. A series of water level detectors have been installed in the watercourse along the Lower Marne with the intention of gathering information to better understand and predict watercourse flow in these areas for future plans.

The current level of water resource development can be modelled on the basis of the known dams, watercourse diversions and estimated usage. Usage from unmetered dams (which are generally only used for non-licensed purposes) has been estimated at 30% of dam capacity, on the basis of the work of McMurray (2003) on usage from stock and domestic dams in the Mount Lofty Ranges. The modelling assumes standard seasonal patterns of usage from dams.

The dams can then be removed from the model to show how the current level of water resource development has affected the flow volume and pattern on the basis of current landscape conditions (the “no dams scenario”, which simulates “adjusted flow”). While the models do not provide a fully accurate simulation of daily flows as they occurred historically, they provide a useful basis for comparing the effects of different levels of dam development on the flow regime.

Modelled impact of dams and watercourse diversions on flow regime

Annual flow

Table 18 shows modelled average annual flow for the period of 1974 to 2003 for the Upper Marne, Upper Saunders and Upper One Tree Hill catchment, a highly developed sub-catchment of the Upper Saunders. The modelled flow is from the no dams scenario and the 2003 (effectively current) level of dams scenario. It can be seen that average annual flow is significantly reduced by the 2003 level of dams, particularly in the highly developed Upper One Tree Hill sub-catchment. Comparison with the whole Upper Saunders results shows that the impacts on streamflow in the highly developed areas are masked at the scale of the whole upper catchment by flow provided from less developed areas.

Table 18 Modelled average annual flow for 1974 - 2003 for different parts of the catchments under the no dams and current dams scenarios (in ML/year), showing percentage reduction from no dams annual flow to current annual flow.
Data from Alcorn (2005) and K. Savadamuthu (personal communication, November 2005).

Flow scenario	Upper Marne	Upper Saunders	Upper One Tree Hill
No dams (adjusted flow)	8,406	1,003	284
Current (2003) dams	6,417	696	116
% reduction in flow	24%	31%	59%

Figure 20 shows annual flow for 1974 – 2003 for the Upper Marne from the modelled no dams and current dams scenarios, as well as the percentage reduction of annual flow from the no dams scenario to the current dams scenario for each year. It can be seen that the impact of dams is highest in dry years (up to 67% reduction in flow) and lower in wet years, showing that the average flow reduction of 24% given in Table 18 masks the level of variation of impact over time.

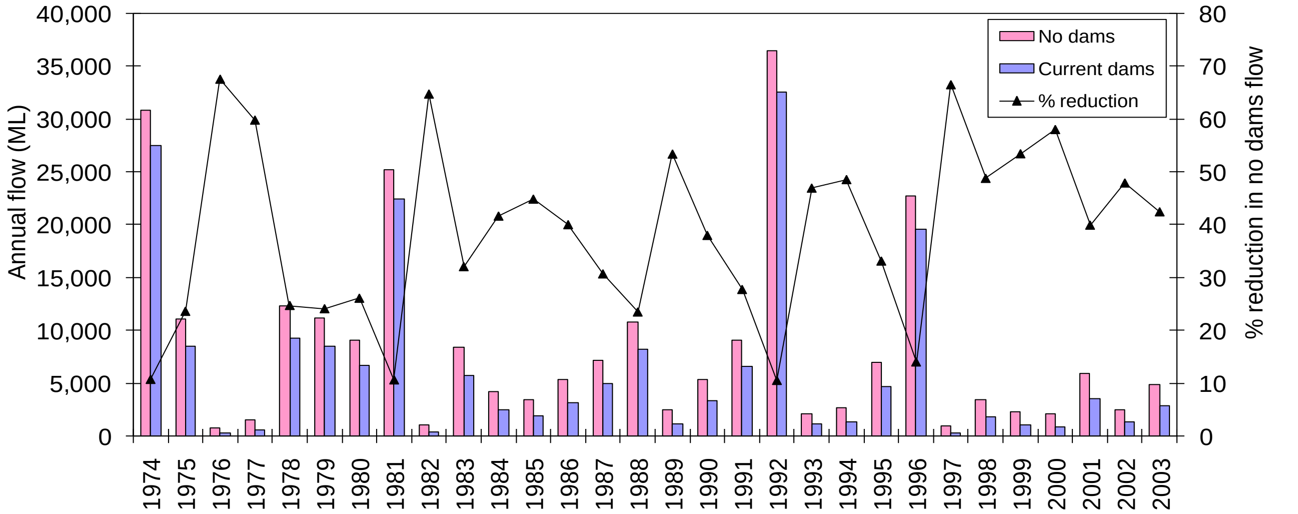


Figure 20 Modelled annual flow for 1974 - 2003 for the Upper Marne under the no dams and current dams scenarios (in ML/month), showing percentage reduction from no dams annual flow to annual current dams flow.
Data provided by DWLBC.

Monthly flow

Figure 21 shows the median monthly flows from the Upper Marne under the no dams and current dams scenarios, as well as the percentage reduction of flow from the no dams scenario to the current dams scenario for each month. It can be seen that the highest impact on monthly flows in percentage terms is during the low flow and transitional flow seasons. The water level in dams is generally low at these times as a result of water usage and evaporation, and so any incoming flow is intercepted by the dam. The dams fill as the high flow season progresses, allowing upstream runoff to pass through the dams and continue down the catchment.

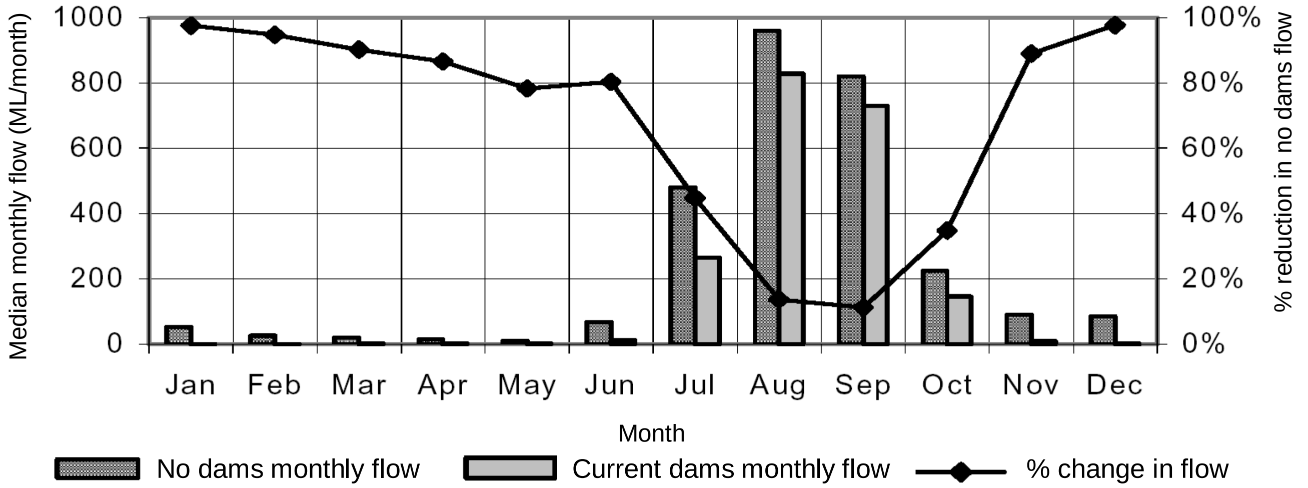


Figure 21 Modelled median monthly flow from the Upper Marne for the no dams and current dams scenarios.
From Savadamuthu (2002).

Daily flow

Table 19 shows the modelled impact of dams on the frequency of different sizes of daily flows from the Upper Marne. It shows that low and mid flow events have potentially been influenced more greatly compared with higher flow events. For example, it can be seen that flows of 1 ML/day or greater occurred for 206 days per year on average under the no dams scenario, but only for 113 days under current conditions. Larger flows of 100 ML/day or more have potentially not been greatly affected, occurring for 15 days per year on average under the no dams scenario compared with 14 days under current conditions.

Table 19 Number of days that a given daily flow rate will be exceeded under the modelled no dams and current dams scenarios.
From Savadamuthu (2002).

Flow rate (ML/day)	**No dams scenario:** Number of days that flow rate is exceeded	**Current dams scenario:** Number of days that flow rate is exceeded	**Difference in number of days that flow rate is exceeded**
0.1	321	153	168
1	206	113	93
5	98	80	18
10	71	63	8
50	27	24	3
100	15	14	1

Summary of current level of water resource development on surface water and watercourse water

The information above shows that the current level of water resource development has had a significant impact on the annual volume of flow from the Upper Marne and Upper Saunders catchments, with higher impacts in drier years compared with wetter years. The flows that have been most affected are low and medium flows (primarily occurring in the low flow and transitional flow seasons) while high flows are less affected. Section 4.2.3 outlines how this water resource development, or the current level of total demand for consumptive use, has affected the water demands of water-dependent ecosystems.

4.2.2 Effects of water resource development - underground water

4.2.2.1 General impacts of water resource development in aquifers

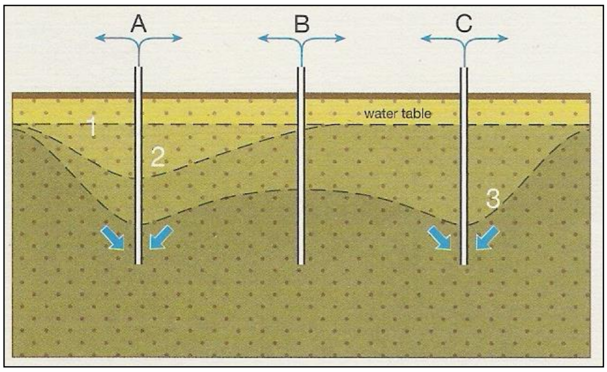
The volume of water held in an aquifer is often termed “storage” and is generally a considerable amount of water. As outlined in Figure 11, water is recharged into aquifers through a variety of mechanisms, and is lost from aquifers primarily through extraction, discharge to watercourses, throughflow to other aquifers, and transpiration where vegetation is able to access the aquifer. If the volume of loss is higher than the volume of recharge, then the volume in storage, and hence the underground water level, will decrease. The water level may decrease below the depth of pumps or the roots of trees tapping into the underground water, or may affect regional discharge processes from one aquifer to another or to a watercourse.

Extraction from a well also leads to local drawdown of underground water level as illustrated in Figure 22. Excessive extraction may create a persistent area of drawdown or “cone of depression” around a well or group of extraction wells. This may influence the direction of the pressure gradient of underground water. A persistent cone of depression may lead to reversal of the direction of flow, potentially drawing in nearby saline water and affecting down-gradient flow. This may also lead to interference in the ability to extract water from affected wells.

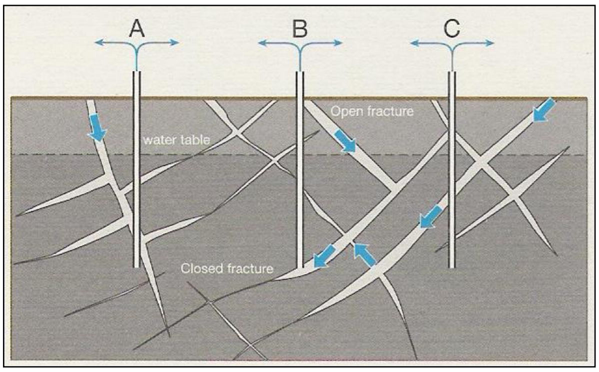
Pumping from a well can also interfere with streamflow. Underground water flows from higher to lower levels, with the level at watercourses typically being the lowest in the landscape. If pumping reduces the water level around the well then underground water has less potential to flow towards the watercourse. This may reduce the amount discharged to watercourses as baseflow, and may even induce flow from the watercourse into the aquifer towards the well.

The key drivers of interference between wells or to water-dependent ecosystems like watercourses are the rate and duration of pumping, and aquifer characteristics such as the type of aquifer media, fracture connectivity and the degree of aquifer confinement.

Sedimentary aquifer



Fractured rock aquifer



1 Water table when no pumping from wells
2 Drawdown that occurs if only well A is pumped. Water levels in well B drop slightly. Water levels in well C remain the same.
3 Combined drawdown effect if both wells A and C pump at the same time. This causes a significant drop in the water level of well B.

Fractures that are intersected by well A have a restricted connection to the fractures intersected by B or C. Therefore pumping from well A will have a limited impact on water levels in B or C.
However in the case of well B and C, the fractures are connected and pumping from either well may cause a decrease in water levels in the other well ("well interference".

Figure 22 Behaviour of aquifer types during pumping.
Figure courtesy of DWLBC.

In a fractured rock aquifer, the likelihood of interference between wells or impact from a well to a water-dependent ecosystem will depend on the connectivity of the fracture sets between them (see Figure 22). On the basis of investigations including pump testing and hydrogeophysical mapping of fracture orientation, it has been estimated that the impacts of drawdown around a well in the fractured rock aquifer in the Marne Saunders PWRA generally would not be felt more than 200 m from the well (T. Wilson, personal communication).
The more consistent nature of the sedimentary aquifer means that when water is pumped from a well, there tends to be a drawdown of underground water level in a circular area around the well. The size and depth of the drawdown is largely governed by the volume and rate of water taking, as well as aquifer characteristics such as how effectively water is able to be transmitted through the aquifer.

The drawdown of underground water level or pressure in response to extraction of a volume of water is greater in a confined aquifer compared with an unconfined aquifer. As a result, two wells the same distance apart pumping at the same rate are more likely to interfere with each other in a confined aquifer than in an unconfined aquifer.

4.2.2.2 Effects of water resource development - fractured rock aquifer

Water resource development in the fractured rock aquifer

Almost 800 water wells have been drilled into the fractured rock aquifer according to the state wells database (accessed via the Drillhole Enquiry System, accessed December 2008). Approximately 250 of these wells are still operational, around 140 have been abandoned, backfilled or similar, and the status of the remainder is unknown. 155 wells of the operational wells have been drilled for irrigation purposes, although this purpose of use has not always continued. There has been a significant increase in the rate of irrigation well drilling in recent times. 94 of the irrigation wells were drilled between 1940 and 1994, with the remaining 61 drilled from 1995 to 2005. Approximately 82 wells in the fractured rock aquifer have water taken from them for licensed purposes at the date of adoption.

Impact of water resource development in the fractured rock aquifer

There is little monitoring data on underground water levels or quality over time in the fractured rock aquifer. This lack of data makes it difficult to make an assessment of the impact of current extraction on the resource, users and the environment. The limited data that is available shows a seasonal pattern in water level, presumably in response to the seasonal pattern of rainfall and hence recharge (see Figure 23). Well 6728-01292 is close to a well used for irrigation and the data from this well in Figure 23 shows a more marked seasonal pattern, perhaps in response to local pumping. There is not sufficient data to make an assessment of long-term trends in water level. Establishing an ongoing monitoring network of underground water level and salinity will be an important part of improving the management of this resource, as outlined in section 9.

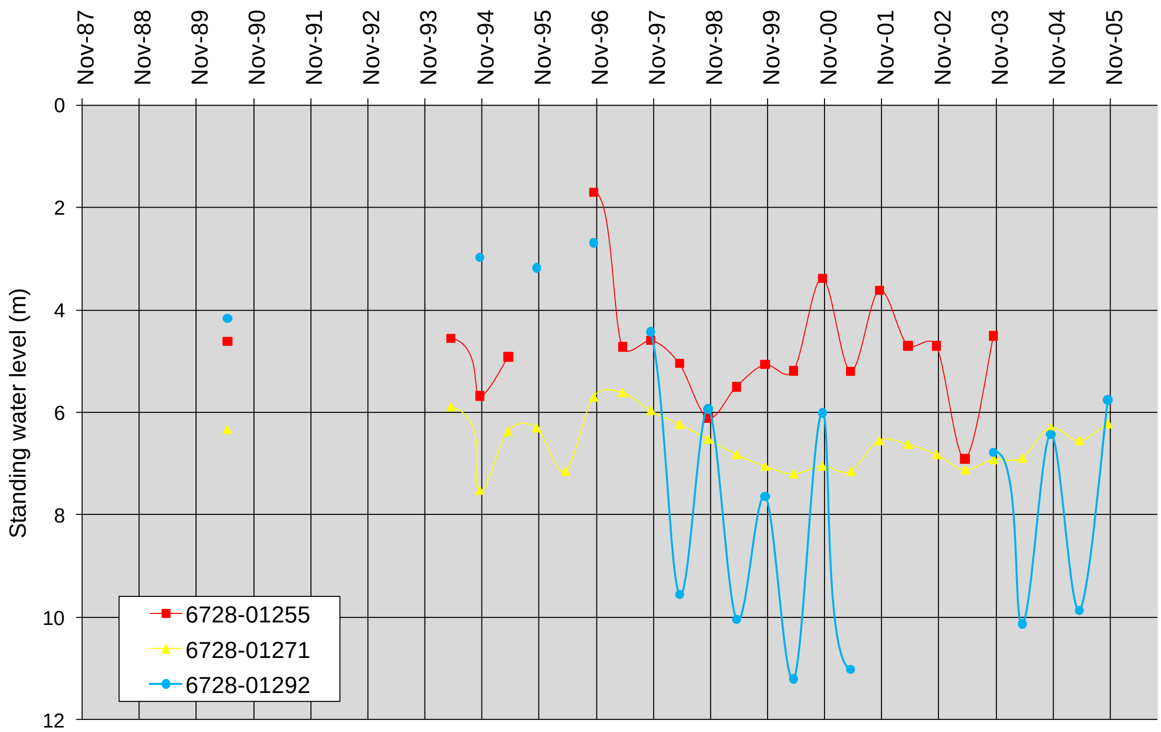


Figure 23 Underground water level over time in three observation wells in the fractured rock aquifer in the Marne Saunders PWRA.
Data from DWLBC (Obswell database – accessed July 2008). Points are shown for dates when data was collected, with no line shown during significant gaps in data collection. Well unit numbers given in legend.

4.2.2.3 Effects of water resource development - sedimentary aquifers

Water resource development in the sedimentary aquifers

Over 570 water wells have been drilled into the sedimentary aquifers according to the state wells database (from the Drillhole Enquiry System, accessed December 2008). Approximately 210 of these wells are still identified as operational, around 150 have been abandoned, backfilled or similar, and the status of the remainder is unknown. 163 wells of the operational wells have been drilled for irrigation purposes, although this purpose of use has not always continued. There has been a significant increase in the rate of irrigation well drilling in recent times. 97 of the irrigation wells were drilled between 1948 and 1994, with the remaining 66 drilled from 1995 to 2005.

Approximately 71 wells in the sedimentary aquifers have water taken from them for licensed purposes at the date of adoption. All of these wells take water from the Murray Group Limestone aquifer and the majority of them are within one kilometre of the Marne River.

Impact of water resource development in the sedimentary aquifers

As for surface water and watercourse water, it is difficult to determine how much of the observed changes in underground water level seen in monitoring data is due to upstream diversion of flow, local extraction of underground water, and/or reduced recharge resulting from climate (e.g. lower rainfall resulting in lower streamflow and lateral throughflow). Monitoring and modelling of underground water level and quality is only available for the Murray Group Limestone aquifer, and so the following information relates to this aquifer only.

Monitoring impacts in the Murray Group Limestone aquifer

The water level in a network of around 30 wells is monitored every two to three months in the Marne Murray Group Limestone aquifer by the Department and by volunteers from the Marne-North Rhine-Saunders Creek Catchment Group. Some of these wells have been monitored since 1980. Around 10 wells are monitored for salinity. The monitoring wells are spread along the Marne River and laterally across the floodplain.

As described in section 2.3.2.4, streamflow is the major source of recharge in the unconfined Murray Group Limestone aquifer underlying the Marne River. Underground water level in the vicinity of the river appears to fluctuate in response to streamflow. The extended low rainfall period of the late 1990s and early 2000s was associated with the lowest recorded underground water levels since monitoring began in 1980 (Barnett *et al* 2001). The falls were greatest at around 3 m near Kongolia, with Figure 24 providing an example of the underground water level in a monitoring well in this area. The underground water level has shown some recovery since this time in response to flows, although have declined again during the recent drought.

Monitoring of underground water levels in the confined Murray Group Limestone aquifer near the Marne River shows significant seasonal changes due to underground water extraction during the irrigation season (see Figure 25). The water level during the recovery (reduced pumping) season has declined since the mid 1990s, but appears to be stabilising in response to the current extraction regime.

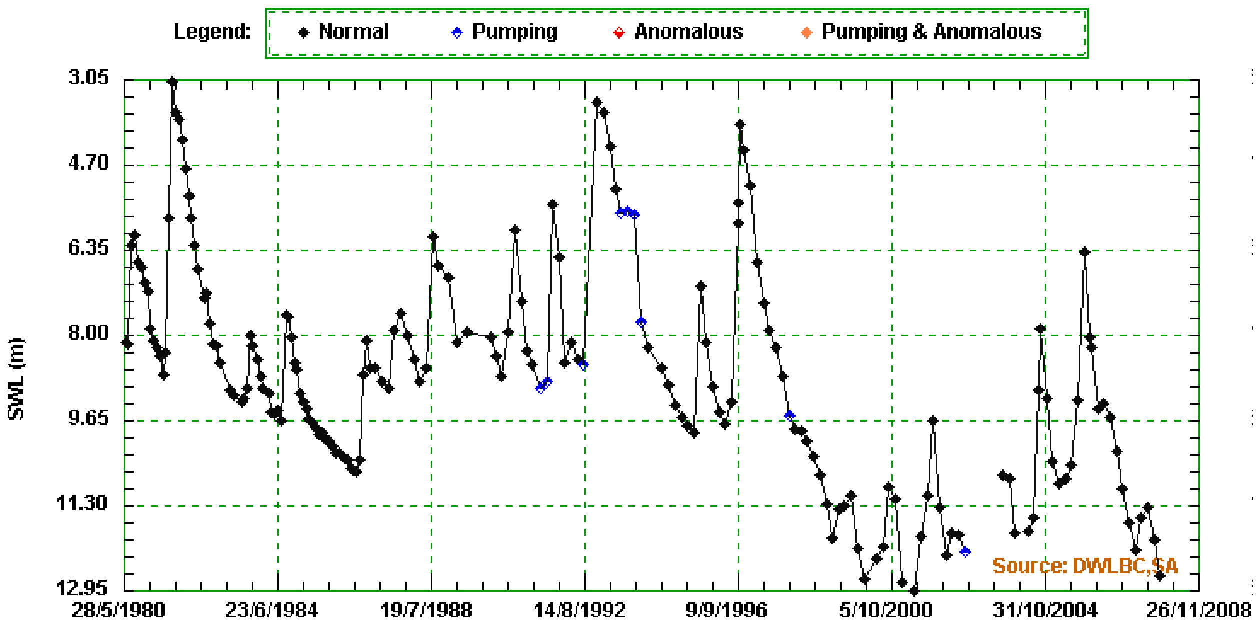


Figure 24 Underground standing water level (SWL) over time in an observation well in the unconfined Murray Group Limestone aquifer in the Marne, close to the area of greatest water level fall around 2000.

Data from DWLBC (Obswell database) for well unit number 6728-181 (ANG010).

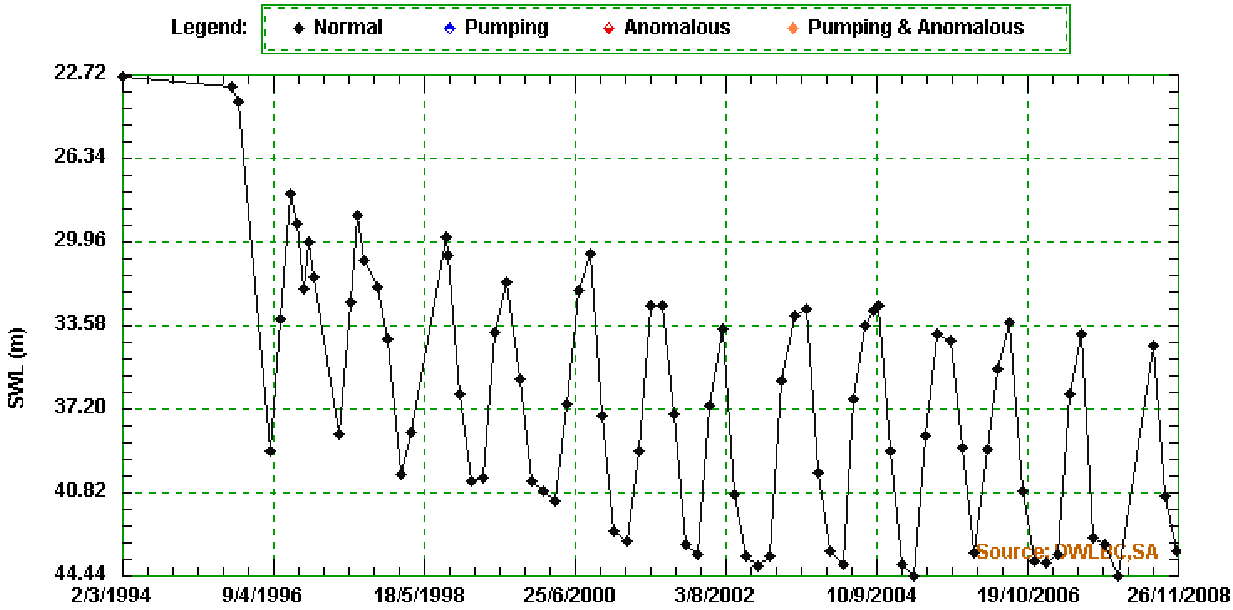


Figure 25 Underground standing water level (SWL) over time in an observation well in the confined Murray Group Limestone aquifer in the Marne, close to the area of intense extraction activity.
Data from DWLBC (Obswell database) for well unit number 6728-2594 (ANG 020).

Modelling impacts in the Murray Group Limestone aquifer

A model simulating underground water level and movement in the unconfined and confined Murray Group Limestone (MGL) aquifer of the Marne has been constructed by DWLBC, as described in Yan and Barnett (2001). The model simulates underground water level over time in response to inputs (streamflow, local rainfall and lateral throughflow from the fractured rock aquifer) and outputs (extraction from wells and vegetation) for grid squares across the area. The model has been calibrated against the underground water level monitoring data described above.

Testing with the model showed that if there was no extraction from the Murray Group Limestone aquifer for irrigation use, water levels at the end of 1999 would be around two metres higher in most areas where the main irrigation activity is located. There would be very little difference away from the irrigated areas (Yan and Barnett 2001).

Summary of current level of water resource development on underground water

The information above shows that the current level of water resource development is likely to have had an impact on underground water levels in the Murray Group Limestone aquifer in the Marne Saunders PWRA. There is insufficient data available to make an assessment in the other aquifers in the Marne Saunders PWRA. Section 4.2.3 outlines how this water resource development, or the current level of total demand for consumptive use, is likely to have affected the water demands of water-dependent ecosystems.

4.2.3 Impacts of current water resource development on water-dependent ecosystems

As outlined in section 3, water-dependent ecosystems respond to the pattern of water moving through their environment. It can be difficult to separate the effects of climate variability and water resource extraction on the pattern of water movement and ecological responses to changes in this pattern. Ecological responses to water resource development are also complicated by other impacts such as land clearance, land use practices, habitat degradation (e.g. by stock access to watercourses), pest species and pollution.

Section 4.2.3.1 describes observations on the condition of water-dependent ecosystems in the Marne Saunders PWRA and likely impacts of changes in water regime. Section 4.2.3.2 uses the flow metrics described in section 3.6 to examine how the current level of surface water resource development has affected key components of the environmental water requirements.

4.2.3.1 Observations and monitoring of condition of water-dependent ecosystems

Assessment of the condition of water-dependent ecological assets has found that the small native fish and submerged aquatic plants of the Marne River catchment are under immediate conservation threat (MREFTP 2003).

Of the 19 small native fish species that once inhabited the Marne River, only nine species remain. Mountain Galaxias populations in and upstream of the Marne Gorge showed potential impacts of inadequate flow regime by either having only large or small individuals present (MREFTP 2003). Ongoing fish monitoring at key sites has shown a continuing trend of poor recruitment of new fish into the population and/or poor survivorship of adults (Hammer 2006). Many of the populations are small and of limited extent, and so are prone to local losses when refuge pools dry up or become uninhabitable. For example, two of the fish monitoring sites in the Upper Marne were dry for the first time in 2008 since the start of annual monitoring in 2001 (Hammer 2008). This pool loss has resulted in local extinction of Mountain Galaxias at those sites until recolonisation occurs from elsewhere. It is likely that drought played a significant role in this pool drying, and the potential impact of water extraction (either underground water or surface water/watercourse water) in this situation is not known.

The unique permanent aquatic habitat provided by the Black Hill Springs and the ecosystems they support are shrinking. Prior to the mid 1990s, the reach comprised a stream length of around 8-9 km starting from just downstream of the township of Black Hill. However, extensive spring drying occurred after 1997 and flowing habitat suitable for River Blackfish now only occurs for a stretch of just over one kilometre. Adult River Blackfish remain at the site, but observations of the population size distribution shows no evidence of successful breeding since 2002. This lack of recruitment may be due to a lack of space and resources for new recruits as the spring fed habitat dries up, or the impacts of the currently relatively high salinity on survival of eggs and larvae (Hammer 2006).

Like native fish, many submerged aquatic plants require permanent water or only tolerate short periods of exposure. As a result, they may be affected greatly by the observed changes in flow regime. Very few aquatic plants now occur in the Marne catchment. The Marne Mouth wetland at Wongulla contained waterlilies (presumably *Ottelia ovalifolia* and *Villarsia reniformis*) until 1995 but these now appear to be locally extinct, probably due to a combination of habitat loss by sedimentation and loss of spring flow. Stands of water ribbons (*Triglochin procerum)* upstream of the Marne Gorge were seeding profusely in October 2001, suggesting they were receiving adequate water at that time, but the absence of this plant from areas such as the temporary wetland habitats in the Marne Valley Conservation Park suggests that the periods of inundation are too brief or ill-timed in the lower parts of the catchment. The Marne Valley Conservation Park was also devoid of any semi-emergent or submerged vegetation in 2001 which strengthens this suggestion. Similarly, there was no evidence that the resident River Red Gums had recruited since 1996 (MREFTP 2003).

Studies of water use by River Red Gums showed that trees throughout the plains zone of the Marne were suffering water stress during the summer - autumn of 2001. Poor tree health in reach M8 (see Figure 16) was associated with oxygen-poor soils, perhaps as a result of point source organic pollution or lack of flushing with oxygenated stream water (Tucker 2001). Widespread poor tree health was observed in the lower parts of reaches M7 and M8 in 2000 (R. Laucke, personal communication), coinciding with low streamflow and dropping underground water levels. The River Red Gums are thought to use underground water from the Murray Group Limestone aquifer (Yan and Barnett 2001), and it is possible that the trees were very water stressed at this time, with no surface water flow and reduced access to the dropping underground water levels. The water levels of this time provide a lower limit for underground water level when determining a water management regime to protect the assumed access by trees to underground water.

The macro-invertebrate communities that have been sampled have been generally in good condition. However, very few samples have been collected from riffle habitats, because these have rarely been present to sample. This suggests that the macro-invertebrate riffle communities are likely to be in poor health because their habitat is rarely present.

4.2.3.2 Impact of dams on flow metrics

As described in section 3.6, a range of flow metrics in different flow seasons have been identified as surrogate measures of environmental water requirements. The degree of deviation from modelled "natural" values for these flow metrics indicates the level of environmental stress, with high deviation equating to high environmental stress. The surface water model described in section 4.2.1.2 can be used to assess how far each of these flow metrics deviate from "natural" under the current level of dam development. This flow deviation analysis allows identification of which ecologically important parts of the flow regime have been affected by water resource development. The analysis therefore provides a guide for what parts of the flow regime need to be targeted by water management policies in order to protect water-dependent ecosystems.

Upper Saunders catchment

Table 20 shows an example of the flow deviation analysis of current conditions for the highly developed One Tree Hill sub-catchment (part a) and the adjacent, less developed Reen Valley sub-catchment (part b) in the Upper Saunders (see Figure 19 for locations of these areas). These areas are shown in Figure 19. The average value for each flow metric under modelled "Natural" (no dams) and Current (2003 dams) conditions are shown in Table 20 for the period 1974-2003. For example, in the Upper One Tree Hill sub-catchment, the modelled median duration of individual fresh events in the low flow season under "natural" conditions is 17.8 days, while under current conditions this is been reduced to 4.8 days (blue highlighted row in the low flow season section of Table 20 (a)). The column "% Change" shows the deviation or percentage change between Current and "Natural" (Current as a percentage of "Natural"). For the above example, the percentage change is 27% - that is, 4.8 days is 27% of 17.8 days. This deviation or percentage change is given a rating in the "Rating" column in accordance with Table 12, ranging from 0 (very low environmental stress) to 3 (high environmental stress).

It can be seen in Table 20 a) that a number of flow metrics in the Upper One Tree Hill sub-catchment show a high deviation from "natural" (rating of 3):

- the mean and/or median in each season (low flow surrogates);
- the duration of freshes in the low flow season;
- the frequency and duration of freshes in the transitional flow season (low to high);
- the duration of freshes in the high flow season;
- the frequency of very high flows in the high flow season; and
- the frequency of freshes in the transitional flow season (high to low).

The relatively low level of farm dam development in the Reen Valley means that only a few flow metrics show a moderate level of deviation, as shown in Table 20 b). In this case, only the mean or median flow in the transitional flow seasons and the high flow season moderately deviate from the "natural" flows.

The outcomes of the flow deviation analysis can then be related back to the environmental water requirements for the relevant reach type, which in the case of the example above is reach S1 (Saunders Hills). Table 21 shows each of the environmental water requirements for the reach (from Table 8) and lists which of the flow metrics are related to each environmental water requirement. The last column makes an assessment of the level of deviation for the related flow metrics, based on the information in Table 20.

Table 20 Results of the seasonal flow deviation analyses in the Saunders catchment. From Doeg and van der Wielen (2007). Values are rounded. n/d means not defined.

Table 20(a) Upper One Tree Hill sub-catchment

	"Natural"	Current	% Change	Rating
Low flow season				
Mean (ML/day)	0.10	0.01	12	3
Median (ML/day)	0.00	0.00	n/d	-
80th percentile (ML/day)	0.00	0.00	n/d	-
Zero flow frequency (/100 years)	108.9	115.5	106	0
Zero flow duration (days)	170.6	170.9	100	0
Freshes frequency (/100 years)	52.8	56.1	106	1
Freshes duration (days)	17.8	4.8	27	3
Transitional flow season (low to high)				
Mean (ML/day)	1.01	0.10	10	3
Median (ML/day)	0.05	0.00	0	3
Zero flow frequency (/100 years)	69.3	85.8	124	0
Zero flow duration (days)	19.2	19.0	99	0
Freshes frequency (/100 years)	132.0	52.8	40	3
Freshes duration (days)	6.1	1.6	27	3
High flow season				
Mean (ML/day)	2.13	0.90	42	3
Median (ML/day)	0.56	0.06	11	3
Coefficient of variation	2.4	4.2	178	1
Freshes frequency (/100 years)	343.2	277.2	81	1
Freshes duration (days)	11.2	4.4	40	3
High flow frequency (/100 years)	349.8	72.6	21	3
High flow duration (days)	2.6	5.0	192	1
Transitional flow season (high to low)				
Mean (ML/day)	1.16	0.83	71	1
Median (ML/day)	0.02	0.00	0	3
Zero flow frequency (/100 years)	59.4	82.5	139	0
Zero flow duration (days)	17.1	25.3	148	0
Freshes frequency (/100 years)	52.8	23.1	44	3
Freshes duration (days)	17.8	13.5	76	1

Table 20 (b) Reen Valley sub-catchment

	"Natural"	Current	% Change	Rating
Low flow season				
Mean (ML/day)	0.20	0.14	68	1
Median (ML/day)	0.00	0.00	n/d	-
80th percentile (ML/day)	0.00	0.00	n/d	-
Zero flow frequency (/100 years)	108.9	112.2	103	0
Zero flow duration (days)	170.1	169.8	100	0
Freshes frequency (/100 years)	49.5	52.8	107	0
Freshes duration (days)	19.4	14.4	74	1
Transitional flow season (low to high)				
Mean (ML/day)	2.01	1.30	65	2
Median (ML/day)	0.00	0.00	n/d	-
Zero flow frequency (/100 years)	2.8	2.9	103	0
Zero flow duration (days)	79.2	89.1	113	0
Freshes frequency (/100 years)	108.9	95.7	88	1
Freshes duration (days)	6.2	5.0	80	1
High flow season				
Mean (ML/day)	4.10	3.25	79	1
Median (ML/day)	0.92	0.62	67	2
Coefficient of variation	2.4	2.6	111	0
Freshes frequency (/100 years)	273.9	287.1	105	0
Freshes duration (days)	13.8	11.3	82	1
High flow frequency (/100 years)	369.6	297.0	80	1
High flow duration (days)	2.4	2.4	98	0
Transitional flow season (high to low)				
Mean (ML/day)	2.01	1.80	89	1
Median (ML/day)	0.02	0.01	50	2
Zero flow frequency (/100 years)	52.8	56.1	106	0
Zero flow duration (days)	21.1	25.8	122	0
Freshes frequency (/100 years)	52.8	42.9	81	1
Freshes duration (days)	15.1	14.8	98	0

The information from Table 21 can then be interpreted to allow an assessment of the likelihood that the environmental objectives will be achieved for assets in this reach under current conditions, as shown in Table 22. Table 22 lists the environmental objectives for the reach (from Table 4) and interprets the information on the level of deviation for relevant flow metrics in order to make this assessment (last column).

Table 22 shows that the majority of the objectives are unlikely to be achieved in the One Tree Hill sub-catchment due to the high level of water resource development in the upper part of the catchment. The severe reduction in low flows throughout the year and impacts on freshes in the higher flow seasons is likely to compromise the persistence of pools, to the detriment of species that rely on aquatic habitat such as fish and in-stream vegetation. The reduction in the frequency and/or duration of freshes is likely to have implications for water quality, habitat maintenance and access to flowing habitat such as riffles. It is also likely to limit the ability of remnant populations to move around and recolonise areas where local extinctions may have occurred through pool drying or other means.

The only environmental objective that is likely to be met in the One Tree Hill sub-catchment is the maintenance of the riparian and floodplain vegetation communities. All of the objectives are likely to be achieved in the less developed Reen Valley.

Table 21 Environmental water requirements for reach S1 (Saunders Hills), together with the key flow metrics associated with each requirement and the level of deviation for each flow metric. From Doeg and van der Wielen (2007).

Environmental water requirement (per Table 8)	Associated flow metrics	Level of deviation for associated flow metrics
Zero flows and low flows at a frequency and duration that provide persistent water in pools throughout the year.	Mean or median in each season. Zero flow frequency and duration in each season.	High to very high deviation in mean or median in One Tree Hill catchment in all seasons. Moderate deviation in mean or median in Reen Valley in 3 seasons (transitional and high flow seasons). Little change in zero flow frequency or duration in One Tree Hill or Reen Valley.
Freshes, mainly in the low flow season, that refill pools or refresh water quality.	Freshes in low flow season.	Frequency of low flow season freshes maintained in One Tree Hill catchment, but duration reduced. Little change in freshes frequency or duration in Reen Valley.
Freshes during the low flow season to clean substrates for fish egg deposition.		
Freshes that allow fish movement between pools over relatively short distances, particularly in the late low flow season or transitional flow season (low to high).	Freshes in low flow season. Freshes in transitional flow season (low to high).	Frequency of low flow season freshes maintained in One Tree Hill catchment, but duration reduced. Frequency of transitional flow season (low to high) freshes maintained in One Tree Hill catchment, but duration reduced. Frequency of high flow season freshes maintained in One Tree Hill catchment, but duration moderately reduced. Little change in freshes frequency or duration in Reen Valley in any season.
Freshes throughout the year that allow macro-invertebrate movement between pools over short distances.	Freshes in each season.	
Freshes or high flows that prevent sedimentation of pools throughout the year.		
Increase in flows between the Low and high flow seasons to trigger fish spawning.	Mean or median in transitional flow season (low to high).	High deviation in One Tree Hill catchment. Moderate deviation in Reen Valley.
Freshes or high flows in Spring/Summer that move seeds or propagules between pools.	Freshes in transitional flow season (high to low) and low flow season.	Frequency of transitional flow season (high to low) freshes decreased in One Tree Hill catchment, but duration unaffected. Frequency of low flow season freshes maintained in One Tree Hill catchment, but duration reduced. Little change in freshes frequency or duration in Reen Valley.

Table 21 continued

Environmental water requirement (per Table 8)	Associated flow metrics	Level of deviation for associated flow metrics
High flows to prevent domination by few plant species, through encroachment, mainly occurring in the high flow season.	High flows in high flow season.	High reduction in frequency in One Tree Hill catchment, but no change in duration. Little impact on frequency or duration in Reen Valley.
High channel forming flows to maintain channel form and pool structure, mainly occurring in the high flow season.		
High overbank flows to regularly flood River Red Gum habitats to support recruitment of new individuals, mainly occurring in the high flow season.		
High overbank flows to deliver riparian organic material, mainly occurring in the high flow season.		

Table 22 Likelihood of achieving environmental objectives for reach S1 (Saunders Hills). From Doeg and van der Wielen (2007).

Environmental objective (per Table 4)	Comments on level of current development on deviation of related metrics from "natural"	Likelihood objective is achieved
Provide suitable flow and habitat conditions for the maintenance of small native fish communities.	One Tree Hill The severe reduction in low flows (mean and/or median) have the potential to compromise the persistence of water in pools over the long term. Particularly over dry years, the lower flows may not be sufficient to completely refill pools, leading to water quality problems. This can be exacerbated by the reduction in the duration of freshes (meaning that less volume of water passes down the system), even though the frequency of low flow season freshes is maintained. This may explain the lack of persistent pools in the upper One Tree Hill catchment (Figure 8), and also has implications for pools in the lower part of the catchment. The reduction in the duration of freshes also limits the time that any fish have to move between pools, meaning that any recolonisation ability will be restricted. The lack of a distinct rise in water level (median flow in transitional flow season (low to high)) may restrict the success of fish spawning in the catchment. Reen Valley There is no significant change in low flow season low flows, zero flows or freshes. The moderate change in low flows over the transitional flow season (low to high) may limit fish breeding, but this may be compensated by the maintenance of fresh frequency and duration over this period.	Unlikely to be achieved in the One Tree Hill catchment. Likely to be achieved in the Reen Valley.

Table 22 continued

Environmental objective (per Table 4)	**Comments on level of current development on deviation of related metrics from "natural"**	**Likelihood objective is achieved**
Maintain macro-invertebrate community at reference condition for edges.	One Tree Hill The severe reduction in low flows (mean and/or median) and fresh duration have the potential to compromise the persistence of water, and the quality of water, in pools over the long term. The reduction in the duration of freshes also limits the time that any macro-invertebrates have to move between pools, meaning that any recolonisation ability will be limited. Reen Valley There is no significant change in low flow season low flows, zero flows or freshes.	Unlikely to be achieved in the One Tree Hill catchment. Likely to be achieved in the Reen Valley.
Provide suitable flow and habitat conditions for the maintenance of the in-stream plant community.	One Tree Hill The severe reduction in low flows (mean and/or median) have the potential to compromise the persistence of water in pools over the long term. Particularly over dry years, the lower flows may not be sufficient to completely refill pools, leading to water quality problems. This can be exacerbated by the reduction in the duration of freshes (meaning that less volume of water passes down the system), even though the frequency of low flow season freshes is maintained. Reen Valley There is no significant change in low flow season low flows, zero flows or freshes.	Unlikely to be achieved in the One Tree Hill catchment. Likely to be achieved in the Reen Valley.
Maintain or enhance riparian and floodplain River Red Gum and Honey Myrtle community. Maintain channel shape and structure.	One Tree Hill While there is a large reduction in high flow frequency in the One Tree Hill catchment, the events still probably occur annually or every few years (frequencies are 73 per 100 years in upper One Tree Hill and 188 per 100 years in One Tree Hill overall). It is unlikely, therefore, that the water requirements of riparian River Red Gums and Honey Myrtles and channel maintenance in the One Tree Hill catchment are compromised by the current level of development. Reen Valley There is no significant deviation in the frequency of very high flows in the Reen Valley, so it is unlikely that the water requirements of riparian River Red Gums and Honey Myrtles and channel maintenance in the Reen Valley are compromised by the current level of development.	Likely to be achieved in the One Tree Hill catchment. Likely to be achieved in the Reen Valley.

Upper Marne catchment

Analysis of different sub-catchments in the Upper Marne shows a similar pattern to the Upper Saunders as described in the previous section, with significant impacts on environmentally important flow components in areas with a high level of dam development (MREFTP 2003, K. Savadamuthu, personal communication).

Table 23 to Table 25 show an analysis for reach M5 (Marne Gorge – see Figure 16), the most downstream reach in the Upper Marne. Table 23 shows the flow deviation analysis for current conditions compared with "natural" values for flow metrics. Table 24 gives an assessment of the level of deviation associated with each of the environmental water requirements for this reach. Table 25 interprets this information to assess the likelihood that the environmental objectives will be achieved in the long term in this reach.

It can be seen that it is unlikely that the environmental objectives will be achieved over the long term for the aquatic assets of Mountain Galaxias, macro-invertebrates and in-stream vegetation. Environmental water requirements that have been particularly affected are low flows outside of the high flow season, and the duration of freshes in the high and transitional flow seasons. These parts of the flow regime are critical for maintaining the presence of aquatic refuge habitat and for supporting fish recruitment and movement of organisms around the catchment. The deviation to environmentally important high flows is low. Environmental objectives for riparian vegetation and maintenance of channel structure are generally associated with high flows, and are likely to be achieved in this reach.

Analysis of the provision of environmental water requirements of reach M5 integrates the behaviour of upstream reaches in addition to assessing local responses. The impacts of dams in highly developed parts of the upstream catchment are still evident at the Marne Gorge during all flow seasons, despite inflow from free-to-flow areas. The current level of water resource development means that it is unlikely that the current flow regime is adequate to supply environmental water requirements to support aquatic organisms in the long term by the end of the Upper Marne. This means that any further water resource development in the Upper Marne will exacerbate the decline in condition of water-dependent ecosystems.

Lower catchments

Flow data is not available for the lower catchments. However, flow data from the downstream end of the upper catchment (reach M5) provides an indication of the water regime flowing to this area. Changes to the pattern of low flows and freshes from the Upper Marne has implications for the downstream reaches, in terms of persistence of water in the Alluvial Fan reach (M6) and for pre-wetting flows that enhance transmission of later flows further downstream towards the Black Hill Springs. The limited change to the high flow regime suggests that overbank flows for River Red Gum regeneration and wetland filling in the Marne Valley Conservation Park still occur with a relatively natural frequency, although the reduction in pre-wetting flows may have reduced the duration of inundation. Land use changes, such as de-snagging and the creation of levees by road crossings in the channel in Reach M7 may further affect the flow regime by not allowing flows to be delivered to the sites where they are required (MREFTP 2003).

Table 23 Results of the seasonal flow deviation analysis for Reach M5 (Marne Gorge) under current conditions.
Adapted from MREFTP (2003), data from DWLBC (1974 – 2003). Values are rounded. n/d means not defined.

	"Natural"	Current	% Change	Rating
Low flow season				
Mean (ML/day)	3.07	1.66	54	2
Median (ML/day)	0.00	0.00	n/d	-
80th percentile (ML/day)	0.00	0.00	n/d	-
Zero flow frequency (/100 years)	146.5	133.2	91	0
Zero flow duration (days)	80.9	98.6	122	0
Freshes frequency (/100 years)	133.2	89.9	68	2
Freshes duration (days)	24.5	21.9	90	1
Transitional flow season (low to high)				
Mean (ML/day)	43.2	28.6	66	2
Median (ML/day)	12.1	5.11	42	3
Zero flow frequency (/100 years)	59.9	63.3	106	0
Zero flow duration (days)	14.1	14.6	104	0
Freshes frequency (/100 years)	266.4	316.4	119	0
Freshes duration (days)	11.4	6.77	59	2
High flow season				
Mean (ML/day)	54.9	46.0	84	1
Median (ML/day)	9.42	4.79	51	2
Coefficient of variation	2.73	3.07	112	0
Freshes frequency (/100 years)	206.5	246.4	119	0
Freshes duration (days)	22.3	15.5	70	2
High flow frequency (/100 years)	286.4	253.1	88	0
High flow duration (days)	3.21	3.04	95	0
Transitional flow season (high to low)				
Mean (ML/day)	4.14	3.16	76	1
Median (ML/day)	0.02	0.00	0	3
Zero flow frequency (/100 years)	86.6	116.6	135	0
Zero flow duration (days)	29.0	32.7	113	0
Freshes frequency (/100 years)	96.6	89.9	93	0
Freshes duration (days)	29.8	19.1	64	2

Table 24 Environmental water requirements for reach M5 (Marne Gorge), together with the key flow metrics associated with each requirement and the level of deviation for each metric.

Environmental water requirements (per Table 8)	Associated flow metrics	Level of deviation for associated flow metrics
Zero flows and low flows at a frequency and duration that provide water in pools throughout the year.	Mean or median in each season. Zero flow frequency and duration in each season.	Low to high deviation for mean and median for low flow and transitional flow seasons, low to moderate deviation in high flow season. Low deviation for zero flows in all seasons.
Regular flows across riffles throughout the year, with some extended periods of flow.	Mean or median in each season.	Low to high deviation for mean and median for low flow and transitional flow seasons, low to moderate deviation in high flow season.
Freshes during the low flow season that refill pools or refresh water quality.	Freshes in the low flow season.	Low deviation for fresh duration, moderate deviation for fresh frequency.

Table 24 continued

Environmental water requirements (per Table 8)	Associated flow metrics	Level of deviation for associated flow metrics
Low flows or occasional freshes that allow macro-invertebrate movement between pools and riffles by fully aquatic species over relatively short distances.	Freshes in each season.	Moderate deviation for fresh duration in high and transitional flow seasons and fresh frequency in low flow season, otherwise little change for other seasons/flow metrics. Note: frequency of freshes in high and transitional flow season (low to high) has gone up under current conditions because the longer duration freshes under natural conditions have been broken into several shorter freshes under current conditions when dams intercept flows.
Freshes that clean sediment from riffle substrate throughout the year to improve habitat quality for macro-invertebrates.		
Freshes or high flows that prevent sedimentation of pools throughout the year.		
Freshes or high flows that move seeds or propagules between pools.		
Freshes that allow fish movement between pools over relatively short distances, particularly in the late low flow season or transitional flow season (low to high).	Freshes in the low flow season and transitional flow season (low to high).	Moderate deviation for fresh duration in transitional flow season (low to high) and fresh frequency in low flow season, little change for fresh frequency in transitional flow season (low to high) and fresh duration in low flow season.
Freshes that clean sediment from riffle substrate during low flow season and transitional flow season (low to high) for cleaning substrate for fish egg deposition.		
Increase in flows over transitional flow season (low to high) as a fish spawning trigger.	Mean or median in the transitional flow season (low to high).	Moderate deviation for mean. High deviation for median.
Variable high and overbank flows that differentially inundate the riparian zone.	High flows and coefficient of variation in the high flow season.	Little change to flow metrics.
High flows that allow fish movement between pools over relatively long distances.	High flows in the high flow season.	Little change to flow metrics.
High flows that occur at a frequency and duration to maintain pool habitat structure.		
High channel forming flows that occur at a frequency and duration to maintain channel form.		
High overbank flows to deliver riparian organic material, mainly occurring in the high flow season.		
High overbank flows to regularly flood River Red Gum habitats to support recruitment of new individuals, mainly occurring in the high flow season.		

Table 25 Likelihood of achieving environmental objectives for reach M5 (Marne Gorge) under current conditions.

Environmental objective (per Table 4)	Comments on level of current development on deviation of related flow metrics from “natural”	Likelihood objective is achieved
Maintain or restore a self-sustaining population of Mountain Galaxias.	The moderate to high reductions in low flows (mean and median) generally seen outside the high flow season has the potential to compromise the persistence of water in pools over the long term. Particularly in dry years, the lower flows may not be sufficient to completely fill pools, leading to water quality problems. The duration of freshes that might help compensate the reduction in low flows have also been moderately reduced in the transitional flow seasons. Water quality issues in pools over the low flow seasons may be exacerbated by the reduction in frequency of freshes at this time. The decrease in duration of freshes in the transitional flow season (low to high) limits the amount of time that fish have to move between pools around breeding season, restricting local recolonisation and mixing of extant populations at this time. Local scale movements are likely to be similarly restricted in the high flow season by the reduction in duration of freshes then, but the minimal changes to high flow metrics allow larger scale movement to take place. The reduction in the distinct rise in water level at the break of season (median flow in transitional flow season (low to high)) and moderate reduction in freshes that clean spawning sites may restrict the success of fish spawning in the catchment. There is generally little deviation in flow metrics associated with maintenance of channel form, pool depth and prevention of sedimentation outside the breeding season.	Unlikely to be achieved.
Maintain macro-invertebrate community at reference condition.	The moderate to high reductions in low flows (mean and median) generally seen outside the high flow season has the potential to compromise the persistence of water in pools and flow over riffles over the long term. Particularly in dry years, the lower flows may not be sufficient to completely fill pools, leading to water quality problems. Water quality issues in pools over the low flow seasons may be exacerbated by the reduction in frequency of freshes at this time. The reduction in the duration of freshes in the high and transitional flow seasons may limit the time available for macro-invertebrates to move between pools and recolonise habitats. There is generally little deviation in flow metrics associated with maintenance of habitat quality, habitat formation or delivery of riparian organic matter.	Unlikely to be achieved over the long term, particularly for riffle community.

Table 25 continued

Environmental objective (per Table 4)	Comments on level of current development on deviation of related flow metrics from "natural"	Likelihood objective is achieved
Maintain high diversity aquatic plant community.	The moderate to high reductions in low flows (mean and median) generally seen outside the high flow season has the potential to compromise the persistence of water in pools over the long term. Particularly in dry years, the lower flows may not be sufficient to completely fill pools, leading to water quality problems. Water quality issues in pools over the low flow seasons may be exacerbated by the reduction in frequency of freshes at this time. There is generally little deviation in flow metrics associated with maintenance of habitat quality and diversity, maintenance of channel structure and movement of seeds or propagules.	Unlikely to be achieved over the long term.
Maintain high diversity riparian plant community.	There is generally little deviation in high flow metrics associated with differential inundation of the riparian zone, maintenance of channel structure and recruitment of woody riparian species.	Likely to be achieved.
Maintain gorge channel shape, substrate type and structure.	There has been little change to high flow metrics associated with maintenance of channel shape, substrate type and structure.	Likely to be achieved.

4.2.3.3 Impact of underground water use on water-dependent ecosystems

As described in section 4.2.2, there is only limited information available to assess the impact of underground water development on that water resource, making it difficult to assess the impact of development on water-dependent ecosystems. Furthermore, it is difficult to separate the effects of surface water development and underground water development on water-dependent ecosystems, given the strong linkages between these water resources. General comments can be made on the basis of observations and existing knowledge.

Baseflow is a significant component of low flows, and these environmentally important parts of the flow regime are already affected by interception of surface water and watercourse water. There is currently insufficient information to assess the impacts of water extraction from the fractured rock aquifer on discharge of baseflow to watercourses in the hills zone.

In the Lower Marne, It is likely that a combination of low rainfall and water extraction of both underground water and streamflow has resulted in a reduction in underground water level during a series of dry years. This level reduction may have contributed to the decline in condition of dependent River Red Gums during this period.

Springflow from underground water to the watercourse is declining in the spring-fed reaches downstream of Black Hill in the Marne catchment, to the detriment of the highly significant water-dependent ecosystems there. This decline in spring flow may be due to a range of factors and is currently not well understood.

4.2.3.4 Summary of the impact of water resource development on environmental water demands

The current level of water resource development is altering the availability and water regime for different water resources in the Marne Saunders PWRA, as outlined in sections 4.2.1 and 4.2.2. These impacts appear to be playing a role in the decline of water-dependent ecosystems, as outlined in section 4.2.3. The flow deviation analysis shows that the environmental water requirements in watercourses are not being met in many parts of the catchment, particularly in highly developed areas. Environmental water requirements associated with low and medium flow events have been particularly affected.

The impact of existing underground water development on environmental water requirements in the Marne Saunders PWRA is not currently well understood.

The water demands of the environment are not being met in many parts of the Marne Saunders PWRA. That is, the capacity of the water resources to meet this particular demand is not sufficient under the current water management arrangements.

4.3 A new water management framework

The previous section shows that the capacity of the water resources is not able to meet all of the current demands. At least one type of demand is not being met, being the environmental water requirements. It is also possible that consumptive demands for water are not being met for some water users. There is community concern about sharing of water between users, both at a local scale (e.g. impacts of dams on downstream neighbours and impacts of underground water level drawdown on neighbouring wells) and at a broader scale (e.g. concerns about less frequent flooding on the plains).

This section outlines a sustainable water management framework that provides a new balance between social, economic and environmental needs for water. The new management framework aims to meet this Plan's objectives and will be implemented through the prescription process, including this water allocation plan. This section also makes an assessment of the likely capacity of the water resources to meet demands under the new management framework.

While this section provides an overview of the water management approach, it does provide a substitute for the detailed principles that manage allocation, transfer and water affecting activities as set out in section 6 to section 8.

4.3.1 General approach when setting allocation limits and extraction rules

The Marne Saunders Water Allocation Plan objectives (section 1.1) have been developed to encapsulate the requirements of the NRM Act and the guidelines of the State NRM Plan for sustainable water management. These objectives form the primary basis for the new sustainable water allocation framework set out in this Plan. A key part of the framework is to balance competing demands within the supply or capacity of the resource. The overall approach has been:

1. Assessment of the supply of water that is likely to be available for all demands on a continuing basis (for at least the 5 years of the life of this Plan), based on previous water resource behaviour and patterns.
2. Setting aside water for the environment. Environmental water provisions have been determined that have an acceptable level of impact of water-dependent ecosystems in the context of other demands, existing water-taking infrastructure and available management tools. The targets/limits for environmental water provisions for the Plan are outlined below for each water resource (sections 4.3.2.1 and 4.3.3.1).
3. Setting aside the full amount of estimated non-licensed demand (as outlined in section 4.1.2) and/or accounting for the impact of non-licensed water capture infrastructure. The amount of water taken for these purposes is generally not regulated by the Plan, except indirectly by the size of the dam in the case of new dam construction. Therefore the full volume of non-licensed water requirements needs to be set aside to avoid consumptive use exceeding supply.
4. Sharing of remaining available water within resource capacity for licensed consumptive use.

Other considerations when setting the water management framework are given below.

- Minimising the impact of new water resource development on users, the water resources and the environment. Any new development should be undertaken such that it is within local scale as well as broader scale sustainability limits.
- Working within the limitations placed by the existing water taking infrastructure. Changing the capacity of infrastructure (e.g. reducing dam capacities) was seen as the least socially acceptable option. Considerable effort was made to develop a broad-scale sustainable allocation approach that incorporates the existing infrastructure, recognising that impacts may still occur to users and the environment at a local scale or in some areas.
- Generally allowing continuation of local scale impacts occurring between neighbours or on water-dependent ecosystems that started prior to adoption of the Plan, provided that this doesn't have broader scale impacts on the water resources and environment.
- Recognising the importance of an adaptive management approach, where robust monitoring and evaluation of resource and ecosystem condition is undertaken to allow a response to be made if necessary. Monitoring and evaluation also improves knowledge and allows refinement of management policy at plan review.

Key elements of the resulting management framework are:

A. Dividing the area into management zones that reflect features including:
   - different water resources;
   - different parts of a water resource that have particular characteristics (e.g. different types of aquifers, parts of the same aquifer with different primary water sources) where the characteristics of the water resources are described in section 2; and
   - environmental reach types as described in section 3.2.

   These management zones are shown in Figure 26 to Figure 30 (section 11) and are briefly described in Table 28 (section 11). The differences between these management zones mean that each will be managed as an independent unit in the Plan with its own allocation limits, infrastructure rules (including dam capacity limits and well buffer zones) and extraction rules. However, the management regime for each management zone has been developed in consideration of the linkages with other management zones.

One of the primary tools for managing water capture at the management zone scale is the use of allocation limits. The total volume allocated in a management zone must not exceed the allocation limit. Sections 4.3.2 and 4.3.3 describe how the allocation limits were set and what they aim to achieve for surface water plus watercourse water, and underground water respectively.

B. Dividing some management zones into management sub-zones that reflect finer scale differences within their parent management zones. Purposes of managing at the scale of the management sub-zone include to:
   - ensure sufficient water and an appropriate environmental water regime is available at points within the management zone;
   - reflect different rainfall and runoff conditions over the area;
   - ensure adequate throughflow to adjacent aquifers; and
   - limit the total volume of underground water taken in an area where creation of a persistent cone of depression is a significant risk.

   The management sub-zones are shown in Figure 31 and Figure 32 (section 11) and are briefly described in Table 29 (section 11). The management sub-zones also have their own local rules and limits which are a subset of those of their parent management zone.

C. Managing resource capacity at a local scale through allocation limits, buffer zones, dam capacity limits, and extraction rules such as returning or not capturing low flows and maximum diversion or extraction rates. These rules apply at the scale of the well, dam or watercourse diversion structure in order to:
   - protect supply to adjacent users;
   - provide an appropriate environmental water regime; and
   - minimise creation of new impacts.

Key aspects of the management approach are discussed in sections 4.3.2 and 4.3.3, including the approaches for setting environmental water provisions, and development of limits to meet these provisions.

Table 26 provides a coarse assessment of the capacity of the resource to meet demands on a continuing basis, on average, under the water management framework set out by this Plan. This assessment is made for different types of demands (e.g. demands by water-dependent ecosystems for low flows and high flows, licensed use of underground water etc), and also at different scales (e.g. local dam scale compared to management zone scale). The assessment is broad and qualitative, based on the outcomes of the modelling and research done to develop the relevant management policies as outlined in sections 4.3.2 and 4.3.3. Brief reasoning for each assessment is given. A “moderate” likelihood means that it is thought to be more likely than not that the capacity of the resource will be able to meet that demand on average. A “high” likelihood means that it is thought to be very likely (but not certain) that the capacity of the resource will be able to meet that demand on average. In some cases, the management policies mean that the capacity of the resource to meet a certain demand is likely to be no worse than under current conditions, which may be variable or not well known.

This is an assessment of the capacity of the resource to meet demands on a long-term average basis. However, in any particular year or place, this will be highly dependent on external factors such as climate in that year and in previous years. It is also important to note that having an allocation does not guarantee the ability to physically access the full volume of allocation every year. Availability of water from year to year will be influenced by climate, water movement and other demands.

The assessment is based on the best available information, but the actual performance of the Plan in managing the capacity of water resources to meet demands will need to be evaluated from monitoring data as outlined in section 9.

4.3.1.1 Climate variability and change

Any assessment of the capacity of the water resources to meet future demands is complicated by climate driven changes in water supply. Much of the work to set allocation limits and associated policy for this Plan is based on historical data on resource supply, particularly from the last 30 or so years. This period includes a range of wet and dry years. The climate is quite variable from year to year and also shows patterns of wetter and drier periods. Future climate and hence water availability may not reflect historical patterns.

In addition, there is a trend towards hotter, drier conditions of large parts of south-eastern Australia and there is strong consensus that these higher temperatures reflect climate change. Modelling of climate change scenarios and resulting impact on water availability through the CSIRO Sustainable Yields project for the Eastern Mount Lofty Ranges region has predicted reductions in average water availability of between 3% and 52% (CSIRO 2007). Furthermore, increasing temperatures and evaporation may increase demand for water, placing further stress on the water resources.

At present there is considerable uncertainty about the quantum of climate change likely to be experienced and its impact on water availability and demand. Therefore the potential impacts of climate change have not been incorporated into this Plan, and it is expected that this will be reviewed in future plans when better information is available.

In the meantime, this Plan has taken a conservative approach to water allocation. No new water will be allocated from those resources where allocations to existing users are at or close to sustainable limits. Only a small amount of water will be available for new allocation under this Plan for those resources where the best available technical information shows that extra water could be taken sustainably.

Adequate monitoring and evaluation to support an adaptive management approach is of key importance to allow responsive management in the face of climatic uncertainty. Section 9 sets out the minimum monitoring framework required to assess water demand, trends in water resource behaviour, environmental responses and the capacity of the resource to meet demands.

Aboriginal nations' position on climate change

Aboriginal people have long experiences with climate change. Their Creation stories tell them of the flooding of their lands and changes to rivers and coast lines. Their old people have watched the impacts of the degradation of their lands and waters since European occupation. They recognise the impacts of global warming on their lands and waters and all living things. In recent years, Peramangk and Ngadjuri have observed changes in their local environment that tells them that climate change is a reality. They see that the breeding behaviour of birds is changing, as is the colour of fish and their behaviour and the fruiting and flowering of their bush foods is changing too and some species have disappeared altogether.

Peramangk and Ngadjuri peoples support action to address climate change and are willing to work with all levels of government to reverse damage done by industrialisation and unsustainable practices.

Table 26 Likelihood for the capacity of the water resources to meet different types of demands on average under the management approaches taken under the Plan. WDEs = Water-dependent Ecosystems; SW/WC = surface water and/or watercourse water; MZ = management zone; MSZ = management sub-zone.

Demand	Scale	Management approach to address demand	Likelihood of capacity meeting demand
WDEs Low flows (surface water)	Local (within reach), entire reach and between reaches	• Return/bypass/avoid capture of low flows.	Moderate - high (when low flows occur, they will be returned/bypassed around licensed dams. Modelling shows mostly low environmental stress for relevant flow metrics, but some local environmental stress in highly developed areas and in areas with substantial non-licensed capture).
WDEs Baseflows	Local (within reach)	• Buffer zones around wells to avoid local underground water level drawdown. • Set maximum extraction rates for large underground water allocations to address greater risk of underground water level drawdown. • SW/WC rules to return low flows to avoid extraction of baseflow once at the surface. • No extraction of SW/WC from spring-fed reaches in plains zone.	No worse than present (new impacts minimised by buffers, but any existing impacts continue).
	Entire reach and between reaches	• Set MZ allocation limit to protect baseflow (avoid regional drawdown). • Return low flows from hills to allow better transmission of subsequent larger flows to Black Hill Springs to improve recharge and subsequent baseflow.	Uncertain for the Black Hill Springs (modelling shows underground water level should be maintained, but highly dependent on rainfall pattern. Also uncertain of causes of current decline in extent of springs). Uncertain for fractured rock (100% of average baseflow volume set aside from recharge, but allocation >> current usage).
WDE High flows	Local (within reach)	• Set consumptive use limits and dam capacity limits at dam scale to limit volume of SW/WC taken locally. • Set maximum diversion rate to allow part of high flow events to go through. • Reduction of total dam capacity over time via recovery of some dam capacity when dams are voluntarily removed.	Moderate (modelling shows acceptable environmental stress, but high level of dam capacity remains unless people remove dams or reduce dam capacity).

Table 26 continued

Demand	Scale	Management approach to address demand	Likelihood of capacity meeting demand
WDE High flows	Reach scale and between reaches	• Set consumptive use limits and dam capacity limits at MSZ and MZ scale to limit volume taken at these scales. • Reduction of total dam capacity over time via recovery of some dam capacity when dams voluntarily removed.	Moderate (modelling shows acceptable environmental stress, but high level of dam capacity remains unless people remove dams or reduce dam capacity).
WDEs Accessible water level	Entire reach	• Set MZ allocation limit to maintain regional water level above previous minima in MGL aquifer.	Moderate (modelling shows underground water level should be maintained, but highly dependent on rainfall pattern).
Non-licensed use (underground water)	Local	• Buffers to avoid local underground water level drawdown. • Set maximum extraction rates for large underground water allocations to address greater risk of underground water level drawdown.	No worse than present (new impacts minimised by buffers, but any existing impacts continue).
	MSZ/MZ	• Protect non-licensed needs when setting allocation limits at MSZ and MZ scale by subtracting estimated non-licensed needs from total supply.	Moderate - high (100% of likely future non-licensed needs set aside from total supply when determining allocation limits).
Non-licensed use (surface water and watercourse water)	Local	• Set consumptive use limits and dam capacity limits at source scale to protect existing supply arrangements. • Subtract estimated non-licensed needs from available supply when assessing allocations and dam construction against local consumptive use and dam capacity limits. • Set maximum diversion rate to allow part of high flow events to go through to downstream users.	No worse than present (new impacts minimised by limits on allocations and dam construction, but any existing impacts continue).
	MSZ/MZ	• Set consumptive use limits and dam capacity limits at MSZ and MZ scale to balance demand between zones, and subtract estimated non-licensed needs.	Moderate (estimated non-licensed needs set aside when determining allocation limits for all resources, but highly dependent on rainfall).

Table 26 continued

Demand	Scale	Management approach to address demand	Likelihood of capacity meeting demand
Licensed consumptive use (underground water)	Local	• Buffers to avoid local underground water level drawdown. • Maximum extraction rates for large underground water allocations to address greater risk of underground water level drawdown.	No worse than present (new impacts minimised by buffers, but any existing impacts continue).
	MSZ/MZ	• Set allocation limits at MSZ and MZ scales so that they are within the supplied volume and to protect throughflow between aquifers.	Moderate (allocation limits are within average supplied, but highly dependent on rainfall. Allocation limits for some management zones are significantly less than theoretical current demand, but are greater than current use for all management zones. Future water needs will need to come from improved efficiency, transfer and other water sources).
Licensed consumptive use (Surface water and watercourse water)	Local	• Set consumptive use limits and dam capacity limits at source scale to protect existing supply arrangements. • Set maximum diversion rate to allow part of high flow events to go through to downstream users.	No worse than present (new impacts minimised by limits on allocations and dam construction, but any existing impacts continue).
	MSZ/MZ	• Set consumptive use limits and dam capacity limits at MSZ and MZ scale to be within supply and to balance demand between zones.	Moderate (consumptive use limits are within average supply, but highly dependent on rainfall. Allocation limits for some management zones and management sub-zones are significantly less than theoretical current demand, but are greater than current use for all management zones. Future water needs will need to come from improved efficiency, transfer and other water sources).
Adequate water quality	Local	• Protective principles requiring water use to not cause water quality deterioration. • Management of water quality impacts of water affecting activities.	No worse than present (minimise new impacts from activities).
	MSZ/MZ	• Set allocation limit for underground water management zones that minimises risk of permanent cone of depression and inflow of adjacent saline underground water.	Moderate (modelling of underground water level shows minimal risk of creating permanent cone of depression).

4.3.2 Developing the surface water and watercourse water allocation limits and extraction rules

4.3.2.1 Environmental water provisions for surface water and watercourse water

The flow metrics and associated environmental stress levels outlined in section 3.6 can be used to help set allocation limits and extraction rules. These flow metrics and environmental stress levels can be used as a tool to assess the environmental water provisions resulting from modelled different surface water and watercourse water management scenarios for the hills zone.

It was agreed through discussions with technical experts and the Marne-Saunders Water Resources Planning Committee that achieving a moderate or better level of environmental stress (equal to or less than a rating of 2 for Table 12) for all flow metrics would provide an improvement in the current environmental water regime, and improve the likelihood of achieving the environmental objectives. Achieving a moderate or better environmental stress rating is referred to in this Plan as the "environmental stress limit". The level of the environmental stress limit was set in the context of the existing level of development and the limited ability to manage existing non-licensed use for the current plan. This level of environmental water provision is a balance between social, economic and environmental needs for water.

The flow regime immediately downstream of new or enlarged dams constructed under this Plan would need to be within the environmental stress limit for all flow metrics, in keeping with the approach of ensuring all new development is "sustainable". However, the flow regime immediately downstream of unmodified dams that pre-date the Plan would not need to be within this environmental stress limit. This is in keeping with the approach of working within the existing infrastructure, and of tolerating pre-existing local scale impacts, **provided that acceptable environmental outcomes are achieved at the broader scale**.

The major water-dependent ecological assets in the hills zone occur in the main watercourses (reaches M2, M4, and the main watercourse of S1, S2 and M5 – see Figure 16). Each tributary feeding into the main watercourses contributes a portion of the necessary environmental water regime. Therefore it was decided that the flow regime coming out of the tributaries (i.e. each of the tributary management sub-zones as identified in Table 29) should be within the environmental stress limits. This means that environmental stress immediately downstream of existing dams may exceed the limits for some flow metrics, but the flow regime should be acceptable by the time it reaches the significant ecological assets in the main watercourse.

The Marne Saunders Water Resources Planning Committee considered that the longer-term aspirational limit should be to achieve a low or better environmental stress (rating of 1 or less) within 20 years.

Flow modelling is not available for the plains zone, so the flow metrics could only be used to assess total input to the area from the hills. Large flows from the hills that provide significant recharge to the aquifers on the plains is an important environmental water need in order to maintain discharge at the Black Hill Springs. The high flow metrics from the downstream end of the Marne hills show minimal deviation from "natural" under current conditions (see Table 23). Therefore it was decided to set a further provision that the average discharge from the hills zone should be no less than under current conditions. The purpose of this provision is to minimise any new impacts on underground water levels in the plains resulting from capture of surface water and watercourse water.

Flows in the spring fed sections of reaches M8 (Lower Marne around Black Hill Springs) and S4 (Lower Saunders) are critically important and already declining, so no new extractions will be allowed from these areas.

4.3.2.2 Setting surface water and watercourse water allocation limits and extraction rules

The three major tools available for managing surface water and watercourse water taking are:

- **Diversion**: managing the pattern of taking, such as not capturing flows below a defined threshold flow rate ("returning low flows") or managing the pumping rate from a watercourse;
- **Capture**: managing the dam capacity; and
- **Use**: managing the volume taken from a dam or watercourse.

These options can be used in different combinations and at different scales.

The capture and consumptive use limits described below generally include all capture or usage from an area, including estimated non-licensed use. It doesn't make any difference to a downstream user or ecosystem if water was taken for licensed or non-licensed purposes, just that it was taken.

Local dam scale limits

Local dam scale limits were set by using modelling to test what combinations of diversion, capture and use would produce a flow regime that was within the environmental stress limits. This work used a unit surface water model consisting of a one square kilometre catchment (with the characteristics of the Upper Marne) draining to a single dam. The flow regime immediately downstream of that dam was then assessed against the environmental stress limits (Savadamuthu 2007).

No combination of capture and use fell within the environmental stress limits if low flows were not returned. Various combinations of capture and maximum use with low flows returned produced a flow regime that fell within the environmental stress limits ("sustainable combinations"). Of these sustainable combinations, a capture limit and usage limit of 30% of average adjusted winter (May – November) runoff from the catchment area upstream of the dam, plus returning low flows, was selected for application to new or enlarged dams. The limit is reduced by any existing dam capacity or usage as relevant in the catchment area upstream of the dam. The limit of 30% of average adjusted winter runoff was selected as a conservative limit, given the high level of environmental stress already seen in parts of the hills zone as a result of existing infrastructure.

Low flows at or below a threshold flow rate must be bypassed, returned or not captured by all licensed dams and other diversion structures, including those of existing users, as a key part of the environmental water provisions. Returning low flows while allowing users to capture higher flows was seen as a preferable management approach compared to further reducing usage limits and/or existing dam capacities. Furthermore, returning low flows provides a much more effective means of restoring the parts of the water regime affected by development of dams. Any dam will need to fill and spill before runoff can get past it into the downstream watercourse. Even if there is no usage from the dam, the water lost via evaporation and seepage will need to be replaced by inflow of runoff before the dam will spill.

The threshold flow rate is set on the basis of the 90th percentile exceedence flow rate from a time weighted, mean daily flow, flow duration curve for the area (i.e. the mean daily flow rate exceeded for 90% of the time). This figure has been selected on the basis of analysis of the frequency of different flow levels to represent environmentally significant low flows. The average annual volume of flow for the period at or below the threshold flow rate is around 10% of the total average annual volume of flow for the Marne catchment (data supplied by DWLBC from flow from the Marne Gorge flow gauging station for 1973 - 1988).

The Plan also includes a range of other limits at the scale of the dam, which aim to minimise impacts on the supply of downstream consumptive demand, and to provide reasonable sharing of water by capping dam capacity to the reasonable needs of the property, and capping allocation at the volume likely to be physically available at that location. These limits are determined on the basis of local characteristics and local supply and demand.

In addition, a maximum diversion rate will be set for extractions from major watercourses in order to ensure that high flow events are shared between users. This rate will be set on an individual basis as the volumetric allocation divided by 20 days, and then converted to a diversion rate in litres per second. Flows over the threshold flow rate are available for 20 days in 60% of years. This figure has been selected on the basis of allowing the allocation volume to be taken over the number of days that it will be available on in the majority of years.

Management sub-zone scale limits

A similar process of modelling different scenarios and testing the resulting flow regime against the environmental stress limits was used to determine a usage limit at the management sub-zone scale. This modelling was carried out on a range of management sub-zones on the basis of the existing infrastructure, and only tested scenarios of different usage and diversion with or without return of low flows.

The environmental stress limits could not be met under any of these scenarios for some highly developed management sub-zones. A usage limit of 30% of average adjusted winter runoff from each management sub-zone in addition to a requirement to return low flows from all dams used for licensed purposes has been set. This limit relies on low flows being returned around all dams and diversion structures used for licensed purposes, including those of existing users. This usage limit meets the environmental stress limits in almost all of the management sub-zones while allowing existing enterprises to remain viable. Although the environmental stress limit may be exceeded for some management sub-zones, at the broader management zone scale this is compensated for by management sub-zones with low levels of development.

The corresponding dam capacity limit of 30% of average adjusted winter runoff has been carried over from the dam scale limits (as described above) to the management sub-zone scale. In the case of the management sub-zones on the plains, the average runoff is considered to be zero. The dam capacity limit for these areas has been set at the current dam capacity instead.

Management zone scale limits

Allocation limits

Environmental water provisions are an important consideration for setting allocation limits for surface water and watercourse water in the Upper Marne and Upper Saunders. Another important consideration is to provide for sharing of the volume available for consumptive use with the users of the sedimentary aquifers on the plains that are recharged by these resources. The volume to be allocated to existing users of surface water (under a separate process under the WR Act – see footnote 6 in section 4.1.3.1) is around 55% of the theoretical demand, while the volume to be allocated to existing users of the connected Murray Group Limestone aquifer is around 58% of the theoretical demand. On the basis of this relative equivalence between the resources, and the fact that the proposed allocations to existing surface water users met the environmental water provision targets at the end of the Upper Marne, it was decided to set the allocation limit for the management zones at the volume to be allocated to licensed existing users.

Surface water and watercourse water are important in the lower catchments to provide recharge to the aquifers and to support water-dependent ecosystems. These flows are uncommon and should be protected. They are also highly variable from year to year, and are likely to only be available for a limited period in most cases. Any water stored in dams on the plains will be subject to high levels of loss via evaporation. On balance, it was decided that the allocation limit for the Lower Marne and Lower Saunders Management Zones would be fixed at the volume to be allocated to existing users. Flows in the spring fed reaches in the lower catchments (M8 and S4) are critically important and transferred allocations will not be able to be taken from these areas.

Comparison of management zone and management sub-zone use limits

The management zone scale limit for surface water and watercourse water is an allocation limit (licensed use only), while the equivalent limit at the management sub-zone scale is a consumptive use limit (i.e. licensed plus estimated non-licensed use). This means that the sum of the consumptive use limits for all the management sub-zones in a management zone is greater than that management zone's allocation limit. The primary purpose of the management zone allocation limit is to prevent new allocations being made from this resource. New non-licensed consumptive use is indirectly managed by restricting the construction of new dam capacity (see below). The management sub-zone consumptive use limits allow water to move around within management zones, up to the local limit that allows each tributary to contribute their share of an environmentally acceptable water regime.

Dam capacity limits

The local (dam-scale) dam capacity limit of 30% of average adjusted winter runoff outlined earlier in this section has been scaled up to provide a long-term target for dam capacity for the management zones. The current total dam capacity in these management zones currently exceeds this target. This means that no additional dam capacity may be constructed in the Marne Saunders PWRA above the current level under the Plan. Existing dam capacity will need to be removed if a new dam is to be constructed.

The usage limits and diversion rules set out in the Plan ensure that an acceptable level of environmental stress and sharing of water between users is achieved with the current network of dams. However, reducing dam capacities to the long-term dam capacity target over time will enhance environmental outcomes and provide better security of supply for users. In order to work towards this long-term target, the Plan includes the “80% rule” which sets out that when dam capacity is removed, only up to 80% of the dam capacity that has been removed may be re-constructed.

Safety net allocations to existing users

Under regulations made under the NRM Act, it is expected that some existing users of surface water and/or watercourse water will be granted a safety net allocation, where the volume allocated exceeds local or management sub-zone scale limits. The safety net allocation is a social and economic consideration to allow existing businesses to continue to operate.

The safety net allocation is made up of two parts, as shown below.

Safety net allocation = Foundation allocation + Extra safety net allocation

Where:

Safety net allocation	50% of maximum theoretical enterprise requirement that the existing user is entitled to, capped at dam capacity (where relevant).
Foundation allocation	the allocation that would have been received under the existing user allocation process without the safety net allocation, being the lesser of their maximum theoretical enterprise requirements, dam capacity (where relevant), available runoff to their diversion structure, or share of the water available for licensed use within their management sub-zone consumptive use limit.
Extra safety net allocation	the difference between the safety net allocation and foundation allocation.

The extra safety net allocation is a compromise in terms of the needs of the environment and downstream users. Therefore if the licensee doesn't require this extra safety net allocation, they should not make a windfall gain from it by transferring it to another user, or by retaining use of the extra safety net allocation if they transfer any of their foundation allocation. Therefore this

Plan includes transfer principles that limit the transfer of extra safety allocations, and limit use of an extra safety net allocation when any of the associated foundation allocation is transferred.

Roof runoff (surface water) allocation limits

Roof runoff is a part of surface water. Use of roof runoff for certain purposes above a threshold volume requires a licence (see section 6.6 for more information). The proportion of rainfall that runs off a roof is considerably higher than the proportion that runs off ordinary land. Therefore part of the roof runoff can be harvested without significantly affecting downstream flow. As a result, new allocations of roof runoff may be made under this Plan, provided that runoff from 15% of the roof area is allowed to return to the environment. The return figure of 15% represents the proportion of rainfall that would have normally returned to the environment.

4.3.3 Developing the underground water allocation limits and extraction rules

4.3.3.1 Environmental water provisions for underground water

Baseflow is a key source of water to the watercourses, particularly to refuge pools during the low flow season and to the spring-fed reaches in the plains zone (reach M8 and S4). Therefore it was decided that where baseflow estimates are available, that volume should be set aside from extraction limits for the underground water to allow it to continue to discharge to the watercourse. Once in the watercourse, baseflow will be managed by the environmental water provisions for surface water and watercourse water. Total demand (including natural discharges such as baseflow as well as all consumptive use) should also not exceed supply to maintain regional underground water levels and hence the continued discharge of baseflow.

In many parts of the Marne Saunders PWRA, the watercourses are linked to the underlying aquifer. Pumping from wells close to the watercourse may reduce discharge of baseflow or even induce discharge from the watercourse to the underground water. This would interfere with the surface water and watercourse water environmental provisions. Therefore new wells and new or transferred allocations will not be permitted where this is likely to interfere with a watercourse or other water-dependent ecosystem that is linked to underground water. This is of particular importance in the spring-fed reaches of the lower catchments (reaches M8 and S4) given the high significance of these assets.

Lower underground water levels in 2000 - 2002 coincided with poor health of River Red Gums on the plains. This poor condition was probably driven by a number of factors, but it is possible that reduced ability to access the lowered underground water contributed to this. Therefore the lowest underground water level experienced during this time provides a target for lowest acceptable underground water level when setting allocation limits for the Murray Group Limestone aquifer.

The location and rate of baseflow discharge at the Black Hill Springs is thought to be driven by the slope of the regional water table in the Murray Group Limestone aquifer. Maintaining this slope can be assisted by capping extraction from the aquifer in combination with management of the recharge of surface water and watercourse water (covered by the environmental water provisions for these resources). An important test for maintenance of local water table gradient is the level in the monitoring wells RIL 1 and RIL 2, located in the Murray Group Limestone aquifer up-gradient of the springs. Increasing low to medium flow events to the Lower Marne may also assist the Black Hill Springs by pre-wetting the channel, allowing subsequent flows to reach further down the channel on the Lower Marne and recharging local aquifers near the springs to provide sustained baseflow.

4.3.3.2 Fractured rock aquifer underground water allocation limits and extraction rules

Key water management issues for the fractured rock aquifer in addition to environmental water provisions are to:

- protect throughflow to the sedimentary aquifers on the plains;
- manage interference between users; and

- share water used for consumptive purposes with the linked surface water and watercourse water resources.

The fractured rock aquifer is highly complex and not well understood. Therefore it is particularly important to take a conservative approach to future use to protect dependent ecosystems and current users. Adaptive management will also be highly important.

Management zone limit

A water balance has been developed for the fractured rock aquifer, in order to protect water movement at the broader scale by ensuring that the outputs/demands (including natural discharge) are within the input/supply. Water input to the fractured rock aquifer is via recharge (as described in section 2.3.2.1). The major outputs are discharge to the watercourse, throughflow to other aquifers and consumptive use (non-licensed and licensed) as described in sections 2.3.2.1, 4.1.2 and 4.1.3. All of the outputs except licensed use can be subtracted from the input to give a maximum volume that could be allocated while protecting the other outputs and regional underground water level on average. This water balance approach gives an allocation limit of between approximately 2,000 and 2,500 ML. Using a cautious approach, the allocation limit for this aquifer has been set at 2,000 ML.

The volume of baseflow is linked both to underground water from the fractured rock aquifer (where it comes from) and the surface water and watercourse water resources (where it goes to). Care must be taken that it is accounted for between all resources. The approach taken has been to subtract 100% of the estimated baseflow volume from the supply (recharge) from the fractured rock aquifer to ensure that it continues to discharge to the watercourse. Environmentally important parts of the flow pattern (which will include flow provided by baseflow) are protected through the limits and extraction rules placed on users of surface water and watercourse water. Therefore users of all these resources are making a contribution to environmental water provisions and are sharing the available resource.

Management sub-zone limit

The Fractured Rock Sub-Zone F2 (Figure 31 in section 11) is thought to provide the major source of recharge to the confined sedimentary aquifers on the plains via throughflow. Therefore an allocation limit of 250 ML has been set for this management sub-zone to protect the major source of recharge to the adjacent confined sedimentary aquifers, ensuring sharing of these linked resources between users.

Local limit

Local scale impacts (i.e. interference between wells; and between wells and watercourses and other water-dependent ecosystems that interact with underground water) will be managed through buffer zones. Operational wells and environmental assets (sections of watercourses that support water-dependent ecosystems and are likely to interact with underground water) will be assigned a buffer zone radiating out from the well or asset. New wells will generally not be permitted where the buffer zone of the proposed well overlaps an existing buffer zone. Transfers and new allocations will generally not be able to be taken from wells with buffer zones that overlap another existing buffer zone.

Some exemptions are provided to these overlapping buffer rules where no significant detrimental impact can be demonstrated, or in keeping with the approach of working within the existing infrastructure and of tolerating pre-existing local scale impacts provided that acceptable outcomes are achieved at the broader scale. However, exemptions to the overlapping buffer rules are generally not allowed where the buffer zone of an environmental asset is overlapped. An affected consumptive user has the opportunity to lower their pump or find an alternative water source, but water-dependent ecosystems do not have these opportunities.

The radius of the buffer zone has been set at 200 m in the fractured rock aquifer. This distance has been determined as the maximum likely distance at which pumping from a well will have a significant impact on underground water levels while pumping is occurring. The extent of significant impact in the fractured rock aquifer is largely related to the size and connection of the fractures, as well as the amount and rate of water extraction.

4.3.3.3 Sedimentary aquifer underground water (Murray Group Limestone aquifer) allocation limits and extraction rules

Key water management issues for the Murray Group Limestone aquifer, in addition to environmental water provisions, are to:

- manage interference between users;
- avoid salinising fresher underground water by drawing in adjacent saltier underground water; and
- share water for consumptive purposes with the linked surface water and watercourse water resources.

The underground water model as described in section 4.2.2.3 was used to test scenarios to see which water management regime met environmental water provisions and other requirements.

For the confined aquifer, no environmental water provisions have been set because there are no ecosystems currently known to be directly depending on this resource. The key management aim is to avoid creating a persistent cone of depression in the underground water level. Such a cone of depression may lead to issues with access to the lowered underground water level, flow reversal and drawing in of saltier water from adjacent areas. Modelling of level and flow direction in response to a variety of water extraction regimes, based on current and likely future extraction patterns, showed that an acceptable level of impact was achieved if:

- the allocation limit for the Confined Zone A Management Zone was set at approximately 330 ML (with the estimated volume required for non-licensed use set aside); and
- the allocation limit for the Confined Sub-Zone C2 (see Figure 31), centred on the current cone of depression, was set at 240 ML.

For the Unconfined Zone 1 Management Zone, the primary source of recharge is from flow from the overlying Marne River. The main target in this management zone is to avoid underground water levels dropping below the minima experienced in the early 2000s. The model was used to test the impact on underground water levels for various combinations of extraction volumes (based on current and likely future patterns of extraction); and recharge from streamflow (based on combinations of median annual streamflow and drier annual streamflow (20^{th} percentile flow; or the annual volume of streamflow that would be exceeded in 4 out of 5 years)). Using an environmentally conservative recharge regime of alternating median and drier annual streamflow, it was found that an acceptable level of impact was experienced when 1,500 - 1,700 ML was taken for consumptive use. Taking estimated non-licensed use into account gives an allocation limit of just over 1,600 ML.

It should be noted that the actual outcome in terms of underground water level will be highly dependent on the pattern of recharge from streamflow, which is very variable over time. Therefore an adaptive management approach, including robust monitoring of water resource behaviour, will be necessary for this and the other water resources.

An exclusion zone for allocations has been placed around the Black Hill Springs in order to protect discharge of baseflow in this area (the Exclusion Zone in Figure 28 in section 11). The underground water model was used to test the impact of water extraction just up-gradient of the western boundary of the Exclusion Zone. It was found that extraction would be likely to have minor impacts on the modelled underground water level in the nearby RIL 2 well close to the western boundary of the Exclusion Zone, and negligible impact on modelled underground water level at a point two kilometres upstream of the current springs.

Allocation limits have been set for the remaining management zones in the Murray Group Limestone aquifer on the basis of a proportion of local recharge, derived from local rainfall.

The approach outlined for buffer zones for the fractured rock aquifer will also be adopted for the Murray Group Limestone aquifer. However, the radius of buffer zones will vary in accordance with aquifer characteristics and the purpose and/or volume of use from the well, in order to reflect the more even flow rate and responsiveness to pumping in sedimentary aquifers.

4.3.3.4 Sedimentary aquifer underground water (Quaternary aquifer) allocation limits and extraction rules

The Quaternary aquifer is thought to be an important source of baseflow on the plains zone and may also be a source of water for vegetation. Availability of water from this aquifer is low, but it provides a source of water for some non-licensed users. Consumptive use from this aquifer will be limited to non-licensed use only under this Plan to protect water-dependent ecosystems and non-licensed users.

The impact of new wells on other wells or water-dependent ecosystems will be managed through buffer zones as for the Murray Group Limestone aquifer.

4.3.3.5 Sedimentary aquifer underground water (Renmark Group aquifer) allocation limits and extraction rules

The Renmark Group aquifer is not thought to provide water for ecosystems given its depth and separation from the surface. It is currently only used for non-licensed purposes in the Marne Saunders PWRA, but is utilised for irrigation in adjacent areas.

Key management issues are likely to include interference between users, and the potential to induce downward leakage from the overlying Murray Group Limestone if the Renmark Group aquifer is locally overdrawn. The key management approaches to deal with these issues are to:

- set an allocation limit of 500 ML based on likely extent and recharge of this aquifer; and
- keep wells separated via buffer zones to avoid interference and intensive use in a small area.

The Renmark Group aquifer is currently poorly understood and so an adaptive management approach is very important here. To this end, licensed users of this aquifer will be required to carry out more intensive monitoring of the impact of use on aquifer response.

4.3.4 Impacts of management approach

When developing the policies for this Plan, the SA MDB NRM Board has considered:

- the present and future water needs of the occupiers of land in relation to the existing requirements and future capacity of land for water using purposes; and
- the likely effect of the policies on the value of land.

The volumes of water available for allocation are thought to be enough to meet present water needs, based on usage data and estimates for non-licensed use as outlined in sections 4.1.2 and 4.1.3.2.

The demand for water is expected to slowly increase as outlined in sections 4.1.2 and 4.1.3.3. The capacity of the land to support further development is thought to be good, and it is likely to be access to water rather than land capacity that limits future development of water-using activities. The lack or low volume of water available for new allocation (depending on the resource) means that any such additional demand will generally need to be met through increases in efficiency, trading or alternative water sources.

It is difficult to predict the likely effect of the provisions of this Plan on land value in the Marne Saunders PWRA. The low or zero volume of water available for new allocation and limits on construction of new dams and wells may affect the value of land that does not currently have access to water. However, the improved security of water supply and granting of a valuable asset may improve the value of land with developed water resources.

5 Effects on other water resources

The NRM Act requires that a water allocation plan includes an assessment of whether taking or use of water from the resource will have a detrimental effect on the quantity or quality of water that is available from any other water resource. If a detrimental effect is occurring or is likely, then the plan must take account of the needs of those dependent on the affected resource.

Interactions between water resources within the Marne Saunders PWRA are described in section 2.3 and accounted for in the policy sections of this Plan, as outlined in sections 4.3.2 and 4.3.3. These interactions include:

- direct linkage between surface water and watercourse water;
- provision of baseflow from the fractured rock, Quaternary and Murray Group Limestone aquifers to the watercourse;
- throughflow from the fractured rock aquifer to the confined Murray Group Limestone aquifer; and
- recharge of the Murray Group Limestone aquifer from the watercourse.

This section undertakes an assessment of the impact of taking and use of prescribed water resources within the Marne Saunders PWRA on water resources outside the Marne Saunders PWRA.

Aboriginal people do not categorise lands and waters, nor put boundaries around them and can therefore find the management processes of water resource plans, prescribed water resource areas and water allocation plans restrictive. There is an assessment within this Plan on the effect of other water resources, by viewing these resources as separate systems within defined areas. However, this does not accord with the Aboriginal worldview that it is one interconnected system and so makes water planning and management challenging for Aboriginal nations.

Figure 1A shows the complexities of current native title boundaries that overlap with different water planning areas and NRM Regions. Note that Ngadjuri have four NRM regions within their native title claim area, making water and NRM planning difficult and at times confusing for this nation.

The 2019 amendments made to the Plan acknowledge that there is a current gap between the knowledge and understanding that Aboriginal people bring on the interconnectedness of water across the landscape and non-Aboriginal knowledge of this interconnectedness. To bridge this gap, investment is required over time and could be assisted by progressing the engagement principles of developing cultural knowledge agreements with Aboriginal nations, as described in section 1.5.

5.1 Effects of taking surface water and watercourse water on other water resources

The Marne Saunders PWRA incorporates the whole catchment areas of the Marne River and the Saunders Creek, and so detrimental effects of taking and using surface water and watercourse water within these catchments are accounted for within the Plan.

The Marne River and Saunders Creek discharge to the River Murray. As described in the draft River Murray water resource plan (DEW, in prep), Murrundi (the River Murray) is core to culture and identity of many Aboriginal peoples across the Murray Darling Basin. After Murrundi crosses from Victoria to South Australia, the River meanders through the traditional lands of the First Peoples of the River Murray and Mallee to the traditional lands of Peramangk and Ngarrindjeri peoples before meeting the sea at a place many refer to as *the meeting of the waters*. Along the way, the River meets with other watercourses, both above and underground, that join the journey bringing life into the surrounding Country and its peoples. While each of the Traditional Owner groups along Murrundi have distinct cultural identities specific to their Country, this concept of connectedness to Murrundi is common to all Aboriginal nations connecting them to each other, to upstream nations and wider nations of connected watercourses.

For Peramangk people, the flow of water within the Marne River and Saunders Creek aided travel and connection between the hills and Murrundi. There is much Aboriginal cultural knowledge of the relationship between flow, water-dependent ecosystems and sustainable livelihoods that would be a valuable addition to scientific knowledge and addressing gaps in the understanding of water resources. In relation to water allocation planning, this cultural knowledge has yet to be taken into account but consideration of this knowledge is further discussed in section 1.5.

Ngarrindjeri have long asserted the importance of the Marne Saunders and Eastern Mount Lofty Ranges watercourses to the health and condition of the Coorong.

As described in section 2.3.1.2, much of the flow generated in the Marne Saunders hills zone is naturally lost from the watercourse on the plains zone as recharge to the underlying aquifers. Significant floods are required for flow to traverse the plains zones. Modelling of the impact of surface water resource development on the different flow components of the Upper Marne and Upper Saunders has shown that high flow events have not been significantly affected by water resource development. It is likely that the anecdotal observations of reduced flooding frequency in the plains zone is driven substantially by lower rainfall in recent times.
Spring flow from the Black Hill Springs is declining and a number of springs closer to the Marne mouth are understood to have dried up in recent times. This reduction in spring flow is likely to have reduced discharge to the Marne mouth wetland at the junction with the River Murray. The reason for this decline is not currently well understood, but is likely to be significantly driven by the anecdotally observed reduction in flooding and associated recharge. This plan includes policies to protect the spring flow which will flow on to the Marne mouth wetland.

5.2 Effects of taking underground water on other water resources

As described in section 2.3.2, the primary direction of flow of underground water is from west to east, with the flow generally following the topography at a local scale.

In the fractured rock aquifer, it is expected that there is likely to be minimal flow across the northern, western and southern boundaries of the hills zone of the Marne Saunders PWRA, given the topography at the top of the ridge on the western boundary. Accessible underground water moving to the east discharges to the sedimentary aquifers, including the Murray Group Limestone, which then flows towards the River Murray.

Underground water extractions from the Murray Group Limestone aquifer have minimal or no impact on the River Murray. Most irrigation extractions are located more than 15 km west of the river, where underground water salinities are below 2,000 mg/L. Generally speaking, underground water salinities are too high, and yields too low for irrigation purposes in the immediate vicinity of the River Murray. In addition the extension of the Morgan Fault, which strikes NE-SW several kilometres west of the river, acts as a permeability barrier to underground water flow towards the River Murray. Watertable elevations to the west of the fault are about 40 m AHD, but to the east of the fault near the river, elevations are less than 5 m AHD (S. Barnett, personal communication).

As described in section 5.1, declining spring flow near the end of the Marne River may be reducing the supply water to the wetland at the junction of the Marne River and the River Murray. This Plan includes policies that are intended to protect this discharge of water from the Murray Group Limestone aquifer and the Quaternary aquifer to the watercourse. These policies include buffer zones and exclusion zones to minimise the impact on underground water level around key areas of spring flow.

5.3 Effects of use on other water resources

This plan includes principles designed to minimise detrimental effects of use of water on the quality of prescribed water resources. The likelihood of any such water quality impacts being conveyed to other water resources will be minimised by these principles to protect water within the Marne Saunders PWRA.

5.4 Summary

In summary, it is expected that the principles in this Plan regarding the taking and use of water from the Marne Saunders PWRA are likely to ensure that there will be no detrimental effects on the quality or quantity of water available in other water resources.

6 Water allocation criteria

Figures, tables and definitions of terms used in sections 6 - 8 are given in section 11. Uncommonly used terms that are defined in section 11 are shown in ***bold italic*** font when they first appear in a principle. Commonly used terms that are defined in section 11 are not shown in bold italic font to improve visual clarity.

6.1 Water allocation objectives

The following objectives apply to the allocation of water from all prescribed water resources in the Marne Saunders PWRA.

Objective A Allocate water sustainably.

Objective B Provide for efficient use of water resources.

Objective C Protect quantity and quality of water for all uses.

Objective D Maintain and where possible rehabilitate water-dependent ecosystems by providing their water needs.

Objective E Minimise adverse impacts of taking and using water on the environment, water resources and water users.

6.2 General allocation principles

The following principles apply to the allocation of water from all prescribed water resources in the Marne Saunders PWRA.

Basis of allocation

1. Water shall be allocated as the volume of water available in a ***water use year***. For the purposes of this Plan, a water use year is defined as the period between 1 July in any calendar year and 30 June in the following calendar year.

Identification of water allocations

2. A water licence endorsed with a water allocation that may be taken shall specify:
   a) the allotment or allotments that the allocation may be used on; and
   b) the source or sources that the allocation may be taken from, identified by location coordinates and/or a unique identifier, such as a well unit number; and
   c) the management zone from which the water allocation is sourced; and
   d) the management sub-zone from which the water allocation is sourced, where relevant.

3. A water allocation that may be taken must only be taken from:
   a) the source or sources endorsed on the licence relating to that allocation; and
   b) the management zone endorsed on the licence relating to that allocation; and
   c) the management sub-zone endorsed on the licence relating to that allocation, where relevant.

4. For the purposes of this Plan:
   - the boundaries of the management zones are shown in GRO Plans 47/2008, 48/2008, 49/2008, 50/2008 and 51/2008. Figure 26, Figure 27, Figure 28, Figure 29 and Figure 30 respectively show key features of these plans at a reduced scale.
   - the boundaries of the management sub-zones are shown in GRO Plans 28/2009 and 1/2009. Figure 31 and Figure 32 respectively show key features of these plans at a reduced scale.
   - the water resource(s) and aquifer that applies to each management zone are shown in the columns "Water resource" and "Aquifer" of Table 28 where relevant.
   - the water resource(s) and aquifer that applies to each management sub-zone are shown in the columns "Water resource" and "Aquifer" of Table 29 where relevant.
   - the management zone that each management sub-zone is a part of is shown in the column "Parent management zone" of Table 29.

5. The following types of allocations shall be identified as such on the licence:
   a) rollover allocations;
   b) artificial recharge allocations;
   c) extra safety net allocations;
   d) foundation allocations;
   e) roof runoff (surface water) allocations;
   f) water allocated for water-dependent ecosystem use; and
   g) water allocated for ***wild flooding***;

   and all types except g) shall always remain as that type of allocation.

Order of taking of allocations

6. Allocations shall be taken in the following order:

   artificial recharge allocations, base water allocations, rollover allocations.

   For the purposes of this Plan, a base water allocation is a water allocation that is not a water (holding) allocation, an artificial recharge allocation or a rollover allocation.

Allocation of water

7. Payment will be required for water allocations obtained from the Minister, in accordance with regulation 47 (4) of the *Natural Resources Management (General) Regulations 2005*, with the exception of the following types of allocations:
   a) roof runoff (surface water) allocations;
   b) rollover allocations; and
   c) artificial recharge allocations.

8. Water shall not be allocated where the allocation would cause the total volume allocated in the relevant management zone to exceed the management zone allocation limit (MZ AL), unless the allocation is:
   a) a rollover allocation;
   b) an artificial recharge allocation;
   c) an extra safety net allocation; or
   d) a roof runoff (surface water) allocation.

   For the purposes of this Plan, the management zone allocation limit for each management zone is given in column "Management zone allocation limit" of Table 28.

Impact of taking and use

9. Water shall not be allocated where the taking and/or use of water will have or will be likely to have a significant detrimental impact on the water resources, water-dependent ecosystems or existing water users. Impacts may include, but are not limited to:
   a) affecting the ability of other users to lawfully take from the water resources;
   b) changes to the underground water level or the timing, duration and/or volume of flow that detrimentally affect water-dependent ecosystems;
   c) decreasing the volume and/or duration of discharge from underground water to surface water/watercourse water or vice versa;
   d) a significant increase in localised or regional drawdown; and/or
   e) an unacceptable impact on water quality.

10. Water shall not be allocated where the taking and/or use of water will have or will be likely to have a significant detrimental impact on the productive capacity of land, including, but not limited to, causing unacceptable changes in salinity, shallow perched water tables, waterlogging or erosion.

Water use efficiency

11. Water shall be used or applied using water efficient technologies and techniques, appropriate for the particular circumstances and in accordance with industry best practice standards.

12. If in the opinion of the Minister a licensee is not meeting principle 11, then the Minister may require the licensee to:
   a) develop, to the satisfaction of the Minister, a program for the efficient use of water containing requirements specified by the Minister from time to time in relation to principle 11; and
   b) comply with the requirements of that program to the satisfaction of the Minister.

13. Subject to principle 14, an allocation shall not be used for ***wild flooding***. For the purposes of this Plan, wild flooding means flood irrigation where no adequate system such as land levelling or irrigation bays is used to ensure a controlled distribution of water.

14. An allocation may be used for ***wild flooding*** for up to 5 years after the date of adoption if:
   a) this practice was used prior to the date of adoption;
   b) the allocation was granted to an existing user pursuant to section 164N of the NRM Act; and
   c) the allocation has not been transferred since the date of adoption.

   Water allocated for wild flooding under these conditions will be converted to water allocation from the same source for the purpose of irrigation 5 years from the date of adoption. The licensee may request an alternative purpose at least one month prior to this conversion date.

Water (holding) allocations

15. Water licences may be endorsed with ***water (holding) allocations***.

16. A water licence endorsed with a water (holding) allocation shall specify the management zone from which the water (holding) allocation is sourced.

17. The purpose of a water (holding) allocation is to preserve the right (subject to the NRM Act) of the holder of the licence to obtain a water allocation that may be taken in respect of the quantity of water allocated by the water (holding) allocation.

18. The quantity of water allocated from a water resource by a water (holding) allocation is reserved for the time when the water (holding) allocation is converted under principle 22 to a water allocation that may be taken and must not be allocated to any other licence or to any other purpose.

19. Principle 18 does not prevent a water (holding) allocation from being transferred to another licence.

20. A water (holding) allocation may be the only allocation endorsed on a water licence or may be one of a number of components of the water allocation of the licence.

21. When applying for a water allocation to be endorsed on a new licence or an existing licence (whether on allocation of the water by the Minister or on transfer from another licence), or at any time after the granting of a water allocation, the applicant or licence holder may request that the allocation be endorsed as a water (holding) allocation.

22. At any time after the endorsement of a water (holding) allocation, the holder for the time being of the licence on which the allocation is for the time being endorsed may request that the Minister convert the whole or a part of the water (holding) allocation to a water allocation that may be taken.

23. The Minister must determine a request under principle 22 as though it were an application for the endorsement of a water allocation and must determine the request on the basis of this Plan.

24. In determining a request under principle 22, the Minister may, depending on this Plan, grant a conversion of a quantity of water less than that applied for.

25. If the water (holding) allocation was endorsed on the licence subject to a condition restricting the part of the water resource from which water could be taken (pursuant to a subsequent water allocation that may be taken), a water allocation endorsed on the licence on conversion of the whole or part of the water (holding) allocation cannot authorise the taking of water outside that part of the resource.

Water-dependent ecosystem use

26. Water allocated for ***water-dependent ecosystem use*** shall not be allocated for any other purpose.

27. Principles 11 and 71 do not apply to an allocation for ***water-dependent ecosystem use***, provided that the Minister is satisfied that the taking and use of the allocation will not have a significant detrimental impact on water-dependent ecosystems.

Returned water

28. Where part or all of an ***extra safety net allocation*** is returned to the Minister, that volume shall not be subsequently allocated.

29. Where a water allocation is forfeited or surrendered to the Minister other than in accordance with principle 28, that water:

   a) shall not be allocated if, immediately before the water allocation was forfeited or surrendered to the Minister, the water was allocated in the Upper Marne, Lower Marne, Upper Saunders, Lower Saunders, Unconfined Zone 1, or Confined Zone A Management Zones;

   b) may either be allocated subject to the principles in this Plan, or not allocated, at the Minister's discretion, if, immediately before the water was forfeited or surrendered to the Minister, that water was allocated in the Unconfined Zone 2, Unconfined Zone 3, Unconfined Zone 4, Unconfined Zone 5, Unconfined Zone 6, Confined Zone B, Renmark Group Aquifer, or Fractured Rock Aquifer Management Zones.

6.3 Allocation of underground water

The following principles apply to the allocation of underground water only. They are in addition to the general objectives and principles outlined in sections 6.1 and 6.2.

Allocation of water

30. Water shall not be allocated in the Unconfined Zone 1 and Confined Zone A Management Zones, except where:
    a) an allocation is obtained:
        i. from the holder of another licence; or
        ii. on the conversion of the whole or part of a water (holding) allocation to a water allocation that may be taken; or
        iii. on the conversion of the whole or part of a water allocation to a water (holding) allocation; or
    b) the allocation is a rollover allocation or an artificial recharge allocation.

31. Water shall not be allocated where the allocation would cause the total volume allocated in the relevant management sub-zone to exceed the management sub-zone allocation limit (MSZ AL) where relevant, unless the allocation is:
    a) a rollover allocation; or
    b) an artificial recharge allocation.

    For the purposes of this Plan, the management sub-zone allocation limit for each relevant management sub-zone is given in column "Management sub-zone allocation limit" of Table 29.

Allocation from multiple wells

32. An allocation may only be granted to be taken from more than one well where:
    a) all of those wells take water from the same management zone and aquifer;
    b) all of those wells take water from the same management sub-zone (where relevant); and
    c) the Minister is satisfied that a single allocation may be granted to be taken from all of those wells without having a significant detrimental impact on the water resources, water-dependent ecosystems or existing water users.

Deemed allocation per well[7]

33. Where an allocation may be taken from more than one well, the allocation volume deemed to be taken from each of those wells shall be the allocation volume that may be taken from all of those wells.

Buffer zones

34. Subject to principles 38 - 43, water shall not be allocated if the allocation would cause the well buffer zone around the existing or proposed well that the allocation would be taken from (as the case may be) to overlap or further overlap:
    a) a well buffer zone linked to the same aquifer around an ***operational well*** owned by another landholder (to "overlap another well buffer zone"); and/or
    b) an environmental buffer zone linked to the same aquifer (to "overlap an environmental buffer zone").

[7] An allocation may be granted to be taken from more than one well in some cases. However, the operation of some principles depends on the volume taken from each well. The purpose of principle 33 is to set out the volume deemed to be taken from each well in the case where a single allocation may be taken from a number of wells.

35. A well buffer zone is a circular area centred on an ***operational well***. The well buffer zone is linked to the aquifer that the well takes water from. The radius of the well buffer zone is determined in accordance with Table 30.

36. An environmental buffer zone is an area radiating from an environmental asset, and both the environmental buffer zone and environmental asset are linked to an aquifer or aquifers. The environmental assets, environmental buffer zones and the aquifers that they are linked to are shown in GRO Plans 54/2008, 55/2008 and 56/2008. Figure 33, Figure 34 and Figure 35 respectively show key features of these plans at a reduced scale.

37. On the conversion of the whole or a part of a water allocation that may be taken to a water (holding) allocation, the well buffer zone around the well or wells from which the water allocation could be taken shall be reduced to the appropriate size (where necessary) in accordance with Table 30.

38. An allocation may be granted to be taken from a well where its well buffer zone will overlap another well buffer zone and/or overlap an environmental buffer zone where:
    a) that allocation was originally granted to an existing user pursuant to section 164N of the NRM Act; and
    b) there has been no change to the location of the well that the allocation may be taken from, except in accordance with principle 43.

39. An allocation may be granted to be taken from a well where its well buffer zone will overlap another well buffer zone where:
    a) the applicant holds an allocation where part or all of that allocation was originally granted to an existing user pursuant to section 164N of the NRM Act to be taken from that well or a well that has replaced it in accordance with principle 43; and
    b) the total volume to be allocated from that well does not exceed the average annual metered usage from that well as recorded by DWLBC for the water use years of 2003/2004, 2004/2005 and 2005/2006; and
    c) the application for the allocation is made by 5pm on the closest business day that is three years from the date of adoption; and
    d) at least one full year of metered usage data as recorded by DWLBC is available for that well for the water use years of 2003/2004, 2004/2005 and 2005/2006.

40. An allocation may be granted to be taken from a well where its well buffer zone will overlap another well buffer zone if the applicant can demonstrate that taking that allocation would have no significant detrimental impact on water levels, yield or water quality in the wells with overlapped buffer zones. The potential for impact will be determined by a properly conducted aquifer test where the methodology and results are approved by the Minister and the test is conducted no earlier than five years prior to the date of application.

41. When an allocation is granted to be taken from a well in accordance with principle 40, a maximum extraction rate from that well (in litres per second) shall be endorsed on the licence, and the licensee must not take water at a greater rate than that maximum extraction rate from that well. The maximum extraction rate will be determined taking the results of the aquifer test into account.

42. Principles 39 and 40 do not apply where an allocation would cause the well buffer zone around the existing or proposed well (as the case may be) to overlap an environmental buffer zone.

Replacement wells

43. Where a well from which a water allocation may be taken is replaced in accordance with principle 125, that allocation may be taken from the replacement well provided that there is no change to the volume of water allocated and the conditions of the allocation.

Maximum extraction rate

44. If the volume of a base water allocation exceeds, or will exceed:
    a) 50 ML in the Fractured Rock Aquifer Management Zone; or
    b) 100 ML in the Unconfined Zone 1, Unconfined Zone 2, Unconfined Zone 3, Unconfined Zone 4, Unconfined Zone 5, Unconfined Zone 6, Confined Zone A, Confined Zone B or Renmark Group Aquifer Management Zones;

    then a maximum extraction rate (in litres per second) shall be endorsed on the licence for the well or wells from which that allocation may be taken, and the licensee must not take water from that well at a rate that exceeds that maximum extraction rate.

45. For the purposes of principle 44, the maximum extraction rate will be determined after taking into account acceptable water level drawdown and recovery during and after a properly conducted aquifer test, where the methodology and results are approved by the Minister and the test is conducted no earlier than five years prior to the date of application.

46. Principle 44 does not apply to an allocation where:
    a) that allocation was originally granted to an existing user pursuant to section 164N of the NRM Act; and
    b) there has been no change to the location of the well that the allocation may be taken from, except in accordance with principle 43.

Rollover

47. Subject to principles 48 - 52, all or part of the volume of a base water allocation that was not taken in a water use year (the “credit year”) may be taken in the water use year immediately following the credit year (the “post-credit year”) and that volume of water will be called a rollover allocation.

48. A rollover allocation shall only be taken from the well or wells that are endorsed on the licence as the source or sources for the base water allocation that was not entirely used in the credit year to give rise to that rollover allocation.

49. A rollover allocation shall not exceed:
    a) the volume of the base water allocation that was not taken from the well or wells in the credit year; or
    b) 20% of the volume of the base water allocation as at 1 July of the post-credit year, regardless of variations in the volume of the base water allocation that occur during that water use year, if the water is allocated in the Fractured Rock Aquifer Management Zone; or
    c) 10% of the volume of the base water allocation as at 1 July of the post-credit year, regardless of variations in the volume of the base water allocation that occur during that water use year, if the water is allocated in the Unconfined Zone 1, Unconfined Zone 2, Unconfined Zone 3, Unconfined Zone 4, Unconfined Zone 5, Unconfined Zone 6, Confined Zone A, Confined Zone B or Renmark Group Aquifer Management Zones.

50. If:
    a) a licensee uses water for non-licensed purposes after it has passed through the meter of a well used for licensed purposes; and
    b) they wish to have that volume accounted for when determining the volume of the rollover allocation;

    then the volume of water used for non-licensed purposes that has passed through the meter must be measured in accordance with state metering specifications.

51. A rollover allocation expires at the end of the post-credit year.

52. Rollover allocations shall not be granted until the start of the second full water use year following the granting of allocations to existing users in the Marne Saunders PWRA.

6.4 Allocation of artificially recharged water

The following principles only apply to the allocation of water that has been drained or discharged into a well pursuant to a permit granted under section 127 (3) (c) of the NRM Act or an environmental authorisation granted under the *Environment Protection Act 1993*. They are in addition to the general objectives and principles set out in sections 6.1 and 6.2.

53. Subject to principles 54 - 58, the basis of allocating water as an artificial recharge allocation will be an entitlement to take, during a water use year, a percentage of the volume of water drained or discharged into a well during that water use year and/or the previous water use year (the “recharge period”).

54. An artificial recharge allocation shall only be granted in relation to water drained or discharged into a well pursuant to a permit granted under section 127 (3) (c) of the NRM Act or an environmental authorisation granted under the *Environment Protection Act 1993*.

55. The volume of an artificial recharge allocation shall not exceed:
    a) 80% of the volume of water drained or discharged into a well in the recharge period for a well that takes water from the Unconfined Zone 1, Unconfined Zone 2, Unconfined Zone 3, Unconfined Zone 4, Unconfined Zone 5, Unconfined Zone 6, Confined Zone A, Confined Zone B, Quaternary Aquifer or Renmark Group Aquifer Management Zones.
    b) 67% of the volume of water drained or discharged into a well in the recharge period for a well that takes water from the Fractured Rock Aquifer Management Zone.

56. An artificial recharge allocation must be taken within 100 metres of the well that the water was drained or discharged into.

57. Artificial recharge allocations shall be taken in the order they accrue.

58. An artificial recharge allocation expires at the end of the first full water use year after the water use year in which the water was drained or discharged into a well.

6.5 Allocation of surface water and watercourse water

The following principles apply to the allocation of surface water and watercourse water only, excluding roof runoff (surface water). They are in addition to the general objectives and principles outlined in sections 6.1 and 6.2. The principles that apply to the allocation of roof runoff (surface water) are set out in section 6.6.

Allocation of water

59. Water shall not be allocated except where:
    a) an allocation is obtained:
        i. from the holder of another licence; or
        ii. on the conversion of the whole or part of a water (holding) allocation to a water allocation that may be taken; or
        iii. on the conversion of the whole or part of a water allocation to a water (holding) allocation; or
    b) the allocation is a rollover allocation.

Allocation by source

60. An allocation may only be granted to be taken from more than one diversion structure if:
    a) all of those diversion structures are in the same management sub-zone; and
    b) all of those diversion structures are ***hydrologically continuous***; and
    c) the flow path and/or watercourse between all of the diversion structures stays within the property that the diversion structures are located on.

61. Where an allocation may be taken from more than one diversion structure, references in this Plan to the diversion structure and the catchment area upstream of it shall be taken to include all of the diversion structures that the allocation may be taken from and the total catchment area upstream of those diversion structures respectively.

Maximum volume of allocation

62. The maximum total volume that may be allocated to be taken from a diversion structure shall not exceed the smallest total volume determined through application of principles 64 to 70 where relevant. If this smallest total volume is equal to or less than the existing allocation from that diversion structure (if any), then the proposed allocation will not be allowed.

Defining common terms used to determine maximum volume of allocation

63. For the purposes of this Plan:
    a) Tributary management sub-zones (MSZs) and main watercourse management sub-zones are shown in GRO Plan 1/2009. Figure 32 shows key features of this plan at a reduced scale. Water taken from the watercourse represented by the main watercourse MSZ is not considered to be part of the adjacent tributary MSZs. Column “Tributary or main watercourse” in Table 29 shows whether a MSZ is a tributary MSZ or a main watercourse MSZ.
    b) A main watercourse diversion structure is a diversion structure that may take water from a main watercourse MSZ.
    c) The volume of the management sub-zone consumptive use limit (MSZ CUL) for each tributary MSZ is given in column “Management sub-zone consumptive use limit” of Table 29.

d) The consumptive use limit that applies in main watercourse management sub-zones is determined on a case-by-case basis for each main watercourse diversion structure as a cumulative MSZ CUL. The cumulative MSZ CUL at a main watercourse diversion structure is the sum of the MSZ CULs for all of the tributary MSZs upstream of that diversion structure.

e) A tributary MSZ is considered to be upstream of a main watercourse diversion structure if the major point of inflow from that tributary MSZ to the main watercourse MSZ is upstream of that main watercourse diversion structure.

The major points of inflow from the tributary MSZs to the main watercourse MSZs are shown in GRO Plan 2/2009. Figure 40 shows key features of this plan at a reduced scale.

f) Consumptive use (CU) is the volume of surface water and watercourse water (excluding roof runoff (surface water)) estimated to be taken for consumptive purposes from a given area or location, including a catchment area, a management sub-zone(s) or a diversion structure. Consumptive use is determined as follows:

$$CU = allocation + NCU$$

where:

CU	Consumptive use (in ML).
allocation	The sum of the volume of base water allocations sourced from surface water and watercourse water (excluding roof runoff (surface water)) from the given area or location (where relevant) (in ML).
NCU	Non-licensed consumptive use. NCU from the given area or location is determined as follows:

$$NCU = (NDC \times 0.3) + NCU_l$$

where:

NCU	Non-licensed consumptive use from the given area or location (in ML).
NDC	Non-licensed dam capacity. NDC is determined as the sum of the capacities of all dams used only for non-licensed purposes in the given area or location (where relevant) (in ML).
NCU_l	Non-licensed consumptive use from licensed diversion structures. NCU_l is determined as the sum of all volumes of non-licensed use taken from licensed diversion structures in the given area or location, if such volumes have been determined by the Minister (where relevant) (in ML).

g) Runoff (R) is the depth of average adjusted winter runoff from an area (in mm), where "winter" means May to November inclusive. The value of runoff that relates to an area is determined as follows:

i. The runoff relating to a tributary MSZ or to a catchment area entirely contained within a tributary MSZ is given in column "Average adjusted winter runoff depth" of Table 29.

ii. If a diversion structure takes water from a tributary MSZ and the catchment area upstream of the diversion structure lies within more than one tributary MSZ, then the runoff relating to that catchment area shall be the runoff for the tributary MSZ that the majority of the catchment area lies within.

iii. For the catchment area upstream of a main watercourse diversion structure, the catchment area will be split into parts in accordance with the boundaries of the tributary MSZs, and the runoff that applies to each part will be the runoff relating to the relevant tributary MSZ.

h) Evaporation (E) from a dam (in ML) is determined as the lesser of the following:

   i. $E = DC \times 0.3$

   ii. $E = DC - CU_D$

   where:

   E Evaporation. Nominal evaporation from a dam (in ML).

   DC Dam capacity. DC is the volumetric capacity of the dam (in ML).

   CU_D Consumptive use from the dam (in ML).

i) Evaporation from a diversion structure that is not a dam is 0 ML.

Maximum volume of allocation – management sub-zone consumptive use limit

64. Water shall not be allocated where the allocation would cause:

    a) the total volume taken for consumptive use from a tributary MSZ to exceed, or further exceed, its MSZ CUL; and/or

    b) the total volume taken for consumptive use at and upstream of any main watercourse diversion structure to exceed, or further exceed, the cumulative MSZ CUL upstream of that diversion structure.

65. For the purposes of principle 64, the total volume to be allocated from a diversion structure (D1) shall not exceed the lesser of the volumes determined by principles 65 a) and 65 b):

    a) where the allocation is to be taken from a tributary MSZ:

    $$TV_{65a} = (MSZ\ CUL - CU_{MSZ}) + CU_{D1}$$

    where:

TV_{65a}	Total volume. The total volume that the allocation or allocations to be taken from diversion structure D1 must not exceed for the purposes of principle 65 a) (in ML).
MSZ CUL	Management sub-zone consumptive use limit. The volume of the MSZ CUL for the MSZ that the allocation is to be taken from (in ML).
CU_{MSZ}	Consumptive use in the management sub-zone that the allocation is to be taken from. CU_{MSZ} is the volume of consumptive use from the management sub-zone that the allocation would be taken from, immediately prior to the allocation (in ML). If the allocation would result from the transfer of an allocation sourced from within the same tributary MSZ, then the volume of this proposed transfer is excluded from CU_{MSZ}.
CU_{D1}	Consumptive use at diversion structure D1. CU_{D1} is the volume of consumptive use from the diversion structure D1 that the allocation would be taken from, immediately prior to the allocation (if any) (in ML).

    b) For all allocations:

    The smallest volume returned by calculating the following equation at each main watercourse diversion structure “x” (WDx) downstream of the diversion structure D1 within the Marne Saunders PWRA that may be affected by the allocation. This calculation must also be made for diversion structure D1 if it is a main watercourse diversion structure:

    $$TV_{65b} = (\text{cumulative MSZ } CUL_{WDx} - CU_{BWDx}) + CU_{D1}$$

where:

TV_{65b} Total volume. The total volume that the allocation or allocations to be taken from diversion structure D1 must not exceed for the purposes of principle 65 b) (in ML).

cumulative MSZ CUL_{WDx} Cumulative management sub-zone consumptive use limit for diversion structure WDx. Cumulative MSZ CUL_{WDx} is the sum of the MSZ CULs for all of the tributary MSZs upstream of diversion structure WDx (in ML).

CUB_{WDx} Consumptive use both at and upstream of diversion structure WDx. CUB_{WDx} is the sum of the volumes of consumptive use at diversion structure WDx, from main watercourse diversion structures upstream of diversion structure WDx, and in the tributary MSZs upstream of diversion structure WDx. All values are determined immediately prior to the allocation (in ML). If the allocation would result from the transfer of an allocation sourced from upstream of diversion structure WDx, then the volume of this proposed transfer is excluded from CUB_{WDx}.

CU_{D1} Consumptive use at diversion structure D1. CU_{D1} is the volume of consumptive use from the diversion structure D1 that the allocation would be taken from, immediately prior to the allocation (if any) (in ML).

Where the equation returns a negative value, TV_{65b} will be zero.

Maximum volume of allocation – dam capacity limit

66. The total volume to be allocated to be taken from a dam shall not exceed the volumetric capacity of that dam.

Maximum volume of allocation – available runoff limit

67. The total volume to be allocated from a diversion structure shall not exceed the average adjusted winter runoff from the catchment area upstream of that diversion structure, taking upstream consumptive use and evaporation into account.

For the purposes of this principle, the total volume to be allocated from this diversion structure (D1) shall not exceed the following:

$$TV_{67} = (A_{D1} \times R_{D1}) – (CU_{UD1} + E_{UD1})$$

where:

TV_{67} Total volume. The total volume that the allocation or allocations to be taken from diversion structure D1 must not exceed for the purposes of principle 67 (in ML).

A_{D1} Area upstream of D1. A_{D1} is the catchment area upstream of diversion structure D1 (in km2).

R_{D1} Runoff at D1. R_{D1} is the average adjusted winter runoff depth for the catchment area upstream of diversion structure D1 (in mm).

CU_{UD1} Consumptive use upstream of D1. CU_{UD1} is determined as the volume of consumptive use in the catchment area upstream of diversion structure D1, excluding consumptive use at diversion structure D1, immediately prior to the allocation (in ML). If the allocation would result from the transfer of an allocation sourced from upstream of diversion structure D1, then the volume of this proposed transfer is excluded from CU_{UD1}.

EU_{D1} Evaporation upstream of D1. EU_{D1} is determined as the evaporation from dams in the catchment area upstream of diversion structure D1, excluding evaporation from diversion structure D1 (in ML).

Maximum volume of allocation – local consumptive use limit for new or enlarged diversion structures

68. Subject to principle 72, the total volume to be allocated to be taken from a diversion structure that has been erected, constructed or enlarged since the date of adoption shall not exceed 30% of the average adjusted winter runoff from the catchment area upstream of that diversion structure, taking upstream consumptive use into account.

    For the purposes of this principle, the total volume to be allocated from this diversion structure (D1) shall not exceed the following:

    $TV_{68} = (A_{D1} \times R_{D1} \times 0.3) – CU_{UD1}$

    where:

TV_{68}	Total volume. The total volume that the allocation or allocations to be taken from diversion structure D1 must not exceed for the purposes of principle 68 (in ML).
A_{D1}	Area upstream of D1. A_{D1} is the catchment area upstream of diversion structure D1 (in km^2).
R_{D1}	Runoff at D1. R_{D1} is the average adjusted winter runoff depth for the catchment area upstream of diversion structure D1 (in mm).
CU_{UD1}	Consumptive use upstream of D1. CU_{UD1} is determined as the volume of consumptive use in the catchment area upstream of diversion structure D1, excluding consumptive use at diversion structure D1, immediately prior to the allocation (in ML). If the allocation would result from the transfer of an allocation sourced from upstream of diversion structure D1, then the volume of this proposed transfer is excluded from CU_{UD1}.

69. In addition to the circumstances outlined in principle 68, principle 68 shall also apply where:
    a) the allocation may be taken from more than one diversion structure in accordance with principle 60, and
    b) any of those diversion structures have been erected, constructed or enlarged since the date of adoption.

Maximum volume of allocation – minimising downstream impact

70. Water shall not be allocated where the allocation would cause the total demand for water to exceed or further exceed the average supply of runoff from the upstream catchment area for any affected diversion structures within the Marne Saunders PWRA. Total demand includes consumptive use and evaporation from diversion structures at and upstream of the affected diversion structure being considered.

    For the purposes of this principle, the total volume to be allocated from a diversion structure (D1) shall not exceed the smallest volume returned by calculating the following at each diversion structure “x” (Dx) downstream of D1 within the Marne Saunders PWRA that may be affected by the allocation:

    $TV_{70} = ((A_{Dx} \times R_{Dx}) – (CU_{BDx} + E_{BDx})) + CU_{D1}$

    where:

TV_{70}	Total volume. The total volume that the allocation or allocations to be taken from diversion structure D1 must not exceed for the purposes of principle 70 (in ML).

A_{Dx} Area upstream of Dx. A_{Dx} is the catchment area upstream of diversion structure Dx (in km^2).

R_{Dx} Runoff at Dx. R_{Dx} is the average adjusted winter runoff depth for the catchment area upstream of diversion structure Dx (in mm).

CU_{BDx} Consumptive use both at and in the catchment area upstream of diversion structure Dx. CU_{BDx} is the total volume of consumptive use at and in the catchment area upstream of diversion structure Dx, immediately prior to the allocation (in ML). If the allocation would result from the transfer of an allocation sourced from upstream of diversion structure Dx, then the volume of this proposed transfer is excluded from CU_{BDx}.

E_{BDX} Evaporation both at and upstream of Dx. E_{BDX} is the total evaporation from dams at and in the catchment area upstream of diversion structure Dx (in ML).

CU_{D1} Consumptive use at diversion structure D1. CU_{D1} is the volume of consumptive use from the diversion structure D1 that the allocation would be taken from, immediately prior to the allocation (if any) (in ML).

Where the equation returns a negative value, TV_{70} will be zero.

Point of taking

71. Water shall not be allocated where the allocation will be taken from a watercourse identified as a ***key environmental asset***, unless:
    a) the allocation was originally granted to an existing user pursuant to section 164N of the NRM Act; and
    b) there is no change to the conditions of the allocation and the location of the point of taking; and
    c) the allocation volume does not increase.

72. Water shall not be allocated to be taken from a diversion structure that has been erected, constructed or enlarged since the date of adoption, except if the diversion structure meets all of the criteria set out in section 8.2 and 8.5.

Maximum diversion rate

73. Water shall not be taken from a ***restricted watercourse*** at a rate that exceeds the maximum diversion rate.

74. For the purposes of principle 73,
    a) ***restricted watercourse***s are marked with an orange line in GRO Plan 3/2009. Key features of this plan are shown in Figure 39 at a reduced scale.
    b) the maximum diversion rate (in litres per second) shall be endorsed on the licence for each diversion structure taking water from a restricted watercourse.
    c) the maximum diversion rate at a diversion structure is calculated as follows:

$$MDR = (allocation \div 20) \div 0.0864$$

where:

MDR is the maximum diversion rate at a diversion structure (in L/s).

allocation is the volume of the allocation that may be taken from the restricted watercourse by the diversion structure (in ML).

0.0864 is a factor to convert from ML per day to litres per second.

75. Principle 73 does not apply where water is taken from a dam lawfully constructed on or across a ***restricted watercourse*** for the purpose of storing water before the date of adoption.

Flow regime

76. Subject to principle 79, any surface water flowing over land and/or water flowing in a watercourse at or below the threshold flow rate:
    a) must not be taken from the watercourse or surface water flow path; and/or
    b) must be bypassed around a diversion structure or otherwise returned to the same watercourse or surface water flow path immediately downstream of the diversion structure as soon as reasonably practical and be of similar or better quality as it was prior to diversion.

77. For the purpose of this Plan, the threshold flow rate at a diversion structure is calculated as follows:

    TFR = UTFR x A

    where:

TFR	Threshold flow rate at a diversion structure (in L/s).
UTFR	Unit threshold flow rate. UTFR is given in column “Unit threshold flow rate” of Table 29 for the management sub-zone that the diversion structure lies within (in $L/s/km^2$).
A	Area. A is the catchment area upstream of the diversion structure (in km^2).

78. The threshold flow rate (in litres per second) shall be endorsed on the licence for each diversion structure that an allocation may be taken from.

79. For a diversion structure where the threshold flow rate is calculated to be one litre per second or less, principle 76 does not apply provided that:
    a) no more than 90% of the volume of flow arriving at the diversion structure is diverted, collected or captured at any time; or
    b) the volume equivalent to 10% of the volume of flow arriving at the diversion structure at any time is returned to the same watercourse or surface water flow path immediately downstream of the diversion structure as soon as reasonably practical and is of similar or better quality as it was prior to diversion.

80. Any device that ensures compliance with principles 76 - 79 shall:
    a) be designed and constructed to ensure its correct operation is automated and can not be manually overridden; and
    b) not increase the area that directs water to the diversion structure beyond the natural size of the catchment area upstream of the diversion structure; and
    c) be maintained in such a condition that it continues to be effective in meeting principles 76 - 79; and
    d) not be obstructed or tampered with in any way.

81. Water shall not be allocated unless the applicant can demonstrate, to the satisfaction of the Minister, how compliance with principles 76 - 80 will be achieved.

Rollover

82. Subject to principles 83 - 89, all or part of the volume of a base water allocation that was not taken in a water use year (the "credit year") may be taken in a subsequent water use year and that volume of water will be called a rollover allocation.

83. A rollover credit for a water use year is the volume of the base water allocation that was not taken in that water use year.

84. A rollover allocation in a water use year (the "relevant water use year") is the sum of the rollover credits from the immediately preceding two water use years, less any of those rollover credits taken in that period, subject to the following:
    a) the volume of the rollover allocation shall not exceed 20% of the base water allocation as at 1 July of the relevant water use year, regardless of variations in the volume of the base water allocation that occur during that water use year; and
    b) if a rollover allocation can be taken from a dam or dams, the sum of that rollover allocation and any base water allocation that may be taken from those dams shall not exceed the capacity of the dam or dams.

85. Rollover credits will be converted to rollover allocations in the order they accrue.

86. Unless taken beforehand, a rollover credit expires at the end of the second water use year after the credit year.

87. If:
    a) a licensee uses water for non-licensed purposes after it has passed through the meter of a diversion structure used for licensed purposes; and
    b) they wish to have that volume accounted for when determining the volume of the rollover credit or rollover allocation;

    then the volume of water used for non-licensed purposes that has passed through the meter must be measured in accordance with state metering specifications.

88. A rollover allocation shall only be taken from the diversion structure or diversion structures that are endorsed on the licence as the source or sources for the base water allocation that was not entirely used in the credit year to give rise to the rollover credit.

89. Rollover credits shall not start to accrue until the first full water use year following the granting of allocations to existing users in the Marne Saunders PWRA. Rollover allocations shall not be granted until the start of the second full water use year following the granting of allocations to existing users in the Marne Saunders PWRA.

6.6 Allocation of roof runoff (surface water)

The following principles apply to the allocation of roof runoff (surface water) only. They are in addition to the general objectives and principles outlined in sections 6.1 and 6.2.

An allocation for taking roof runoff (surface water) is not required where the taking is in accordance with the Notice of Authorisation to take water in the *South Australian Government Gazette*, 16 March 2006, pages 906 - 912, or as may be amended from time to time.

90. Water shall only be allocated as roof runoff (surface water) where runoff from a minimum of 15% of the ***connected roof area*** is returned to the environment:
    a) by as close as practicable to the natural path; and
    b) as soon as reasonably practical following precipitation; and
    c) in a manner that does not cause significant detrimental impacts to the environment, including but not limited to erosion.

91. The maximum volume (in ML) that may be allocated shall not exceed the volume determined by:

$$TV = \frac{\text{connected roof area} \times \text{rainfall} \times 0.85}{1{,}000{,}000}$$

where:

TV — Total volume. The total allocation volume of roof runoff (surface water) that is not to be exceeded for a given connected roof area (in ML).

connected roof area — The area of roof that drains (usually through gutters and downpipes) to water storage facilities. Where there are multiple connected roof areas on a property, the connected roof area for the property is the total of all connected roof areas for that property (in m^2).

rainfall — average annual rainfall (in mm) determined in accordance with Attachment 5 in the Notice of Authorisation to Take Water (*South Australian Government Gazette*, 16 March 2006, pages 906 - 912) or as may be amended from time to time. This attachment is reproduced in Figure 41 in this Plan.

92. If a roof runoff (surface water) allocation is converted to a water (holding) allocation, it shall continue to be identified on the licence as a runoff (surface water) allocation and will continue to be subject to principles that are relevant to this type of allocation.

7 Transfer criteria

Figures, tables and definitions of terms used in sections 6 - 8 are given in section 11. Uncommonly used terms that are defined in section 11 are shown in ***bold italic*** font when they first appear in a principle. Commonly used terms that are defined in section 11 are not shown in bold italic font to improve visual clarity.

7.1 Water transfer objectives

The following objectives apply to the transfer of water licences and/or allocations for all prescribed water resources in the Marne Saunders PWRA.

Objective A Allocate water sustainably.

Objective B Provide for efficient use of water resources.

Objective C Protect quantity and quality of water for all uses.

Objective D Maintain and where possible rehabilitate water-dependent ecosystems by providing their water needs.

Objective E Minimise adverse impacts of taking and using water on the environment, water resources and water users.

7.2 General transfer principles

The following principles apply to the transfer of water licences and/or allocations for all prescribed water resources in the Marne Saunders PWRA.

93. Part or all of a water (holding) allocation may be transferred to another licence as a water (holding) allocation without consideration of the allocation and transfer criteria set out in sections 6.3, 6.5, 7.3 and 7.5, provided that there is no change to both the volume and conditions of the allocation. However, if the licence receiving the transfer is to specify which management sub-zone the water (holding) allocation is sourced from, then principles 31, 64 and 65 shall apply where relevant.

94. A water allocation shall not be transferred from one management zone into another management zone.

95. A water allocation may be transferred within a management zone, including transfers between management sub-zones that are part of that management zone.

96. A rollover allocation shall not be transferred, except where there is no change to the location of the point of taking.

97. A water allocation shall not be transferred between water resources, except in accordance with principle 105.

7.3 Transfer of underground water

The following principles apply to the transfer of underground water only. They are in addition to the general objectives and principles outlined in sections 7.1 and 7.2.

98. Subject to principle 99, a water allocation shall only be transferred where the proposed transfer is consistent with the allocation criteria set out in sections 6.1, 6.2 and 6.3 of this Plan.

99. Despite principle 98, a water allocation may be transferred without consideration of the allocation criteria in section 6.3 of this Plan where:
    a) there is no change to the location of the point of taking and conditions of the allocation; and
    b) the volume of water allocated does not increase.

Changing buffer zones on transfer

100. On the transfer of the whole or part of a water allocation, the radius of the well buffer zone around the well or wells from which the water allocation could be taken prior to the transfer shall be reduced (where necessary) in accordance with Table 30.

101. Principle 100 does not apply in the case of a temporary transfer.

7.4 Transfer of artificial recharge allocations

The following principles apply to the transfer of artificial recharge allocations only. They are in addition to the general objectives and principles outlined in sections 7.1 and 7.2.

102. An artificial recharge allocation shall not be transferred, except where there is no change to the location of the point of taking.

7.5 Transfer of surface water and watercourse water

The following principles apply to the transfer of surface water and watercourse water only, excluding roof runoff (surface water). They are in addition to the general objectives and principles outlined in sections 7.1 and 7.2.

103. Subject to principle 104, a water allocation shall only be transferred where the proposed transfer is consistent with the allocation criteria set out in sections 6.1, 6.2 and 6.5 of this Plan.

104. Despite principle 103, a water allocation may be transferred without consideration of the allocation criteria set out in section 6.5 of this Plan where:
    a) there is no change to the location of the point of taking and conditions of the allocation; and
    b) the volume of water allocated does not increase.

Transfer between surface water and watercourse water resources

105. An allocation may be transferred between the surface water and watercourse water resources within a management zone.

Transfers involving extra safety net allocations

106. An ***extra safety net allocation*** shall not be transferred, except where it is transferred on a permanent basis together with the entire associated ***foundation allocation*** with no change to the:
    a) location of the point of taking; and
    b) volume of water allocated; and
    c) conditions of the allocation.

107. If part or all of a ***foundation allocation*** is transferred on a permanent basis, then all of the associated ***extra safety net allocation*** will revert to the Minister, except if the transfer is in accordance with principle 106.

108. No part of a ***foundation allocation*** shall be transferred on a temporary basis, unless the transferor agrees that a condition will be placed on their licence such that all of the associated ***extra safety net allocation*** is not able to be taken. This condition may only be removed when:

   c) the foundation allocation returns to the original licence; or

   d) a water allocation equivalent to the transferred foundation allocation is transferred to the original licence for at least the duration of the transfer of the foundation allocation.

7.6 Transfer of roof runoff (surface water)

The following principles apply to the transfer of roof runoff (surface water) only. They are in addition to the general objectives and principles outlined in sections 7.1 and 7.2.

109. A roof runoff (surface water) allocation shall not be transferred to become watercourse water or surface water that is not roof runoff (surface water).

110. Water allocated as roof runoff (surface water) shall not be transferred, except if there is no change to the location of taking and conditions of the allocation.

8 Water affecting activities

Figures, tables and definitions of terms used in sections 6 - 8 are given in section 11. Uncommonly used terms that are defined in section 11 are shown in ***bold italic*** font when they first appear in a principle. Commonly used terms that are defined in section 11 are not shown in bold italic font to improve visual clarity.

Sections 127 (3) and (5) of the NRM Act set out a number of water affecting activities that may require a permit in order to be undertaken. A permit for a water affecting activity is not required when section 129 of the NRM Act provides that a permit is not required.

Otherwise, a person may only undertake any of the activities listed in Table 26A if authorised to do so by a permit granted by the relevant authority in accordance with the relevant objectives and principles set out in this chapter.

Other approvals may also be required for an activity in addition to a water affecting activity permit. In accordance with the *Native Title Act 1993* (Cth), applications for permits on land where native title has not been extinguished will require the Minister to consider the application of the *Native Title Act 1993* (Cth) or where modified by an ILUA the process in the ILUA prior to the grant of the permit.

Landholders and/or those undertaking works related to any of the activities listed in Table 26A should also be aware of their legal obligations under the *Aboriginal Heritage Act 1988*, which provides for the protection and preservation of Aboriginal sites, objects and remains within South Australia.

Owners or occupiers of a parcel of land, and agents of these (including staff, contractors and subcontractors), have legal responsibilities under the *Aboriginal Heritage Act 1988* when Aboriginal sites, objects or remains are discovered or where they may be at risk of damage, disturbance or interference.

Further information for landholders, contractors and grant recipients on what to do, who to contact and about divulging information about Aboriginal sites, objects and remains is available from the SA MDB NRM Board, and the Aboriginal Affairs and Reconciliation agency within the Department of State Development.

Other approvals outside of the *Aboriginal Heritage Act 1988* and *Native Title Act 1993* (Cth) may also be needed.

Where:
- a permit is not required for an activity because the activity is subject to another approval in accordance with section 129 of the Act; and
- the Department or the SA MDB NRM Board have opportunity to provide comment or direction on that approval,

then that comment or direction shall be based at a minimum on the relevant objectives and principles from this chapter.

All permit applications for the water-affecting activities listed in this section will be assessed against the general objectives and principles in section 8.2. Additional, more detailed, assessment criteria are defined for each of the water-affecting activities (section 8.3 - 8.10) that specifically apply to that activity in addition to the general principles and objectives.

Table 26A Water affecting activities relevant authority reference table

Water affecting activity	Relevant authority
Drilling, plugging, backfilling or sealing of a well in accordance with section 127 (3) (a) of the NRM Act	The Minister
Repairing, replacing or altering the casing, lining or screen of a well in accordance with section 127 (3) (b) of the NRM Act	The Minister
Draining or discharging water directly or indirectly into a well in accordance with section 127 (3) (c) of the NRM Act	The Minister
The erection, construction, modification, enlargement or removal of a dam, wall or other structure that will collect or divert, or collects or diverts— a) water flowing in a prescribed watercourse; or b) surface water flowing over land in a surface water prescribed area, in accordance with section 127 (3) (d) of the NRM Act	The SA MDB NRM Board
The erection, construction or placement of any building or structure in a watercourse or lake or on the floodplain of a watercourse in accordance with section 127 (5) (b) of the NRM Act	The SA MDB NRM Board
Draining or discharging water directly or indirectly into a watercourse or lake in accordance with section 127 (5) (c) of the NRM Act	The SA MDB NRM Board
Depositing or placing an object or solid material in a watercourse or lake in accordance with section 127 (5) (d) of the NRM Act	The SA MDB NRM Board
Destroying vegetation growing in a watercourse or lake or growing on the floodplain of a watercourse in accordance with section 127 (5) (g) of the NRM Act	The SA MDB NRM Board
Excavating or removing rock, sand or soil from a watercourse or lake or the floodplain of a watercourse, or from an area near to the banks of a lake so as to damage, or create the likelihood of damage to, the banks of the lake, in accordance with section 127 (5) (h) of the NRM Act	The SA MDB NRM Board
Using water in the course of carrying on a business in an NRM region at a rate that exceeds 1 ML per year if the water has been brought into the region by means of a pipe or other channel in accordance with section 127 (5) (i) of the NRM Act	The Minister
Using effluent in the course of carrying on a business in an NRM region at a rate that exceeds 1 ML per year in accordance with section 127 (5) (j) of the NRM Act	The Minister

8.1 Interface with the SA MDB Regional NRM Plan

The objectives and principles for assessing water affecting activities set out in the Plan operate in conjunction with the principles and objectives set out in the Natural Resources Management Plan for the South Australian Murray–Darling Basin Natural Resources Management Region (‘Regional NRM Plan’). As set out in the section of the Regional NRM Plan relating to water affecting activities:

‘A water allocation plan may set out additional policies [in relation to water affecting activities] that the Board will take into account when considering an application for a permit. The policies in a water allocation plan may be different to the policies in the Regional NRM Plan. To the extent that a water allocation plan includes different policies, the policies in the Regional NRM Plan will not apply to that prescribed water resource.

8.2 General objectives and principles

The following general objectives and principles apply to all water affecting activity permit applications.

8.2.1 Objectives

Objective A: Protect water-dependent ecosystems.

Objective B: Protect waterbody and floodplain geomorphology and aquifer structure.

Objective C: Provide for equitable and sustainable water sharing.

Objective D: Protect water quality for all uses.

Objective E: Maintain hydrological and hydrogeological systems, including natural discharge and recharge between water resources.

Objective F: Minimise interference between users.

Objective G: Minimise adverse impacts of water affecting activities on the environment, water resources and water users.

8.2.2 Principles

117. A water affecting activity will be conducted in such a way that it ensures all of the following:
    a) maintenance of acceptable water quality;
    b) equitable sharing of the water available for consumptive use;
    c) maintenance of natural hydrological and hydrogeological systems;
    d) preservation of environmental water requirements and ecosystems dependent on water;
    e) protection against the risk of harm to public and private assets and public safety from flooding; and
    f) continued monitoring of potential impacts from the activity.

118. A water affecting activity must not:
    a) cause or exacerbate soil erosion, bank or bed destabilisation of a watercourse or lake or erosion of a floodplain;
    b) be located in ecologically or culturally sensitive areas where this will or is likely to have significant detrimental impacts, where ecologically sensitive areas include, but are not limited to, key environmental assets;
    c) have significant detrimental impacts on water resources, other natural resources, or communities at both local and regional levels;
    d) have significant detrimental impacts on water-dependent ecosystems, biodiversity and habitat preservation, where impacts may result from changes in factors including, but not limited to:
        i. ecologically significant components of the water regime;
        ii. ability of aquatic biota to migrate;
        iii. habitat presence, quality and/or availability;
        iv. sedimentation; and/or
        v. ecologically significant components of water quality;
    e) cause or exacerbate unnatural waterlogging and/or rising water tables;
    f) cause unacceptable deterioration in the quality of surface water, underground water or water in a watercourse or lake;

g) create or exacerbate the incidence or intensity of local or regional flooding or increase the flood risk to public and private assets, communities or individuals, unless the activity is associated with licensed flood irrigation and does not cause adverse impacts to other assets, communities or individuals; and
h) impact on authorised devices or activities for scientific purposes.

8.3 Constructing, backfilling or repairing wells

The following principles apply specifically to an activity under

- Section 127 (3) (a) of the NRM Act, comprising drilling, plugging, backfilling or sealing of a well; or
- Section 127 (3) (b) of the NRM Act, comprising repairing, replacing or altering the casing, lining or screen of a well;

which for the purposes of section 8.3 will be referred to as the “activity” or “activities”. These principles are additional to the general principles and objectives expressed for all water affecting activities in section 8.2.

Construction and works on wells

119. The equipment, materials and method used for the activity shall not adversely affect the quality of the underground water resource.

120. Aquifers shall be protected during the activity to prevent adverse impacts on the integrity of an aquifer.

121. Where a well passes through two or more aquifers, an impervious seal must be made and maintained between the aquifers to prevent leakage between aquifers.

122. Wells drilled for the drainage or discharge of water into a well at pressures greater than gravity shall be pressure cemented along the full length of the casing.

Location of wells

123. A well shall not be drilled if the well buffer zone that would be assigned to the well overlaps:
    a) An environmental buffer zone linked to the same aquifer; or
    b) A well buffer zone linked to the same aquifer around an ***operational well*** owned by another landholder;

    where environmental buffer zones and well buffer zones are determined in accordance with principles 35 and 36.

124. Despite principle 123, a well for taking water only for non-licensed purposes may be drilled where:
    a) the spatial arrangement of existing well buffer zones, environmental buffer zones and the proponent’s property boundaries at the time of application is such that it is not possible or reasonably practical to meet the requirements of principle 123; and
    b) the well is drilled a minimum of 50 m from any ***environmental assets*** and any ***operational wells*** where those environmental assets and operational wells take water from or are linked to the same aquifer as the proposed well, unless the size of the property precludes this requirement; and
    c) the well buffer zone that would be assigned to the well does not overlap a ***key environmental buffer zone*** linked to the same aquifer.

    For the purposes of this Plan, key environmental buffer zones and the aquifers they are linked to are shown in GRO Plans 60/2008 and 61/2008. Figure 37 and Figure 38 respectively show key features of these plans at a reduced scale.

Replacement wells where buffers overlap

125. Despite principle 123, if a well (the “original well”) needs to be replaced, then a replacement well may be drilled provided that:
    a) the original well is backfilled in accordance with a permit issued pursuant to section 127 (3) (a) of the NRM Act; and
    b) the replacement well is within 20 metres of the original well; and
    c) the replacement well takes water only from the same aquifer as the original well.

Deepening wells where buffers overlap

126. Despite principle 123, a well may be deepened provided that it does not penetrate a different aquifer.

8.4 Drainage or discharging water into a well

The following objectives and principles apply specifically to an activity under section 127 (3) (c) of the NRM Act, comprising draining or discharging water directly or indirectly into a well (“artificial recharge”). They are additional to the general principles and objectives expressed for all water affecting activities in section 8.2.

In addition to the requirements outlined below for artificial recharge, a managed aquifer recovery (MAR) scheme will also require a water allocation and licence for the recovery component of the scheme if the recovered water is used for licensed purposes. This allocation must be granted in accordance with the policies for the allocation of artificially recharged water outlined in section 6.4 of this Plan.

It is also important to note that a water allocation and licence will be required to take the water to be artificially recharged into a well if:
- the water to be artificially recharged is a prescribed water resource, such as surface water or watercourse water; and
- the artificially recharged water will be recovered for licensed purposes.

8.4.1 Objectives

Objective A The sustainable operation and management of managed aquifer recovery schemes.

Objective B Reasonable and practicable measures taken to avoid the discharge of waste to the receiving underground water resource during artificial recharge.

Objective C Artificial recharge of water into a well so as not to cause environmental harm.

Objective D Artificial recharge of water directly or indirectly into a well so as not to adversely affect:
- a) the quality of underground water;
- b) the integrity of the aquifer, for example, but not limited to, the aquifer’s confining layer and the ability of the aquifer to transmit water;
- c) watertables, for example, but not limited to, water logging, land salinisation and damage to infrastructure (roads, buildings, foundations etc);
- d) any underground water-dependent ecosystem or ecologically sensitive area that depends on or is affected by the underground water resource;
- e) the ability of other persons to lawfully take from that underground water; or
- f) the longevity of operations.

Objective E The activity of artificial recharge should not be at variance with the National Water Quality Management Strategy – Australian Guidelines for Water Recycling: Managing Health & Environmental Risks, Phase 1 2006 and other related policies.

8.4.2 Principles

127. Water may be artificially recharged into a well where the concentrations of water quality parameters in the water to be artificially recharged do not exceed the water quality criteria outlined in Schedule 2 of the *Environment Protection (Water Quality) Policy 2003* or as may be amended from time to time.

Hydrogeological Assessment

128. A hydrogeological assessment is required to be conducted by a suitably qualified person and provided to the relevant authority as part of an application for a permit to artificially recharge water into a well. The assessment must detail:
    a) water levels and salinity of local underground water; and
    b) transmissivity and storage co-efficient of the aquifer from pump testing, and whether pump testing has shown any effect of extractions on other water users; and
    c) the capacity of the aquifer to accept water; and
    d) the recommended injection pressure that protects the integrity of the aquifer; and
    e) the recommended recovery volume; and
    f) proximity of other users including commercial, industrial, stock, domestic or environmental, their well and pump depths, and the aquifer they are accessing; and
    g) advice on how either low or high underground water levels may affect nearby landowners and water users and the environment; and
    h) any other information considered necessary by the relevant authority.

129. An exemption to principle 128 may apply if the proposed risk to the water resource is considered negligible (for example, but not limited to, the discharge of roof runoff under gravity with no intended recovery) in the opinion of the relevant authority.

Monitoring Prior to Commencement of Operations

130. For the purposes of principle 127, the following samples must be taken prior to the commencement of artificial recharge:
    a) one sample (unless otherwise specified by the relevant authority) of the ***ambient underground water***; and
    b) one or more samples of the water to be artificially recharged, at a time to adequately represent the quality and variability of quality of the water that will be artificially recharged (e.g. winter runoff for surface water).

    All samples must be collected by a suitably qualified person in accordance with Australian Standard (AS) 5667, Water quality – sampling, and all samples must be analysed by a National Association of Testing Authorities (NATA) accredited laboratory.

131. For the purpose of principle 130, the ***ambient underground water*** sample should be collected from the proposed point of artificial recharge, or as near as possible to the proposed point of artificial recharge, and from the same aquifer as that in which artificial recharge is proposed, as recommended by the relevant authority. The following parameters in the ambient underground water must be sampled, analysed and reported to the relevant authority:
    a) pH, total dissolved solids (TDS), turbidity, ammonia, nitrate, nitrite, total phosphorus, sodium, chloride, sulphate, calcium, magnesium, bicarbonate, iron,

total arsenic, total boron, total cadmium, total chromium, total lead, total manganese, total zinc, total coliforms and faecal coliforms.

Additional parameters may be reasonably required following discussions with the relevant authority.

132. For the purposes of principle 130, the following parameters (at a minimum) in the water to be artificially recharged must be sampled, analysed and reported to the relevant authority:
   a) Where the water to be artificially recharged is surface water and/or watercourse water (including water from a dam or lake, including imported water that has been held in a catchment dam) or water directly pumped from a watercourse or roof runoff:
      i. pH, TDS, turbidity, ammonia, nitrate, nitrite, total phosphorus, sodium, chloride, sulphate, calcium, magnesium, bicarbonate, iron, total arsenic, total boron, total cadmium, total chromium, total lead, total manganese, total zinc, total coliforms and faecal coliforms; and
      ii. where the water to be artificially recharged comes from a supply likely to contain pesticides, Giardia, Cryptosporidium, volatile organic compounds and petroleum hydrocarbons (including but not limited to water from land used for intensive agriculture or industrial purposes), those substances, material and characteristics; and
      iii. any additional parameters requested by the relevant authority.
   b) Where the water to be artificially recharged is imported water and/or treated effluent:
      i. pH, TDS, turbidity, ammonia, nitrate, nitrite, total phosphorus, sodium, chloride, sulphate, calcium, magnesium, bicarbonate, iron, total arsenic, total boron, total cadmium, total chromium, total lead, total manganese, total zinc, total coliforms and faecal coliforms; and
      ii. if the water has been treated by chlorination, sufficient representative samples must be taken and analysed for trihalomethanes; and
      iii. any additional parameters requested by the relevant authority.

   If the water provider can supply analysis results for the parameters outlined in principle 132 (b) (i) (ii) & (iii), no additional monitoring is required prior to the commencement of artificial recharge.

Ongoing Monitoring

133. One sample (unless otherwise directed by the relevant authority) must be taken of the ***ambient underground water*** annually as follows:
   a) samples of underground water should be collected at the point of artificial recharge;
   b) samples should be analysed for the parameters outlined in principle 131;
   c) all samples must be collected by a suitably qualified person in accordance with AS5667, Water quality – sampling; and
   d) all samples must be analysed by a NATA accredited laboratory and reported to the relevant authority.

134. Ongoing sampling, analysis and reporting of roof runoff, surface water or watercourse water that is artificially recharged will not be required unless otherwise specified by the relevant authority. Ongoing sampling, analysis and reporting of imported water and effluent water that is artificially recharged must be undertaken on an ongoing basis as specified by the relevant authority, unless the supplier of the water:
   a) ensures the water quality criteria will be maintained at a consistent level year round; or
   b) provides regular water quality analysis to the relevant authority.

135. If a review of monitoring results indicates that concentrations of a parameter are absent or below detection limits, that parameter does not need to continue to be monitored on an ongoing basis, unless otherwise specified by the relevant authority.

136. Where artificial recharge results in any significant adverse impacts (including, but not limited to, increased water levels or pressure, deterioration in the quality of water in the aquifer, damage to the integrity of the aquifer, impacts to other water users or environmental assets), further artificial recharge operations must cease either permanently or until such time that the relevant authority is satisfied that the adverse impacts can be either effectively managed or prevented.

8.5 Water storages and diversions

The following principles apply specifically to an activity under section 127 (3) (d) of the NRM Act, comprising the erection, construction, modification, enlargement or removal of a dam, wall or other structure that will collect or divert, or collects or diverts:

- water flowing in a watercourse in the Marne-Saunders PWRA; or
- surface water flowing over land in the PWRA;

which for the purposes of section 8.5 will be referred to as the "activity" or "activities". These types of structures are referred to collectively as "diversion structures". These principles are additional to the general principles and objectives expressed for all water affecting activities in section 8.2.

Siting and construction

137. Diversion structures shall be designed and constructed in accordance with best practice standards.

138. A diversion structure shall not:
    a) be constructed at or within 200 metres upstream or downstream of ecologically sensitive areas, where ecologically sensitive areas include, but are not limited to, ***key environmental assets***; and
    b) be constructed in areas prone to erosion; and
    c) contribute to salinity or intrusion of saline underground water into watercourses; and
    d) contribute to unacceptable underground water mounding or significant detrimental impacts through underground water level changes.

139. Diversion structures shall be designed, sited, constructed and maintained in a manner that:
    a) minimises the removal or destruction of in-stream or riparian vegetation (including through inappropriate inundation); and
    b) minimises soil erosion and siltation, including but not limited to erosion of the spillway.

140. Erection, construction, modification, enlargement, removal and maintenance of a diversion structure must be undertaken in a manner that prevents silt or sediment from entering the watercourse. Measures to prevent movement of silt or sediment may include, but are not limited to, diversion drains, revegetation, straw bale barriers, filter fences, sediment traps and detention basins.

141. Dams shall not be erected, constructed or enlarged on or across ***restricted watercourses***, except in accordance with principle 154.

142. Subject to principles 141 and 154, dams shall only be constructed as ***off-stream dams***, unless it can be demonstrated to the relevant authority's satisfaction that there is no suitable location available on the property for it to be constructed as an off-stream dam.

143. Where a new dam is constructed, the applicant must demonstrate the completed capacity of the dam, using a licensed surveyor, to the relevant authority's satisfaction. Where the capacity of an existing dam is to change as a result of modification, enlargement or removal, the applicant must demonstrate the capacity of the dam before and after the activity, using a licensed surveyor, to the relevant authority's satisfaction.

Management zone dam capacity limit

144. No permits shall be granted for the erection, construction or enlargement of a dam while the total capacity of dams in the management zone that the activity is proposed for is the same as or greater than the relevant management zone dam capacity limit (MZ DCL).

145. For the purposes of this Plan, the MZ DCL is determined as follows:
   a) The MZ DCL at the date of adoption shall be the total capacity of dams (in ML) that is present in the management zone at the date of adoption.
   b) Subject to principles 145 d) and 145 e), where the total capacity of dams in a management zone is reduced through the removal of dam capacity:
      i. in accordance with a permit issued pursuant to section 127 (3) (d) of the NRM Act or in accordance with any other authorisation; and
      ii. demonstrated and notified in accordance with principle 161;

   then the MZ DCL for that management zone will become:

   $$MZ\ DCL = MZ\ DCL_{prior} - (0.2 \times DC_{removed})$$

   Where:

   MZ DCL The new management zone dam capacity limit (in ML).

   $MZ\ DCL_{prior}$ Management zone dam capacity limit prior to the removal of dam capacity (in ML).

   $DC_{removed}$ Dam capacity that was removed (in ML).
   c) Principle 145 b) will continue to operate until the MZ DCL becomes equal to or less than the Management zone long-term dam capacity target (MZ LDCT) given in column "Management zone long-term dam capacity target" of Table 28, at which point the value of the MZ DCL will become the value of the MZ LDCT.
   d) Where:
      i. dam capacity is removed in accordance with a permit issued pursuant to section 127 (3) (d) of the NRM Act, or in accordance with any other authorisation; and
      ii. the dam capacity removal is demonstrated and notified in accordance with principle 161; and
      iii. that dam capacity was removed for the purpose of providing environmental benefit,

   then the MZ DCL for the management zone that the dam capacity was removed from shall be reduced by the volume of dam capacity that was removed.

e) Where:

   i. dam capacity is removed in accordance with a permit issued pursuant to section 127 (3) (d) of the NRM Act, or in accordance with any other authorisation; and
   ii. the dam capacity removal is demonstrated and notified in accordance with principle 161; and
   iii. that dam capacity was removed for the purpose of consolidating dams within a property, and
   iv. the dam capacity removal notification is accompanied by an application to erect, construct or enlarge a dam or dams within the same property as the remaining part of the process of consolidating dams within that property;

   then the MZ DCL for the management zone that the dam capacity was removed from shall become:

$$MZ\ DCL = MZ\ DCL_{prior} - (DC_{removed} – [\text{lesser of } DC_{requested} \text{ or } DC_{allowable}])$$

   Where:

MZ DCL	The new management zone dam capacity limit (in ML).
$MZ\ DCL_{prior}$	Management zone dam capacity limit prior to the removal of dam capacity (in ML).
$DC_{removed}$	Dam capacity that was removed (in ML).
$DC_{requested}$	Dam capacity that is requested in the application to erect, construct or enlarge a dam or dams (in ML).
$DC_{allowable}$	The allowable dam capacity that may be erected, constructed or enlarged in accordance with this Plan for that application (in ML).

f) For the purposes of this Plan

   i. "Consolidating dams within a property" means any process by which dams are removed and either replaced with new dams or enlarged existing dams upon the same property, thus reducing the total number of dams on the property, provided that the total dam capacity on the property remains the same or less than the capacity prior to dam capacity removal.
   ii. For the purposes of principle 145 e), "an application to erect, construct or enlarge a dam or dams" means an application pursuant to section 127 (3) (d) of the NRM Act, or an application for development authorisation for an equivalent activity made to the appropriate authority under the *Development Act 1993*.

Maximum dam capacity

146. The capacity of a new or enlarged dam shall not exceed the smallest total dam capacity determined through application of principles 147 to 152 where relevant. If this smallest total dam capacity is equal to or less than the existing dam capacity at the proposed construction site (if any), then the proposed new dam capacity will not be allowed.

Maximum dam capacity – management zone dam capacity limit

147. A permit shall not be granted to erect, construct or enlarge a dam when that activity would cause the total capacity of dams in a management zone to exceed the management zone dam capacity limit.

For the purposes of this principle, the capacity of the new or enlarged dam (D1) shall not exceed the following:

$TDC_{147} = (MZ\ DCL – DC_{MZ}) + DC_{D1}$

where:

TDC_{147}	Total dam capacity. The total volume of dam capacity of dam D1 that must not be exceeded for the purposes of principle 147 (in ML).
MZ DCL	Management zone dam capacity limit for the management zone that dam D1 would lie within, determined in accordance with principle 145 (in ML)
DC_{MZ}	Dam capacity in the management zone. DC_{MZ} is the total capacity of dams at the date of application in the management zone that dam D1 would lie within (in ML).
DC_{D1}	Dam capacity of D1. DC_{D1} is the existing dam capacity of dam D1 at the date of application, if any (in ML). Where dam D1 is a new dam, then $DC_{D1} = 0$ ML.

Maximum dam capacity – management sub-zone dam capacity limit

148. A permit shall not be granted to erect, construct or enlarge a dam when that activity would cause the total capacity of dams in a management sub-zone to exceed, or further exceed, the management sub-zone dam capacity limit.

For the purposes of this principle, the capacity of the new or enlarged dam (D1) shall not exceed the following:

$TDC_{148} = (MSZ\ DCL – DC_{MSZ}) + DC_{D1}$

where:

TDC_{148}	Total dam capacity. The total volume of dam capacity of dam D1 that must not be exceeded for the purposes of principle 148 (in ML).
MSZ DCL	Management sub-zone dam capacity limit for the management sub-zone that dam D1 would lie within, given in column “Management sub-zone dam capacity limit” of Table 29 (in ML).
DC_{MSZ}	Dam capacity in the management sub-zone. DC_{MSZ} is the total capacity of dams at the date of application in the management sub-zone that D1 would lie within (in ML).
DC_{D1}	Dam capacity of D1. DC_{D1} is the existing dam capacity of dam D1 at the date of application, if any (in ML). Where dam D1 is a new dam, then $DC_{D1} = 0$ ML.

Maximum dam capacity – local dam capacity limit

149. The capacity of a new or enlarged dam shall not exceed 30% of average adjusted winter runoff from the catchment area upstream of the dam, taking upstream dam capacity into account. This dam capacity that shall not be exceeded is determined as:

$TDC_{149} = (A_{D1} \times R_{D1} \times 0.3) – DC_{UD1}$

where:

TDC_{149}	Total dam capacity. The total volume of dam capacity of dam D1 that must not be exceeded for the purposes of principle 149 (in ML).
A_{D1}	Area upstream of D1. A_{D1} is the catchment area upstream of dam D1 (in km^2)
R_{D1}	Runoff at D1. R_{D1} is the average adjusted winter runoff depth for the catchment area upstream of dam D1, determined in accordance with principle 63 g) (in mm).
DC_{UD1}	Dam capacity upstream of D1. DC_{UD1} is the volume of dam capacity in the catchment area upstream of dam D1, excluding the existing dam capacity of dam D1 (if any), at the date of application (in ML).

Maximum dam capacity – minimising downstream impact

150. A permit shall not be granted to erect, construct or enlarge a dam where that activity would cause the total potential demand for water to exceed or further exceed the average supply of runoff from the upstream catchment area for any affected diversion structures within the Marne Saunders PWRA. Total potential demand includes dam capacity and consumptive use from diversion structures that are not dams at and upstream of the affected diversion structure being considered.

For the purposes of this principle, the capacity of the new or enlarged dam (D1) shall not exceed the smallest volume returned by calculating the following equation at each diversion structure “x” (Dx) downstream of D1 within the Marne Saunders PWRA that may be affected by the activity:

$TDC_{150} = ((A_{Dx} \times R_{Dx}) – (DC_{BDx} + CUS_{BDx})) + DC_{D1}$

where:

TDC_{150}	Total dam capacity. The total volume of dam capacity of dam D1 that must not be exceeded for the purposes of principle 150 (in ML).
A_{Dx}	Area upstream of Dx. A_{Dx} is the catchment area upstream of diversion structure Dx (in km^2)
R_{Dx}	Runoff at Dx. R_{Dx} is the average adjusted winter runoff depth for the catchment area upstream of diversion structure Dx, determined in accordance with principle 63 g) (in mm).
DC_{BDx}	Dam capacity both at and upstream of Dx. DC_{BDx} is the total volume of dam capacity at diversion structure Dx (if relevant) and in the catchment area upstream of diversion structure Dx, at the date of application (in ML).
CUS_{BDx}	Consumptive use from diversion structures that are not dams both at and upstream of Dx. CUS_{BDx} is the total volume of consumptive use from diversion structures that are not dams at diversion structure Dx (where relevant) and in the catchment area upstream of diversion structure Dx, at the date of application (in ML). Consumptive use is determined in accordance with principle 63 f).
DC_{D1}	Dam capacity of D1. DC_{D1} is the existing dam capacity of dam D1 at the date of application, if any (in ML). Where dam D1 is a new dam, then $DC_{D1} = 0$ ML.

Where the equation returns a negative value, TDC_{150} for D1 will be zero.

Maximum dam capacity – twice property-scale dam capacity requirements

151. A permit shall not be granted to erect, construct or enlarge a dam where that activity would cause the total capacity of dams on a property to exceed twice the reasonable water requirements for the property from dams.

For the purposes of this principle, the capacity of the new or enlarged dam (D1) shall not exceed the following:

$TDC_{151} = ((2 \times (\text{allocation} + RPR)) - DC_{prop}) + DC_{D1}$

where:

TDC_{151}	Total dam capacity. The total volume of dam capacity of dam D1 that must not be exceeded for the purposes of principle 151 (in ML).
allocation	allocation taken from dams on the property (if any) (in ML).
RPR	the reasonable property-scale requirement for dam capacity that the relevant authority considers to be appropriate to supply the reasonable non-licensed annual water needs of the property that is to include dam D1 (in ML). When determining this reasonable property-scale dam capacity, elements to be considered may include, but are not limited to: a) stock watering requirements related to the carrying capacity of the land; b) property size; c) local climate; d) net evaporative loss from the dam; and e) domestic requirements where appropriate, but excludes provision for storage of more than one year of supply.
DC_{prop}	Dam capacity on the property. DC_{prop} is the total capacity of existing dams at the property for which dam D1 is proposed, at the date of application (if any) (in ML).
DC_{D1}	Dam capacity at D1. DC_{D1} is the existing dam capacity of dam D1 at the date of application (if any) (in ML). Where dam D1 is a new dam, then $DC_{D1} = 0$ ML.

152. For the purposes of principle 151, where a dam is to be erected, constructed or enlarged on a property (the “new property”) that has been created by a land division (or series of land divisions) of a larger property (the “original property”) after the date of adoption, RPR and DC_{prop} will be determined on the basis of the original property, including an allowance for additional domestic water requirements on the new property where relevant.

153. Principles 144 to 152 do not apply where:
   a) The structure to be constructed is authorised by the Minister or SA MDB NRM Board for the specific purpose of measuring streamflow; or
   b) The dam to be constructed is solely for the purpose of improving water quality prior to returning the diverted water to the same watercourse or flow path within three days of diversion or collection, with loss of water volume only allowed via minimised seepage and evaporation from the water body. The proponent must demonstrate the intended operation, maintenance and monitoring of the proposed water quality improvement dam to the satisfaction of the relevant authority as part of such a permit application.

Replacement dams

154. Where a dam (the “original dam”) has been washed away, a permit may be granted to construct a replacement dam of the same capacity as the original dam despite principles 144 to 152, provided that:
    a) the capacity of the original and replacement dams are demonstrated by a licensed surveyor to the relevant authority’s satisfaction; and
    b) the replacement dam is constructed in the same location as the original dam or on a part of the same property that is ***hydrologically continuous*** with the original dam within the property; and
    c) if the original dam was constructed on or across a ***restricted watercourse***, the replacement dam may be constructed on a segment of that watercourse with a ***stream order*** that is the same or less than the stream order of the segment of watercourse that the original dam was constructed on or across.

Flow regime

155. Subject to principle 156, a dam, wall or other structure that collects or diverts surface water flowing over land or water from a watercourse must include a device that ensures that any flows at or below the threshold flow rate:
    a) will not be collected or diverted; and/or
    b) will be bypassed around the diversion structure or otherwise returned to the same watercourse or surface water flow path immediately downstream of the diversion structure as soon as reasonably practical and be of similar or better quality as it was prior to diversion;

    where the threshold flow rate is calculated in accordance with principle 77.

156. For a diversion structure where the threshold flow rate is calculated to be one litre per second or less, principle 155 does not apply provided that:
    a) no more than 90% of the volume of flow arriving at the diversion structure is diverted or captured at any time; or
    b) the volume equivalent to 10% of the volume of flow arriving at the diversion structure at any time is returned to the same watercourse or surface water flow path immediately downstream of the diversion structure as soon as reasonably practical and is of a similar or better quality as it was prior to diversion.

157. Any device that ensures compliance with principles 155 or 156 shall:
    a) be designed and constructed to ensure its correct operation is automated and can not be manually overridden; and
    b) not increase the area that directs water to the diversion structure beyond the natural size of the catchment area upstream of the diversion structure; and
    c) be maintained in such a condition that it continues to be effective in meeting principle 155 or 156; and
    d) not be obstructed or tampered with in any way.

158. The design of the device that will achieve the outcomes required by principles 155 to 157 must be approved by the relevant authority prior to the granting of a permit for erection, construction, modification or enlargement of a diversion structure.

159. Principles 155 to 158 do not apply to structures authorised by the Minister or relevant authority for the specific purpose of measuring stream flow.

Reduction of capacity if water allocation is transferred permanently

160. A condition shall be placed on permits for erection, construction or enlargement of dams such that if:
    a) the dam is used to capture or store a water allocation; and
    b) that water allocation is permanently diminished by means of a transfer or another mechanism,

    then the volumetric capacity of the dam to store water shall be reduced by the volume of the water allocation that will no longer be taken from the dam.

Notification on removal of dams or reduction of dam capacity

161. When a dam has been removed or the capacity of a dam has been reduced in accordance with a permit issued under section 127 (3) (d) of the NRM Act or other authorisation, the authorisation holder shall provide written notification of dam capacity removal to the relevant authority. The dam capacity removal will not be considered to have occurred until it is demonstrated to the relevant authority's satisfaction. The date of dam capacity removal shall be the date and time of receipt of written notification of dam capacity removal, unless subsequent investigation shows that the capacity has not been removed to the relevant authority's satisfaction.

Processing of permit applications

162. Permit applications for this activity will be assessed in the order in which they are received. Assessment of a permit application will not begin until the previous application has been determined.

163. All permit applications received prior to a date of dam capacity removal as defined in principle 161 shall be determined before the relevant management zone dam capacity limit is reduced or considered in accordance with principle 145.

8.6 Building, structure, object or solid material in a watercourse, lake or floodplain

The following principles apply specifically to an activity under:

- Section 127 (5) (b) of the NRM Act, comprising the erection, construction or placement of any building or structure in a watercourse or lake or on the floodplain of a watercourse; and
- Section 127 (5) (d) of the NRM Act, comprising depositing or placing an object or solid material in a watercourse or lake.

For the purposes of section 8.6, these activities will be referred to as the "activity" or "activities" and the subject building, structure, object or solid material will be referred to as the "item". These principles are additional to the general principles and objectives expressed for all water affecting activities in section 8.2.

164. Depositing or placing an object or solid material in a watercourse or lake may only occur where it is for the purpose of:
    a) the construction of an erosion control structure, including but not limited to a rock chute or rip rap; or
    b) an authorised activity for scientific purposes, including but not limited to, flow measuring devices;

    where an "authorised activity" means a device, structure or activity authorised by the Minister, relevant authority or a Local Government Authority in accordance with this Plan.

165. Items that impede the flow of water must be designed to bypass or otherwise return flows at or below the threshold flow rate in accordance with principles 155 to 157, excluding structures authorised by the Minister or relevant authority for the specific purpose of measuring streamflow.

166. Any activity or item used in the control or prevention of watercourse erosion must be designed with regard to the nature and conditions of the site, and upstream and downstream of the site.

167. Items must be maintained in an appropriate condition to perform their intended function in accordance with section 135 (8) of the NRM Act.

8.7 Drainage or discharge of water into a watercourse or lake

The following principles apply specifically to an activity under section 127 (5) (c) of the NRM Act, comprising draining or discharging water directly or indirectly into a watercourse or lake. They are additional to the general principles and objectives expressed for all water affecting activities in section 8.2.

168. Drainage or discharge of water into a watercourse or lake must only be undertaken where adequate protective measures have been taken to minimise erosion and degradation in the quality of the receiving water. Protective measures may include, but are not limited to:
   a) detention basins to regulate the rate, volume and quality of water discharged;
   b) reuse of drainage or discharge water under conditions that would not present a risk to public or environmental health;
   c) litter traps;
   d) pre-treatment of the water before discharge; and/or
   e) discharge into the receiving watercourse at times of naturally high flow.

   All treatment devices must be appropriately managed and maintained to ensure that they continue to function according to their design.

8.8 Vegetation clearance

The following principles apply specifically to an activity under section 127 (5) (g) of the NRM Act, comprising destroying vegetation growing in a watercourse or lake or growing on the floodplain of a watercourse. They are additional to the general principles and objectives expressed for all water affecting activities in section 8.2.

169. A permit under this Plan is only required for destroying vegetation growing in a watercourse or lake or growing on the floodplain of a watercourse where that activity will occur within an area defined as a ***key environmental asset***.

170. A permit shall not be granted for destroying native vegetation if it:
   a) has significance as habitat for wildlife;
   b) has a high level of diversity of plant species or has rare or endangered plant species or plant associations; and/or
   c) has value as a remnant of the vegetation association characteristic of the district or region prior to extensive clearance for agriculture.

171. A permit shall not be granted for destroying vegetation associated with draining or taking water from a wetland.

8.9 Excavation or removal of rock, sand or soil

The following principles apply specifically to an activity under section 127 (5) (h) of the NRM Act, comprising excavating or removing rock, sand or soil from a watercourse or lake or the floodplain of a watercourse; or from an area near to the banks of a lake so as to damage, or create the likelihood of damage to, the banks of the lake. They are additional to the general principles and objectives expressed for all water affecting activities in section 8.2.

172. A permit is not required to desilt a dam on a watercourse provided that:
    a) the capacity of the dam is not increased; and
    b) material removed from the dam is not placed in the watercourse in which the dam is located or on the floodplain of the watercourse.

8.10 Use of effluent and imported water

The following principles apply specifically to an activity under:

- Section 127 (5) (i) of the NRM Act, comprising using water in the course of carrying on a business in the Marne-Saunders PWRA at a rate that exceeds 1 ML per annum if the water has been brought into the region by means of a pipe or other channel ("using imported water"); or
- Section 127 (5) (j) of the NRM Act, comprising using effluent in the course of carrying on a business in the Marne-Saunders PWRA at a rate that exceeds 1 ML per annum ("using effluent").

They are additional to the general principles and objectives expressed for all water affecting activities in section 8.2.

173. A permit under this Plan is only required for using effluent or imported water where:
    a) the effluent or imported water will be applied to land directly or following use in another process; and/or
    b) imported water will be stored in a dam that is not a ***turkey nest dam***.

174. A permit shall not be granted for the use of effluent if the effluent will be stored in a dam that is not a ***turkey nest dam***.

175. A permit for using effluent will not be required where the user or type of enterprise is legally obligated to comply with a mandatory code of practice that encompasses storing and using effluent in a manner that is consistent with these principles. Examples of such a code of practice include, but are not limited to, the Environment Protection Authority's Code of Practice for Milking Shed Effluent (2003).

176. Where effluent is imported into the Marne Saunders PWRA then that water will be treated as effluent for the purposes of this section.

177. Storage and/or use of effluent or imported water must not:
    a) cause a rise in underground water level sufficient to detrimentally affect structures, assets or natural resources;
    b) affect the productive capacity of land by causing significant detrimental impacts including but not limited to increasing salinity, sodicity, waterlogging, perched water tables, toxicity and nutrient concentrations;
    c) cause significant detrimental impacts on water-dependent ecosystems; and
    d) result in unacceptable changes to the quality of water resources.

178. A permit shall not be granted for the use of effluent in an area defined as a ***key environmental asset***.

179. Effluent and chlorine-treated imported water shall not be discharged directly or indirectly into watercourses.

180. Storage facilities for effluent and imported water shall be constructed and operated in a manner that prevents significant detrimental impacts on quality of water resources and health of water-dependent ecosystems.

181. Effluent must only be stored in a closed system with no natural catchment that is constructed to prevent:

    a) leakage to the surrounding soils (unless carried out as a component of an approved aquifer storage scheme); and
    b) overflow onto land or into watercourses.

9 Monitoring

9.1 Monitoring by licensees and permit holders

9.1.1 Water use reporting

The following information will be provided to the SA MDB NRM Board by licensees and permit holders (imported water and/or effluent) on or before 31 July each year as part of water use annual reporting:

- Licensee name, address and contact details
- Licence and permit numbers
- Meter numbers, meter readings and source identifier
- Where water is used for irrigation, the type of crop(s) irrigated, the area of each crop(s) irrigated, the volume or proportion of water applied to each crop type (where relevant) and the type of irrigation system
- Where water is used for other licensed purposes, the nature and size(s) of each purpose(s) and where relevant, the volume or proportion of water applied to each purpose
- Other information as required by the SA MDB NRM Board

This requirement for annual water use reporting does not apply to water (holding) allocations.

Annual water use reporting forms will be distributed by, and returned to, the SA MDB NRM Board. This information will be collated into a district annual report by the SA MDB NRM Board and will be provided to licensees and made available on the Board's website and on request.

9.1.2 Water resource monitoring

All licensed water users will be required to submit an annual water sample collected from their licensed source(s) for salinity testing to the SA MDB NRM Board by 30 June each year, where the timing and method of sample collection must be to the satisfaction of the SA MDB NRM Board.

This requirement for provision of water samples for salinity testing does not apply to water (holding) allocations.

Where water allocations are granted to be taken from the Renmark Group Aquifer Management Zone, the licensee must undertake a monitoring and reporting program as specified by the Minister of parameters including, but not limited to, water level and quality in relevant wells.

The requirements for monitoring water quality associated with a water affecting activity permit for draining or discharging water into a well are outlined in principles 130 - 135.

9.1.3 Water-dependent ecosystem use monitoring and reporting

Water allocated for the purposes of water-dependent ecosystem use may include non-active environmental use (where water is retained in aquifers, surface water and/or watercourses) and active environmental use including but not limited to activities such as watering naturally occurring habitat.

Where an allocation is granted for the purpose of water-dependent ecosystem use and the allocation is used actively, the licensee must implement a monitoring and reporting program designed to the Minister's satisfaction to assess achievement against objectives for the use.

9.2 Monitoring and assessment of water resources and the environment

Monitoring and evaluation of water resources and water-dependent ecosystems provides a mechanism for assessing whether the Plan's objectives are being met, identifies actions that need to be taken to protect the resource, and improves knowledge of behaviour of the resource and water-dependent ecosystems for future policy development.

Table 27 sets out triggers that indicate potential threats to the ability of the water resource to continue to meet demands. If monitoring shows that a trigger has been reached, the following actions will occur:

- undertake investigations to determine the likely causes of stress;
- undertake investigations to determine likely negative impacts;
- if necessary, assess what options are available for remedial action;
- report to stakeholders including licensees; and
- implement remedial action(s) as required.

Table 27 also sets out the minimum monitoring requirements for assessment of the triggers and lists the organisation(s) that will primarily carry out the monitoring and evaluation.

More intensive monitoring will provide a more detailed assessment. Aspects of the monitoring programs need to be refined and optimised to ensure conditions are monitored in areas where usage is most likely to lead to impact. The monitoring programs will also need to be responsive to changing patterns of usage across the catchment once trading occurs under the Plan. The Department and the SA MDB NRM Board will work together with the community to develop and implement suitable monitoring programs to complement the Plan's key monitoring requirements, including the monitoring and evaluation desires of Aboriginal nations described in section 1.5.4.2.

Results of the monitoring programs will be reported upon at least once every three years. The reports will be made available on the SA MDB NRM Board's website and on request.

There is a range of monitoring to be undertaken to improve understanding and prediction of behaviour of the water resources and responses of water-dependent ecosystems to the water regime. The Department, the SA MDB NRM Board and other stakeholders will work together to develop and implement such a monitoring program based on resources such as Kawalec and Roberts (2005) and Cottingham *et al* (2005).

Table 27 Resource condition triggers and monitoring requirements for trigger assessment

Water resource / asset	Trigger for action	Monitoring requirements	Responsibility
Confined Murray Group Limestone aquifer, focusing on Confined Zone A Management Zone	Water pressure: sustained flattening of the pressure gradient between pumping seasons or reversal of the pressure gradient.	Quarterly monitoring of water level using existing network of monitoring wells plus at least 2 additional monitoring wells near the eastern edge of Confined Zone A to detect flow reversal. Evaluation every 2 years at minimum.	The Department. Cost share between The Department and the SA MDB NRM Board to drill additional sites if required.
	Salinity: increase greater than 2% per year, averaged over 5 years, in 50% or more of the monitoring wells.	Monitoring of salinity before and after irrigation season in wells where salinity increase is most likely. Evaluation every 2 years at minimum.	The Department
Unconfined Murray Group Limestone aquifer, focusing on Unconfined Zone 1 Management Zone	Water level: decline below the minimum water level experienced between 1998 – 2002 inclusive in any of the monitoring wells.	Quarterly monitoring of water level using existing network. Evaluation every 2 years at minimum.	The Department
	Salinity: long-term increase in salinity in monitoring wells.	Monitoring of salinity before and after irrigation season in wells where salinity increase is most likely. Evaluation every 2 years at minimum.	The Department
Surface water and watercourse water	Comparison of actual flow against modelled flow under the same conditions for the “no dams” scenario, with a trigger condition of an environmental stress rating of 2 or greater as per section 3.6.	Continuous flow gauging at existing station at Marne Gorge (A4260605 Marne River at Marne Gorge). Continuous water level recording plus collection of adequate flow gaugings for existing station downstream of Saunders Gorge. Rainfall at existing Keyneton Bureau of Meteorology (BOM) station or similar. New rainfall monitoring station for Saunders catchment as outlined in Kawalec and Roberts (2005) Evaluation every 2 years at minimum.	The Department for Marne Gorge flow gauging station. BOM for existing rainfall station. SA MDB NRM Board for water level recording with flow gaugings and new Saunders rainfall station (and adopt Keyneton rainfall site if discontinued by BOM). Evaluation by the Department and SA MDB NRM Board in partnership.
	Salinity: long-term increase in salinity.	Continuous salinity monitoring at existing network of water level detector sites and Marne Gorge flow gauging station. Evaluation every 2 years at minimum.	The Department for Marne Gorge flow gauging station SA MDB NRM Board for water level detector sites and evaluation.

Table 27 continued

Water resource / asset	Trigger for action	Monitoring requirements	Responsibility
Fractured rock aquifer	Water level – long-term decrease in water level in monitoring wells.	Quarterly monitoring of water level in monitoring wells. Existing network needs to be expanded to provide adequate coverage. Evaluation every 2 years at minimum.	The Department
	Salinity: long-term increase in salinity in monitoring wells.	Monitoring of salinity before and after irrigation season in wells where salinity increase is most likely. Existing network needs to be expanded to provide adequate coverage. Evaluation every 2 years at minimum.	The Department
All water resources	n/a	Regular reading of metered usage from licensed sources to provide information to help interpret resource behaviour.	The Department
Baseflow at key ecological sites	Long-term decline in discharge or level of baseflow and long-term increase in salinity at Black Hill Springs and reach S4.	Continuous water level and salinity recording at existing water level detector sites at Black Hill Springs and Lenger Reserve. Evaluation every 2 years at minimum.	SA MDB NRM Board
Key fish populations	Failure to meet environmental objectives for fish as set out in section 3.4 over the longer term (several years).	Fish monitoring program set out in Hammer (2007b) for the Marne and Saunders catchments. Evaluation every 2 years at minimum.	SA MDB NRM Board
River Red Gum health	Long-term decline (over several years) in health of River Red Gums.	Annual assessment of health of River Red Gums at reaches throughout the area using the method of Angas Bremer Water Management Committee (2005) or similar. Evaluation every 2 years at minimum.	SA MDB NRM Board
Condition of water-dependent ecosystems	Failure to meet environmental objectives as set out in section 3.4 over the longer term (several years).	Monitoring condition of vegetation community, geomorphology and macro-invertebrate community at key sites (fish monitoring sites as a base) at least every 3 years.	SA MDB NRM Board

10 Links with other acts, agreements and plans

In preparing this water allocation plan, the SA MDB NRM Board has had regard to the issues set out in section 7 of the NRM Act.

The Plan shows consistency with the following plans and policies:

- relevant management plans under the *Coast Protection Act 1972*;
- relevant development plans under the *Development Act 1993*;
- relevant environment protection policies under the *Environment Protection Act 1993*;
- relevant plans of management under the *National Parks and Wildlife Act 1972*;
- the *Native Vegetation Act 1991*
- the South Australia's Strategic Plan 2007
- the Natural Resources Management Plan for the South Australian Murray–Darling Basin Natural Resources Management Region;
- The Guidelines for the preparation of water allocation plans, December 2005;
- the State Natural Resources Management Plan; and
- the Intergovernmental Agreement on a National Water Initiative 2004.

11 Policy tables, policy maps, acronyms and definitions

11.1 Policy tables

Table 28 Characteristics of management zones in the Marne Saunders PWRA

Management zone name	Water resource	Aquifer	Zone description	Management zone allocation limit (ML)	Management zone long-term dam capacity target (ML)
Confined Zone A	UGW[8]	MGL[9] (confined)	Sedimentary (confined – Marne)	332.314	n/a
Confined Zone B	UGW	MGL (confined)	Sedimentary (confined – Saunders)	44	n/a
Unconfined Zone 1	UGW	MGL (unconfined)	Sedimentary (unconfined – Marne stream recharge)	1,613.453	n/a
Unconfined Zone 2	UGW	MGL (unconfined)	Sedimentary (unconfined – Saunders)	128	n/a
Unconfined Zone 3	UGW	MGL (unconfined)	Sedimentary (unconfined – diffuse - north east of Cambrai)	1.5	n/a
Unconfined Zone 4	UGW	MGL (unconfined)	Sedimentary (unconfined – diffuse - north of Kongolia)	15	n/a
Unconfined Zone 5	UGW	MGL (unconfined)	Sedimentary (unconfined – diffuse - south of Black Hill)	14	n/a
Unconfined Zone 6	UGW	MGL (unconfined)	Sedimentary (unconfined – diffuse - north of Black Hill)	7.5	n/a
Exclusion Zone	UGW	MGL (unconfined)	Sedimentary (unconfined – Black Hill exclusion zone)	0	n/a
Quaternary Aquifer	UGW	Quaternary	Sedimentary – Quaternary aquifer	0	n/a
Renmark Group Aquifer	UGW	Renmark Group	Sedimentary – Renmark Group aquifer	500	n/a
Fractured Rock Aquifer	UGW	Fractured rock	Fractured rock aquifer	2,000	n/a
Upper Marne	SW & WC [10]	n/a	Upper Marne catchment	1,135.372*	2,402
Lower Marne	SW & WC	n/a	Lower Marne catchment	95.408*	46
Upper Saunders	SW & WC	n/a	Upper Saunders catchment	50.410*	264
Lower Saunders	SW & WC	n/a	Lower Saunders catchment	4.495*	71

[8] Underground water
[9] Murray Group Limestone
[10] Surface water and watercourse water
* The sum of allocations to existing users (excluding extra safety net allocations, to simplify accounting if these allocations are returned to the Minister)

Table 29 Characteristics of management sub-zones in the Marne Saunders PWRA

Management sub-zone name	Parent management zone	Water resource	Aquifer	Tributary or main watercourse	Management sub-zone allocation limit (ML)	Management sub-zone consumptive use limit (ML)	Average adjusted winter runoff depth (mm)	Unit threshold flow rate (L/s/km^2)	Management sub-zone dam capacity limit (ML)
Confined Sub-Zone C1	Confined Zone A	UGW[11]	MGL[12] (confined)	n/a	332.314	n/a	n/a	n/a	n/a
Confined Sub-Zone C2	Confined Zone A	UGW	MGL (confined)	n/a	240	n/a	n/a	n/a	n/a
Fractured Rock Sub-Zone F1	Fractured Rock Aquifer	UGW	Fractured rock	n/a	2,000	n/a	n/a	n/a	n/a
Fractured Rock Sub-Zone F2	Fractured Rock Aquifer	UGW	Fractured rock	n/a	250	n/a	n/a	n/a	n/a
M1-01	Upper Marne	SW & WC[13]	n/a	Tributary	n/a	535	98	2	535
M1-02	Upper Marne	SW & WC	n/a	Tributary	n/a	287	84	2	287
M1-03	Upper Marne	SW & WC	n/a	Tributary	n/a	167	60	2	167
M1-04	Upper Marne	SW & WC	n/a	Tributary	n/a	49	45	2	49
M1-05	Upper Marne	SW & WC	n/a	Tributary	n/a	270	40	2	270
M1-06	Upper Marne	SW & WC	n/a	Tributary	n/a	31	19	2	31
M1-07	Upper Marne	SW & WC	n/a	Tributary	n/a	106	68	2	106
M1-08	Upper Marne	SW & WC	n/a	Tributary	n/a	36	56	2	36
M1-09	Upper Marne	SW & WC	n/a	Tributary	n/a	149	43	2	149
M1-10	Upper Marne	SW & WC	n/a	Tributary	n/a	109	26	2	109
M1-11	Upper Marne	SW & WC	n/a	Tributary	n/a	26	9	2	26
M2-01	Upper Marne	SW & WC	n/a	Tributary	n/a	81	16	1.5	81
M2-02	Upper Marne	SW & WC	n/a	Tributary	n/a	55	26	1.5	55
M2-03	Upper Marne	SW & WC	n/a	Tributary	n/a	137	32	1.5	137

[11] Underground water
[12] Murray Group Limestone
[13] Surface water and watercourse water

Table 29 continued

Management sub-zone name	Parent management zone	Water resource	Aquifer	Tributary or main watercourse	Management sub-zone allocation limit (ML)	Management sub-zone consumptive use limit (ML)	Average adjusted winter runoff depth (mm)	Unit threshold flow rate ($L/s/km^2$)	Management sub-zone dam capacity limit (ML)
M2-04	Upper Marne	SW & WC	n/a	Tributary	n/a	158	27	1.5	158
M2-05	Upper Marne	SW & WC	n/a	Tributary	n/a	28	18	1.5	28
M2-06	Upper Marne	SW & WC	n/a	Tributary	n/a	27	18	1.5	27
M2-07	Upper Marne	SW & WC	n/a	Tributary	n/a	24	18	1.5	24
M2-08	Upper Marne	SW & WC	n/a	Tributary	n/a	22	14	1.5	22
M2-09	Upper Marne	SW & WC	n/a	Tributary	n/a	9	11	1.5	9
M2-10	Upper Marne	SW & WC	n/a	Tributary	n/a	38	12	1.5	38
M2-11	Upper Marne	SW & WC	n/a	Tributary	n/a	19	10	1.5	19
M2-12	Upper Marne	SW & WC	n/a	Tributary	n/a	14	10	1.5	14
M2-13	Upper Marne	SW & WC	n/a	Tributary	n/a	11	10	1.5	11
M2-14	Upper Marne	SW & WC	n/a	Tributary	n/a	9	8	1.5	9
M2-15	Upper Marne	SW & WC	n/a	Tributary	n/a	6	7	1.5	6
M3	Upper Marne	SW & WC	n/a	Tributary	n/a	24	3	1.5	24
M4	Lower Marne	SW & WC	n/a	Tributary	n/a	21	2	1.5	21
M5	Lower Marne	SW & WC	n/a	Tributary	n/a	36.7*	0	1.5	36.7*
M6	Upper Marne	SW & WC	n/a	Main watercourse	n/a	See principle 65 b)	n/a	2	n/a**
M7	Lower Marne	SW & WC	n/a	Main watercourse	n/a	See principle 65 b)	n/a	1.5	n/a**
M8	Upper Marne	SW & WC	n/a	Main watercourse	n/a	See principle 65 b)	n/a	1.5	n/a**

* The management sub-zone consumptive use limit and management sub-zone dam capacity limit for M5 and S6 have a nominal value (existing dam capacity for the management sub-zone) given that local average runoff depth is zero.

** There is no management sub-zone dam capacity limit for M6, M7, M8, S7 and S8 because these are main watercourse management sub-zones, and are made up entirely of restricted watercourses. No new dams may be constructed on restricted watercourses (as per principle 141), so there is no requirement to set a management sub-zone dam capacity limit for these zones.

Table 29 continued

Management sub-zone name	Parent management zone	Water resource	Aquifer	Tributary or main watercourse	Management sub-zone allocation limit (ML)	Management sub-zone consumptive use limit (ML)	Average adjusted winter runoff depth (mm)	Unit threshold flow rate (L/s/km^2)	Management sub-zone dam capacity limit (ML)
S1-01	Upper Saunders	SW & WC	n/a	Tributary	n/a	77	23	1.5	77
S1-02	Upper Saunders	SW & WC	n/a	Tributary	n/a	13	18	1.5	13
S1-03	Upper Saunders	SW & WC	n/a	Tributary	n/a	13	15	1.5	13
S1-04	Upper Saunders	SW & WC	n/a	Tributary	n/a	4	11	1.5	4
S1-05	Upper Saunders	SW & WC	n/a	Tributary	n/a	12	7	1.5	12
S1-06	Upper Saunders	SW & WC	n/a	Tributary	n/a	4	7	1.5	4
S2-01	Upper Saunders	SW & WC	n/a	Tributary	n/a	38	17	1.5	38
S2-02	Upper Saunders	SW & WC	n/a	Tributary	n/a	19	16	1.5	19
S2-03	Upper Saunders	SW & WC	n/a	Tributary	n/a	13	16	1.5	13
S2-04	Upper Saunders	SW & WC	n/a	Tributary	n/a	9	15	1.5	9
S2-05	Upper Saunders	SW & WC	n/a	Tributary	n/a	9	15	1.5	9
S2-06	Upper Saunders	SW & WC	n/a	Tributary	n/a	5	15	1.5	5
S2-07	Upper Saunders	SW & WC	n/a	Tributary	n/a	16	11	1.5	16
S2-08	Upper Saunders	SW & WC	n/a	Tributary	n/a	10	10	1.5	10
S2-09	Upper Saunders	SW & WC	n/a	Tributary	n/a	7	11	1.5	7
S2-10	Upper Saunders	SW & WC	n/a	Tributary	n/a	5	9	1.5	5
S2-11	Upper Saunders	SW & WC	n/a	Tributary	n/a	11	11	1.5	11
S3	Lower Saunders	SW & WC	n/a	Tributary	n/a	37	5	1.5	37
S4	Lower Saunders	SW & WC	n/a	Tributary	n/a	24	5	1.5	24
S5	Lower Saunders	SW & WC	n/a	Tributary	n/a	11	4	1.5	11
S6	Lower Saunders	SW & WC	n/a	Tributary	n/a	7.8*	0	1.5	7.8*
S7	Upper Saunders	SW & WC	n/a	Main watercourse	n/a	See principle 65 b)	n/a	1.5	n/a**
S8	Lower Saunders	SW & WC	n/a	Main watercourse	n/a	See principle 65 b)	n/a	1.5	n/a**

Table 30 Radius of well buffer zones

Management zone(s)	Aquifer	Type of use	Radius of buffer zone (m)
Confined Zone A Confined Zone B	MGL[14] (confined)	Water allocation that can be taken with a volume of greater than or equal to 10 ML	1,000
		Water allocation that can be taken with a volume of less than 10 ML	500
		Non-licensed use and/or water (holding) allocation only	250
Unconfined Zone 1 Unconfined Zone 2 Unconfined Zone 3 Unconfined Zone 4 Unconfined Zone 5 Unconfined Zone 6 Exclusion Zone	MGL (unconfined)	Water allocation that can be taken with a volume of greater than or equal to 10 ML	200
		Water allocation that can be taken with a volume of less than 10 ML	100
		Non-licensed use and/or water (holding) allocation only	50
Quaternary Aquifer	Quaternary	Non-licensed use only	25
Renmark Group Aquifer	Renmark Group	Any	2,000
Fractured Rock Aquifer	Fractured rock	Any	200

[14] Murray Group Limestone

11.2 Policy maps

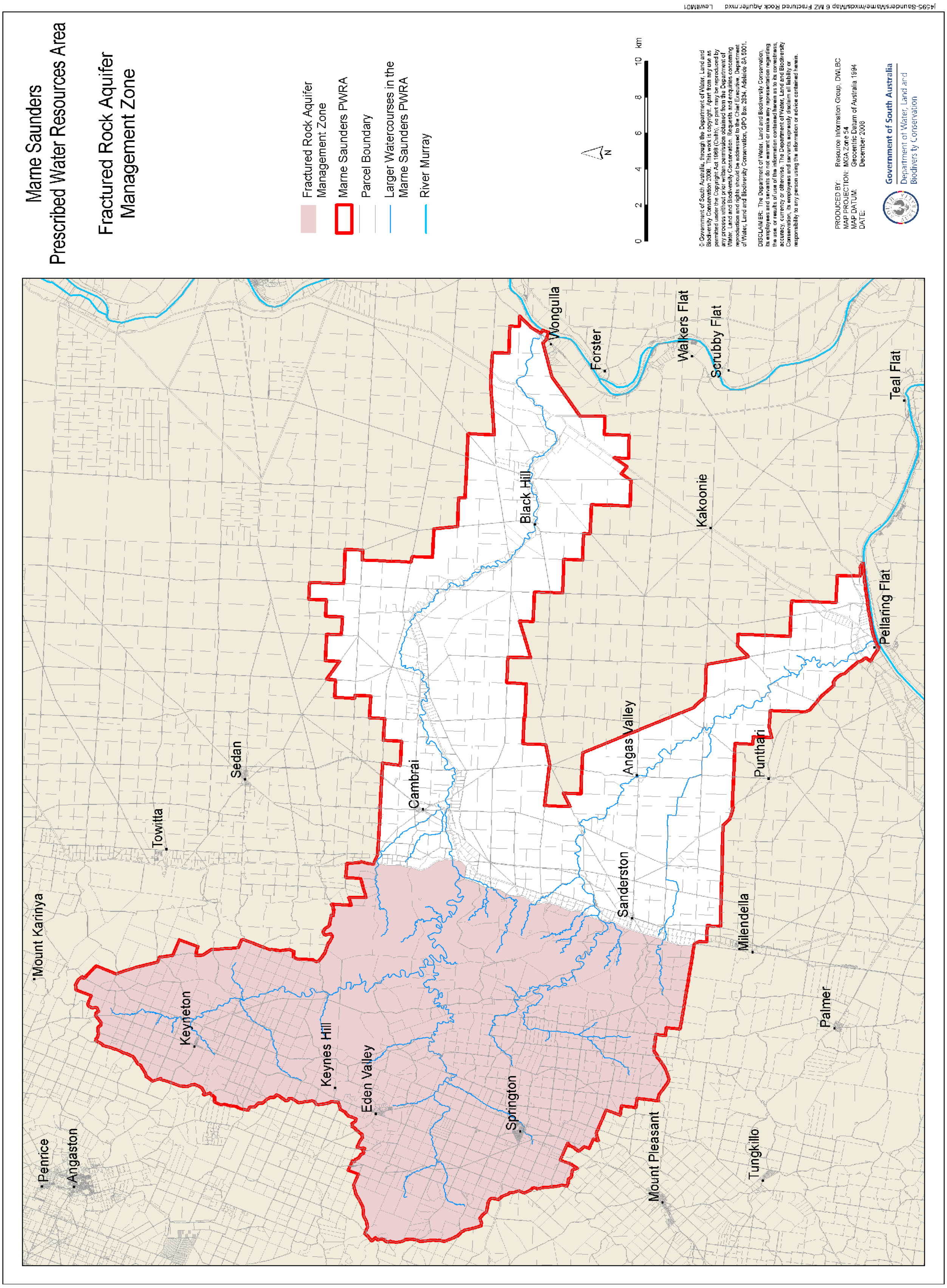


Figure 26 Marne Saunders PWRA Fractured Rock Aquifer Management Zone. This figure shows key features of GRO Plan 47/2008.

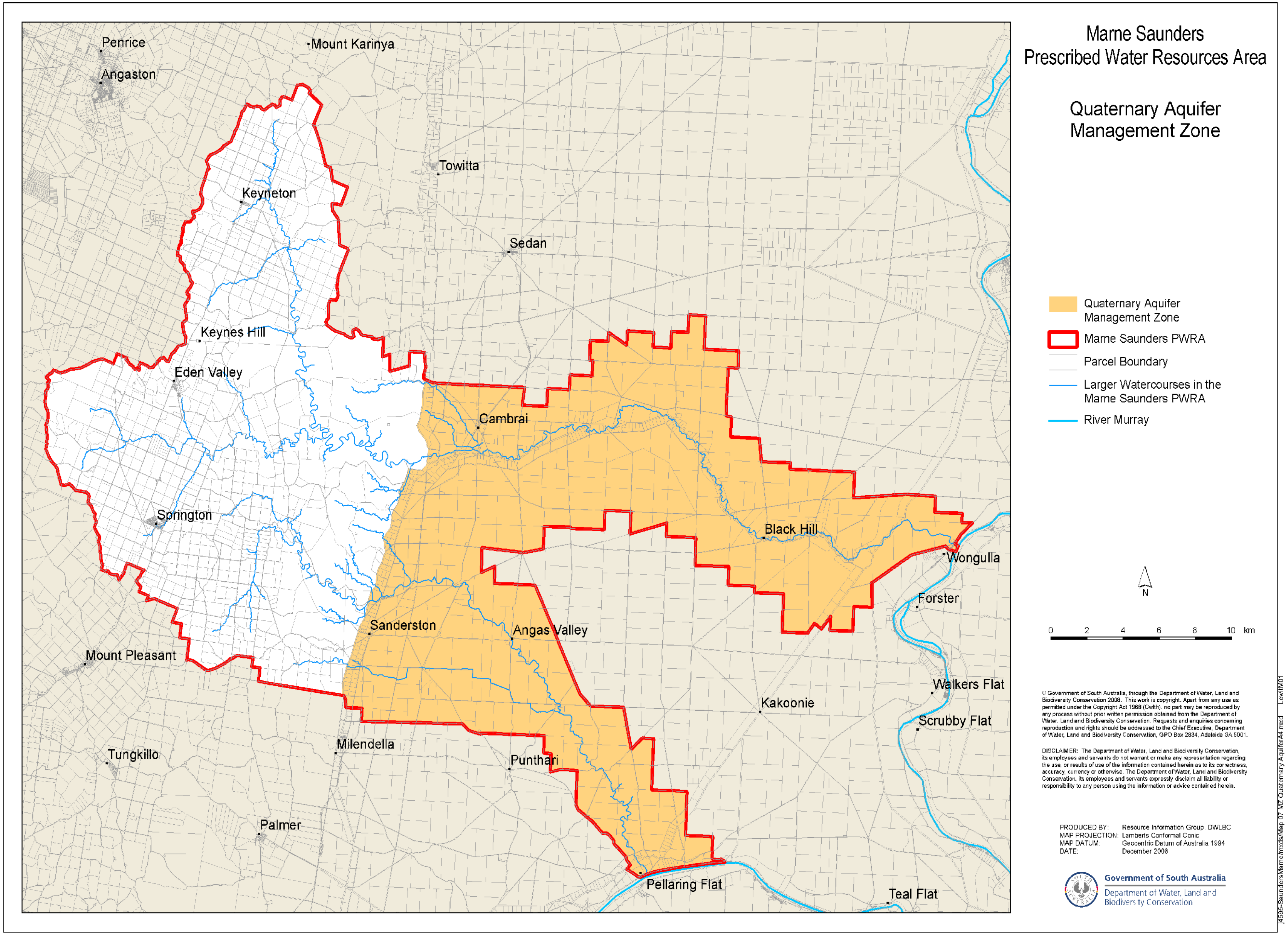


Figure 27 Marne Saunders PWRA Quaternary Aquifer Management Zone. This figure shows key features of GRO Plan 48/2008.

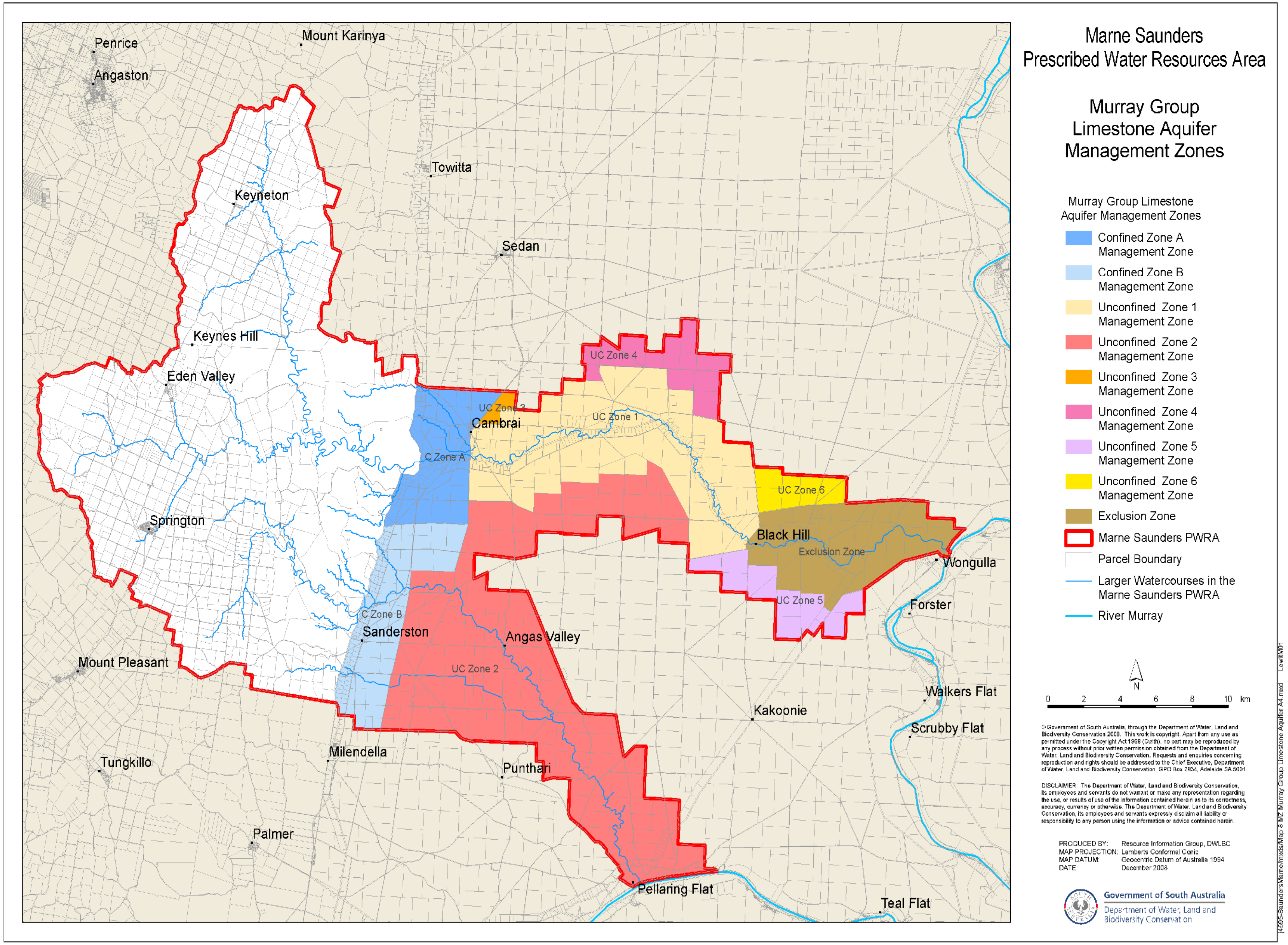


Figure 28 Marne Saunders PWRA management zones in the Murray Group Limestone aquifer. This figure shows key features of GRO Plan 49/2008.

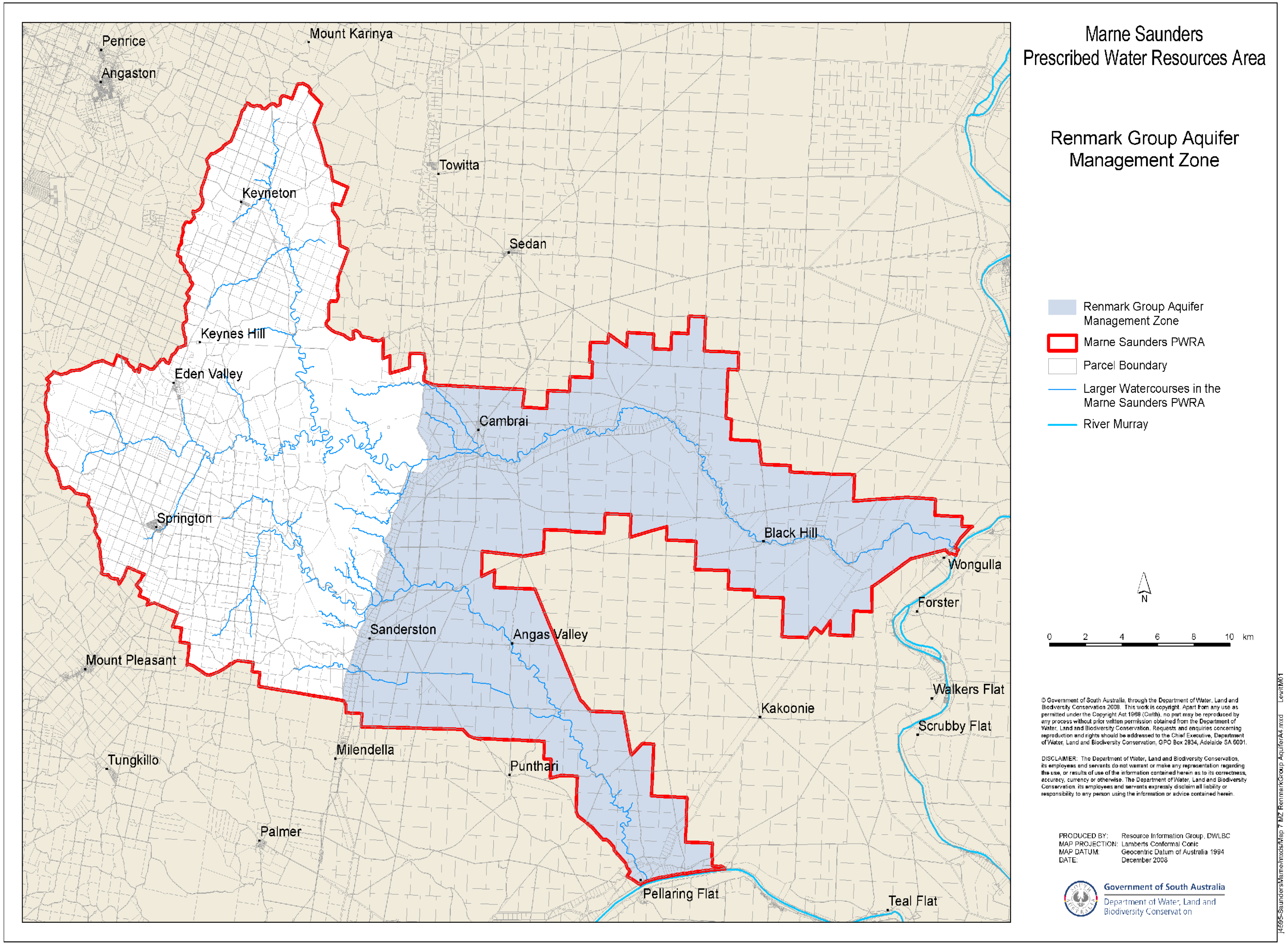


Figure 29 Marne Saunders PWRA Renmark Group Aquifer Management Zone. This figure shows key features of GRO Plan 50/2008.

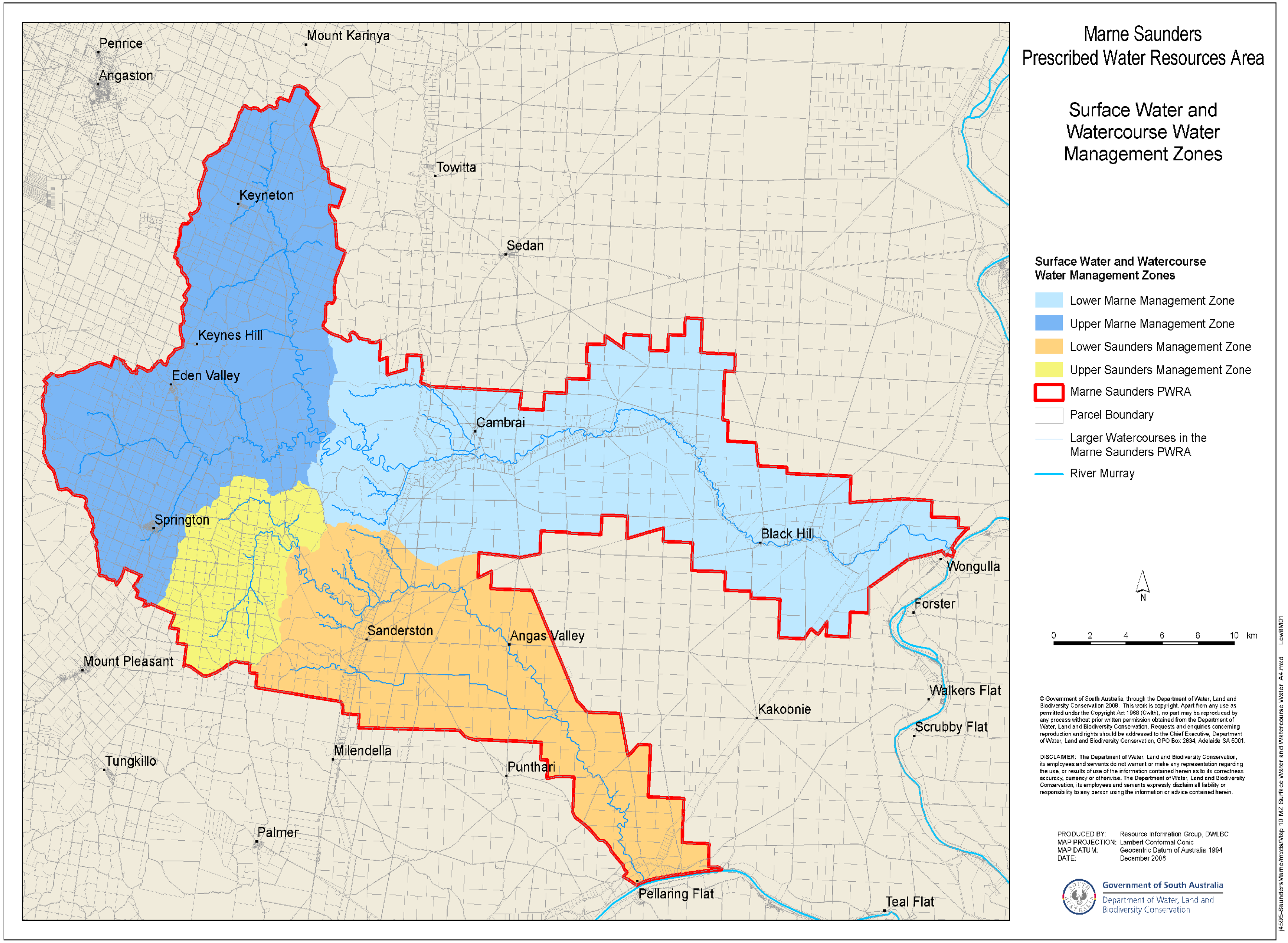


Figure 30 Marne Saunders PWRA management zones (surface water and watercourse water). This figure shows key features of GRO Plan 51/2008.

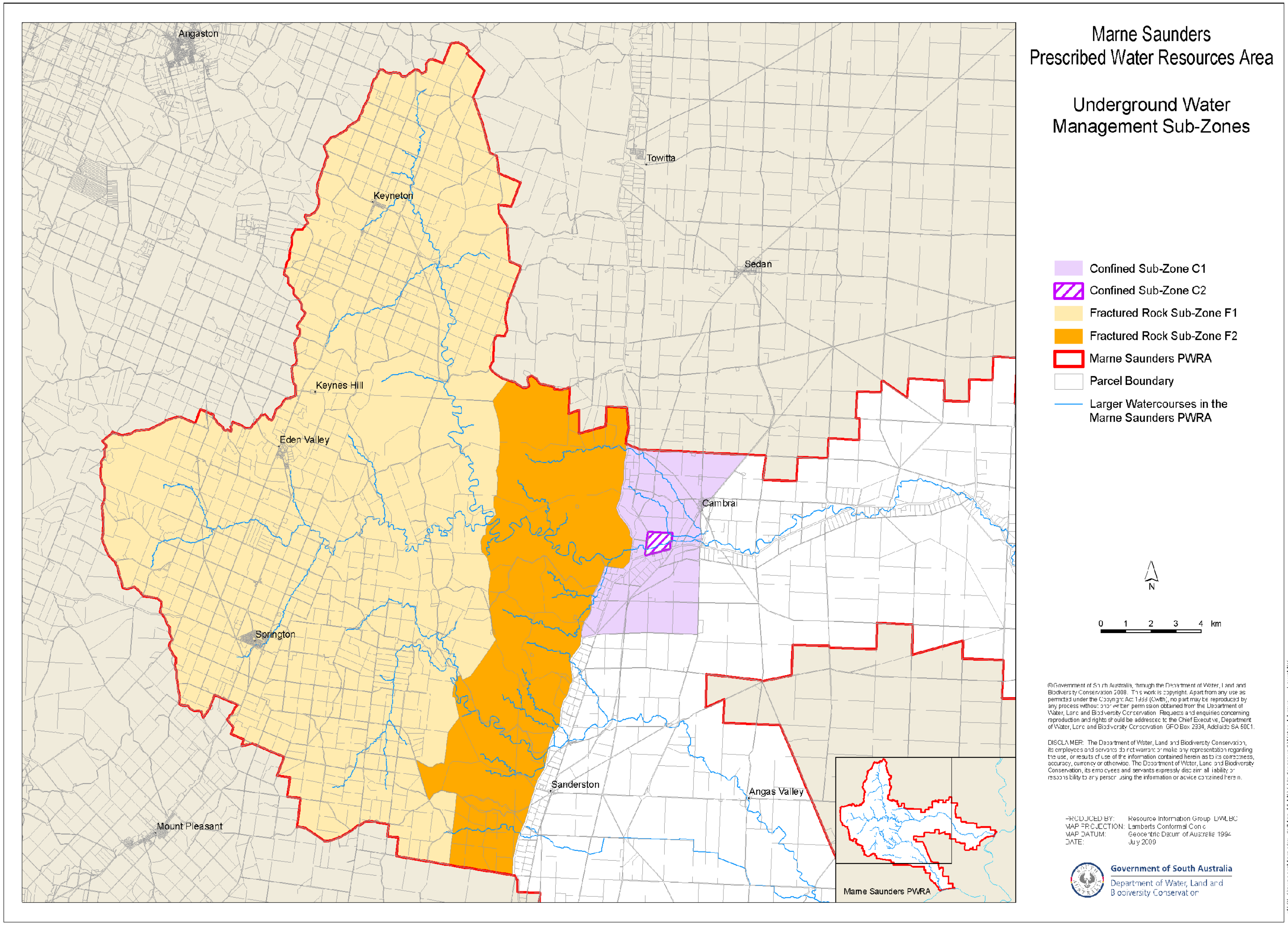


Figure 31 Marne Saunders PWRA management sub-zones (underground water). This figure shows key features of GRO Plan 28/2009.

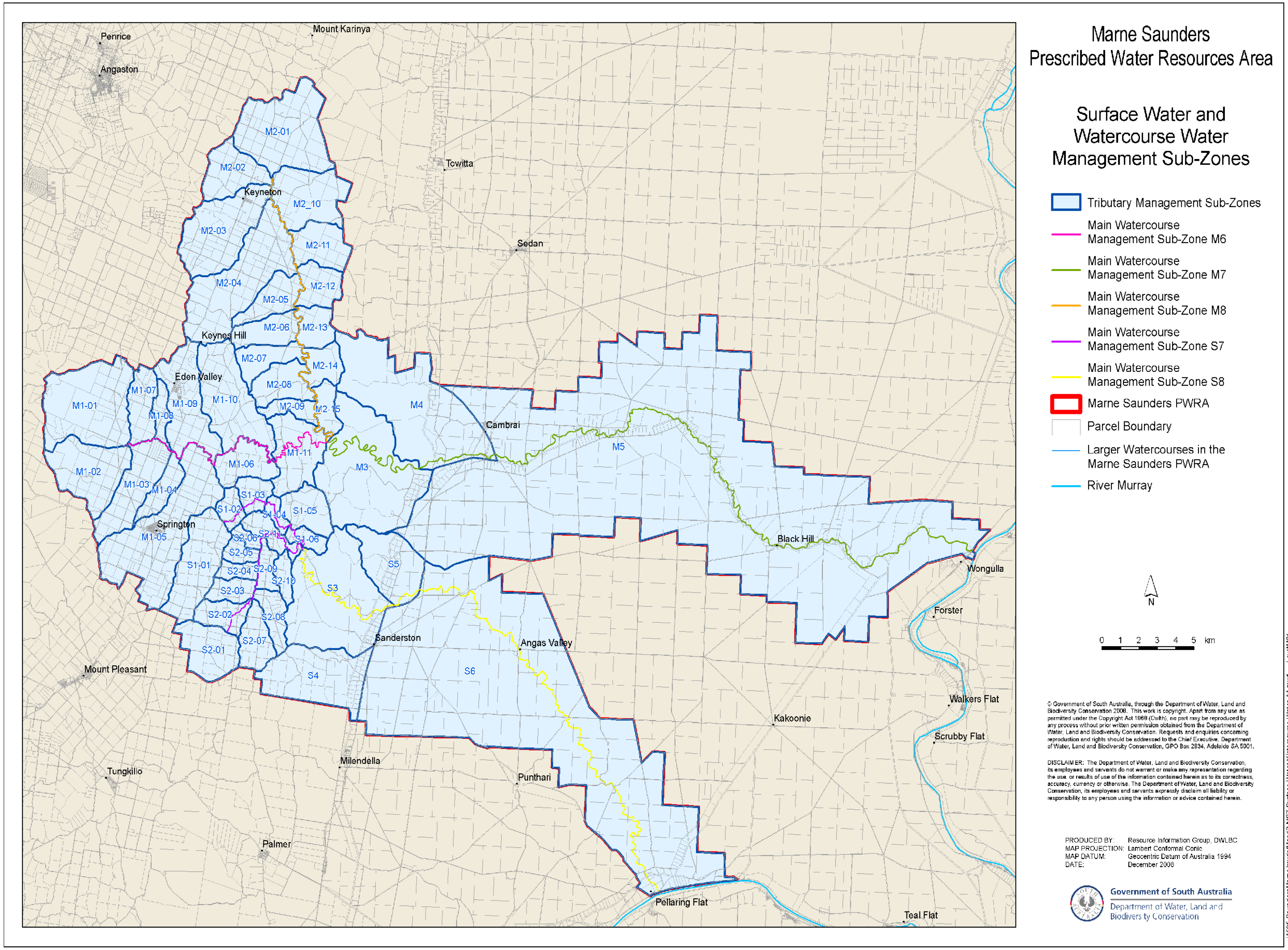


Figure 32 Marne Saunders PWRA management sub-zones (surface water and watercourse water). This figure shows key features of GRO Plan 1/2009.

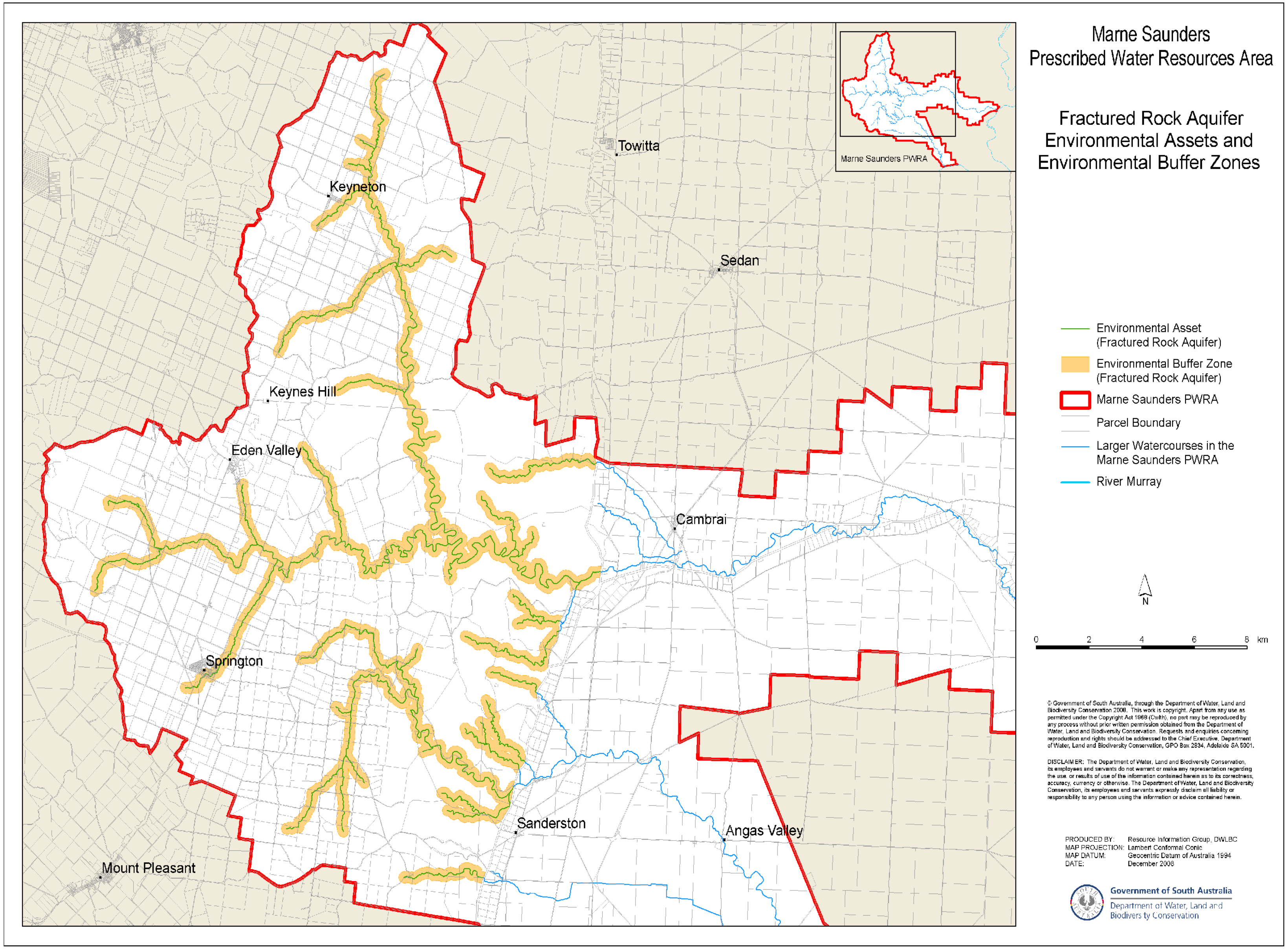


Figure 33 Marne Saunders PWRA environmental assets and environmental buffer zones (fractured rock aquifer). This figure shows key features of GRO Plan 54/2008.

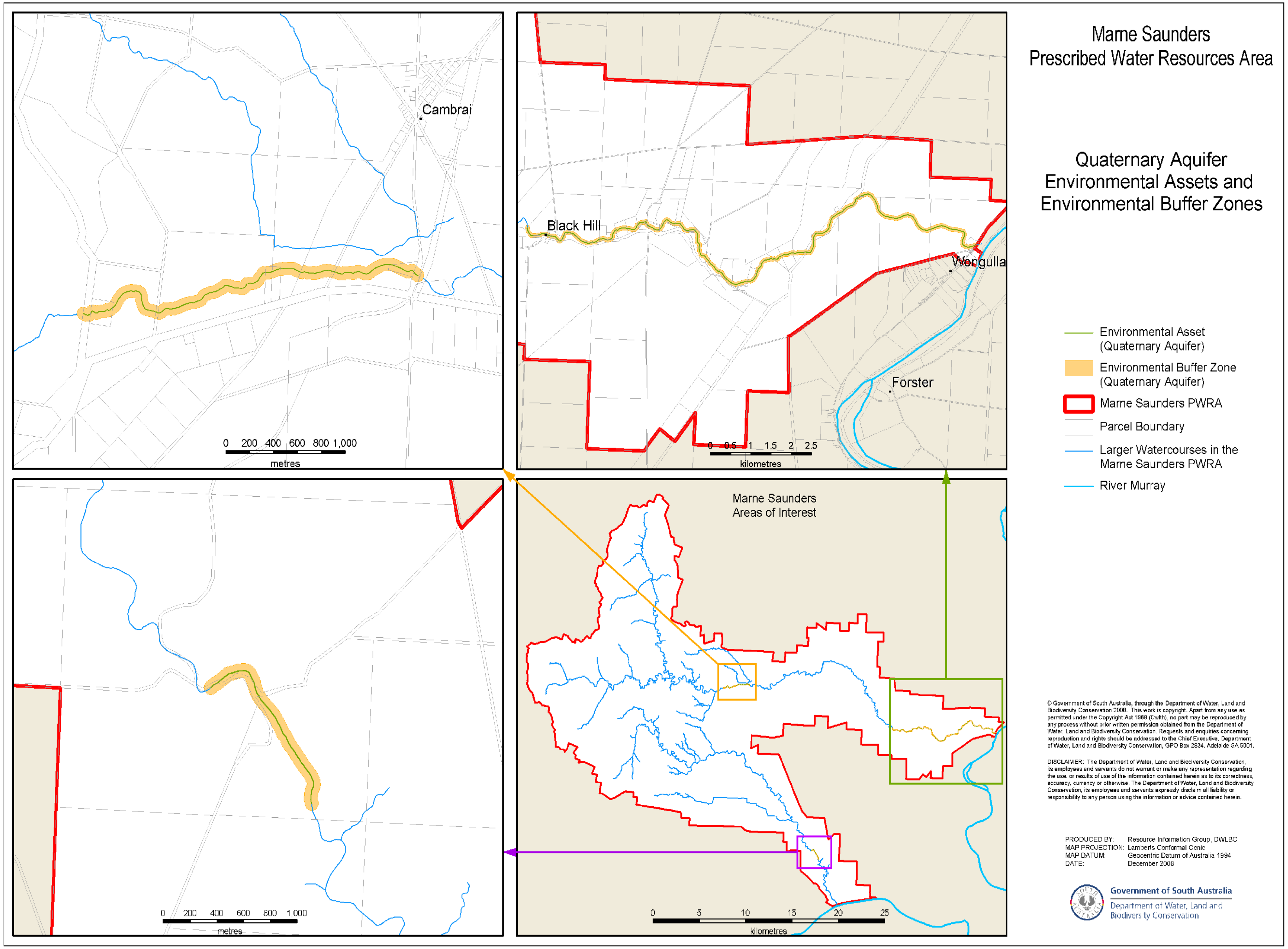


Figure 34 Marne Saunders PWRA environmental assets and environmental buffer zones (Quaternary aquifer). This figure shows key features of GRO Plan 55/2008.

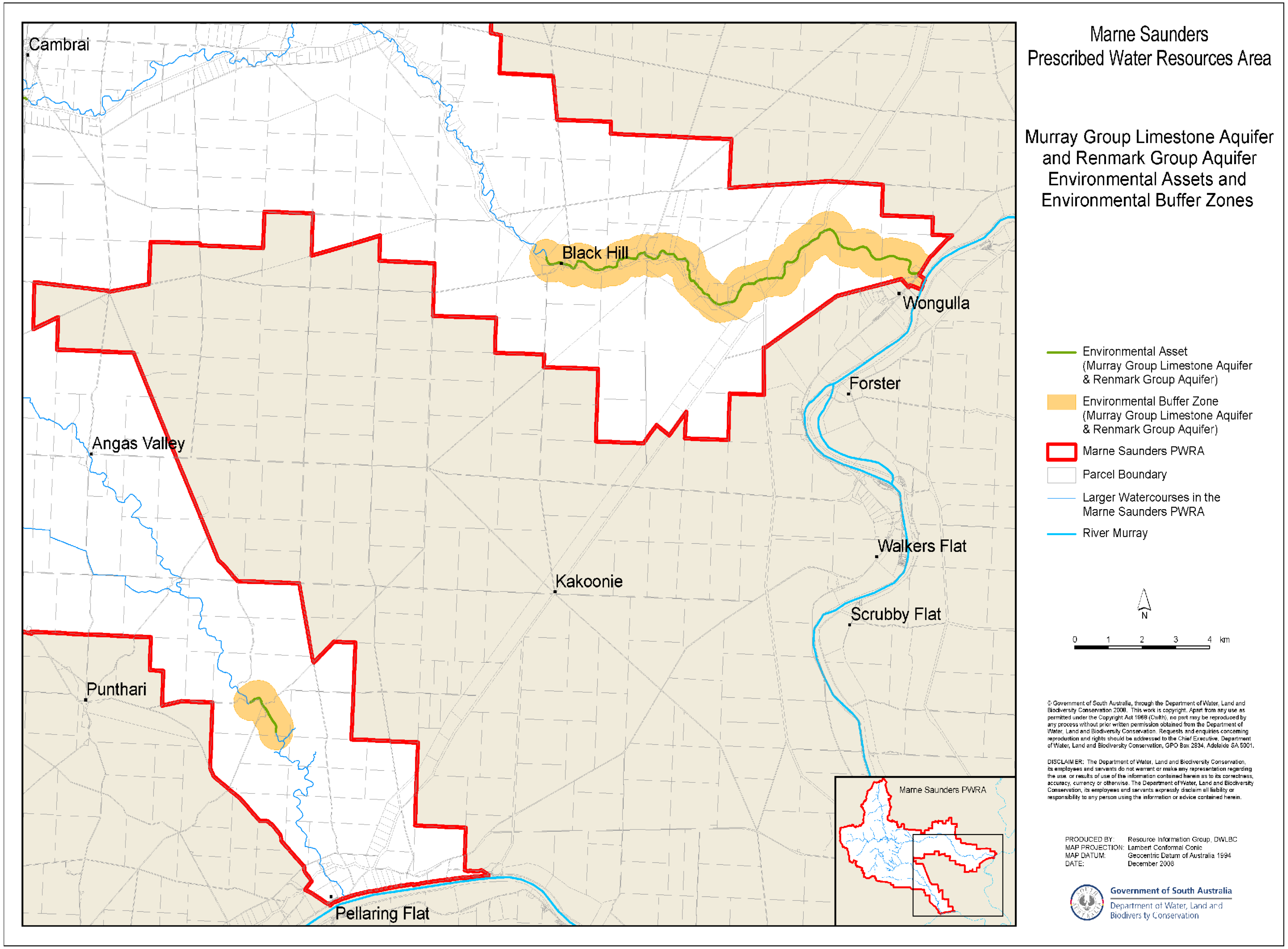


Figure 35 Marne Saunders PWRA environmental assets and environmental buffer zones (Murray Group Limestone aquifer and Renmark Group aquifer). This figure shows key features of GRO Plan 56/2008.

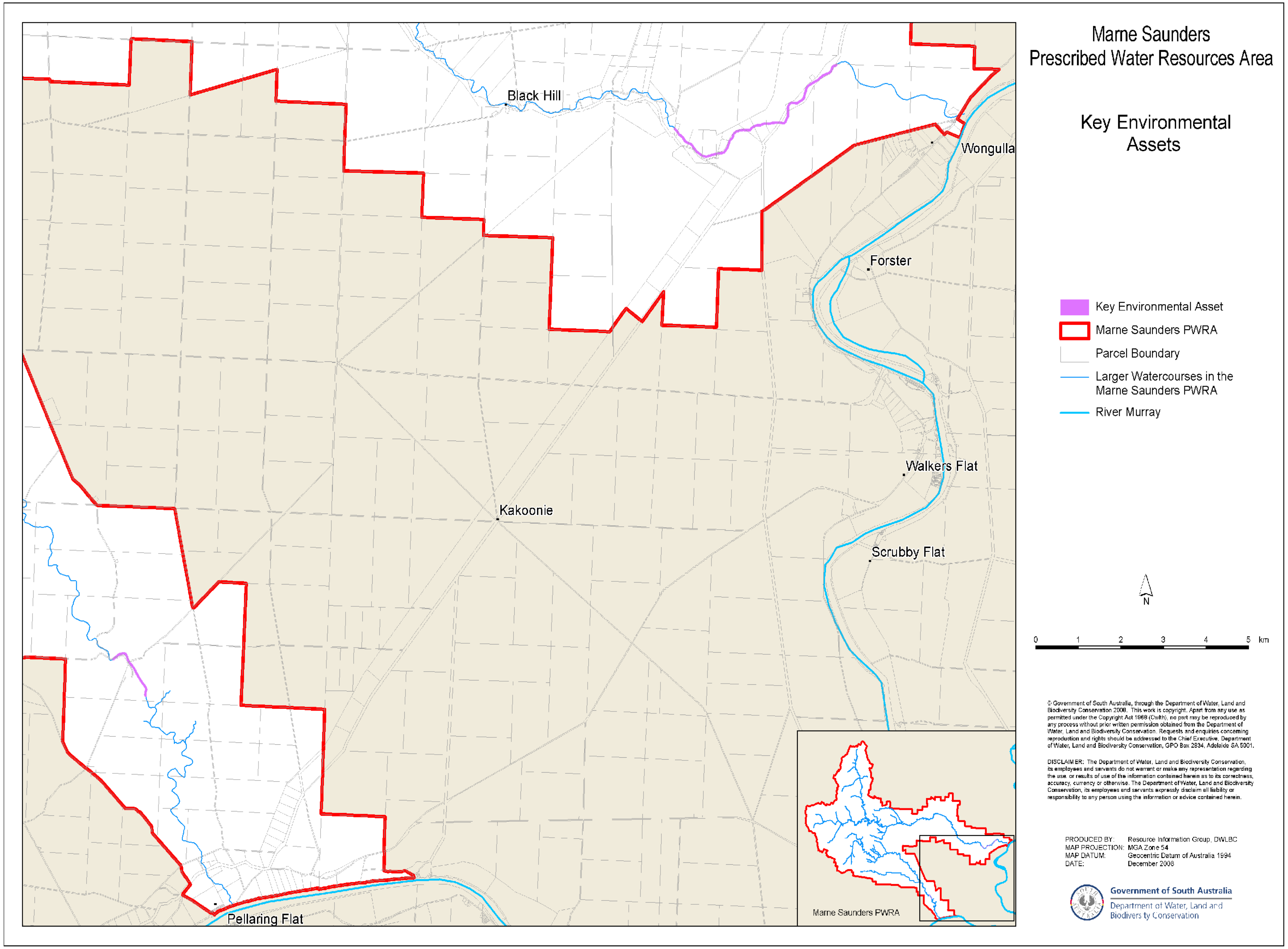


Figure 36 Marne Saunders PWRA key environmental assets. This figure shows key features of GRO Plan 58/2008.

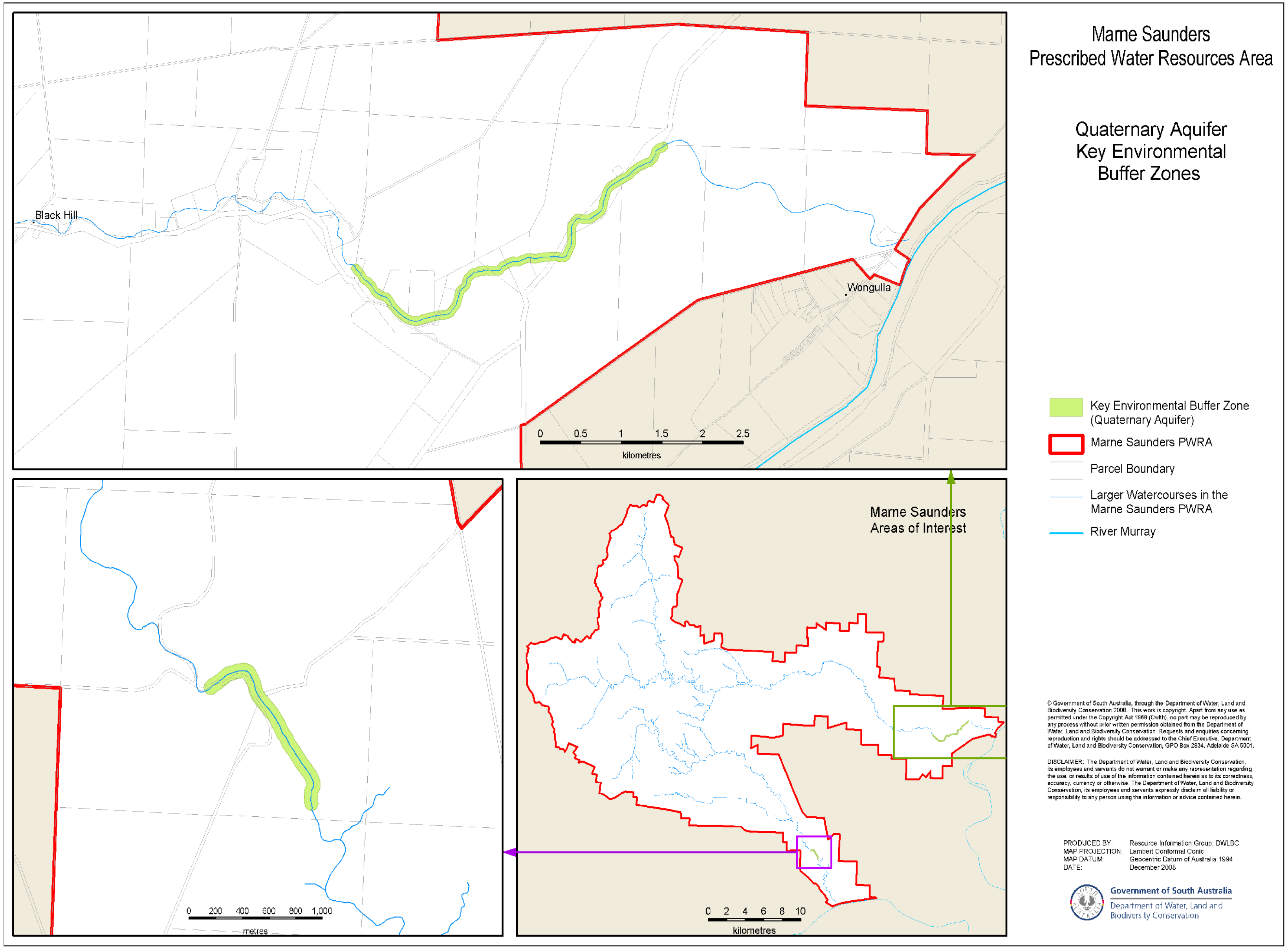


Figure 37 Marne Saunders PWRA key environmental buffer zones (Quaternary aquifer). This figure shows key features of GRO Plan 60/2008.

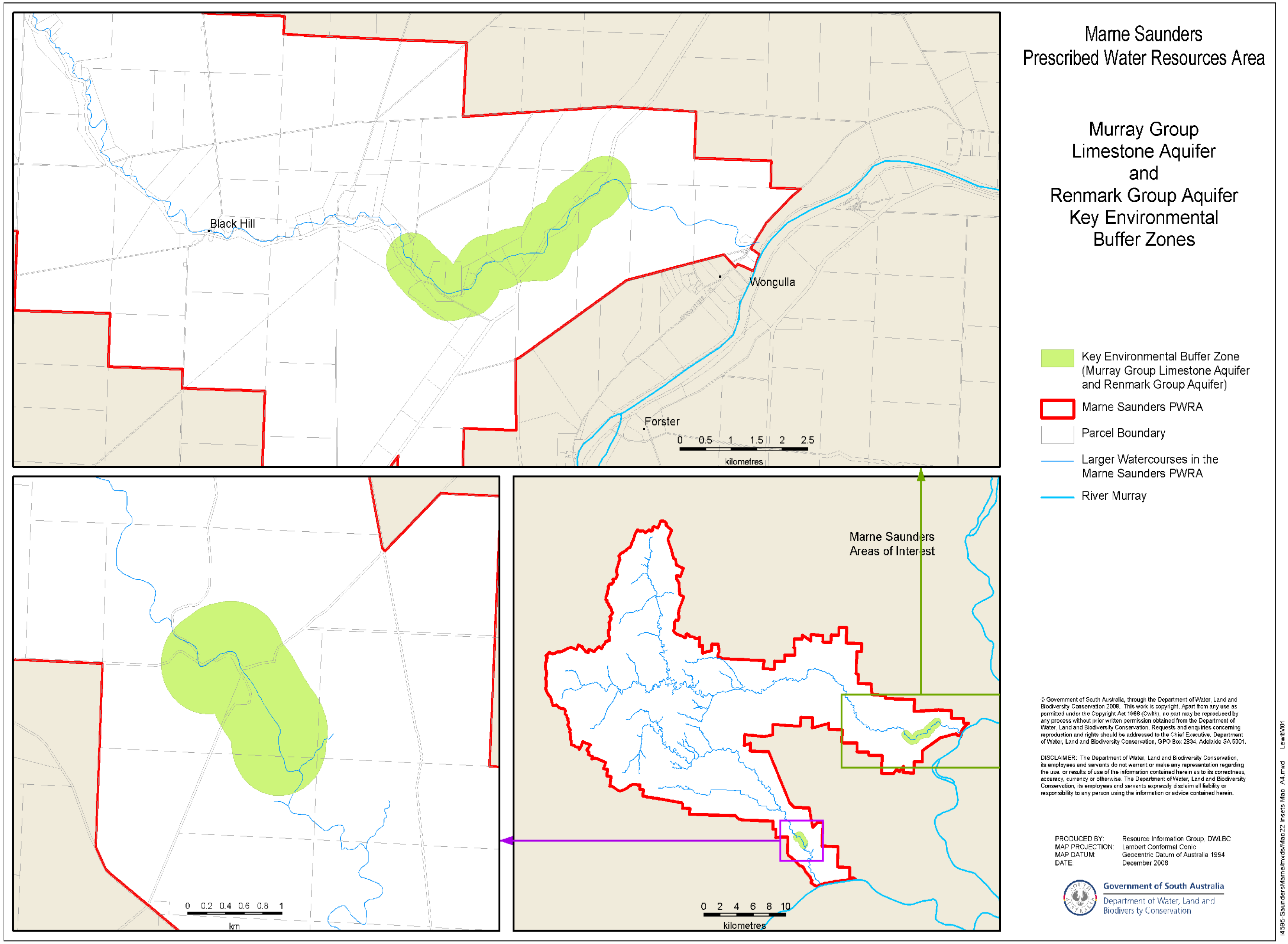


Figure 38 Marne Saunders PWRA key environmental buffer zones (Murray Group Limestone aquifer and Renmark Group aquifer). This figure shows key features of GRO Plan 61/2008.

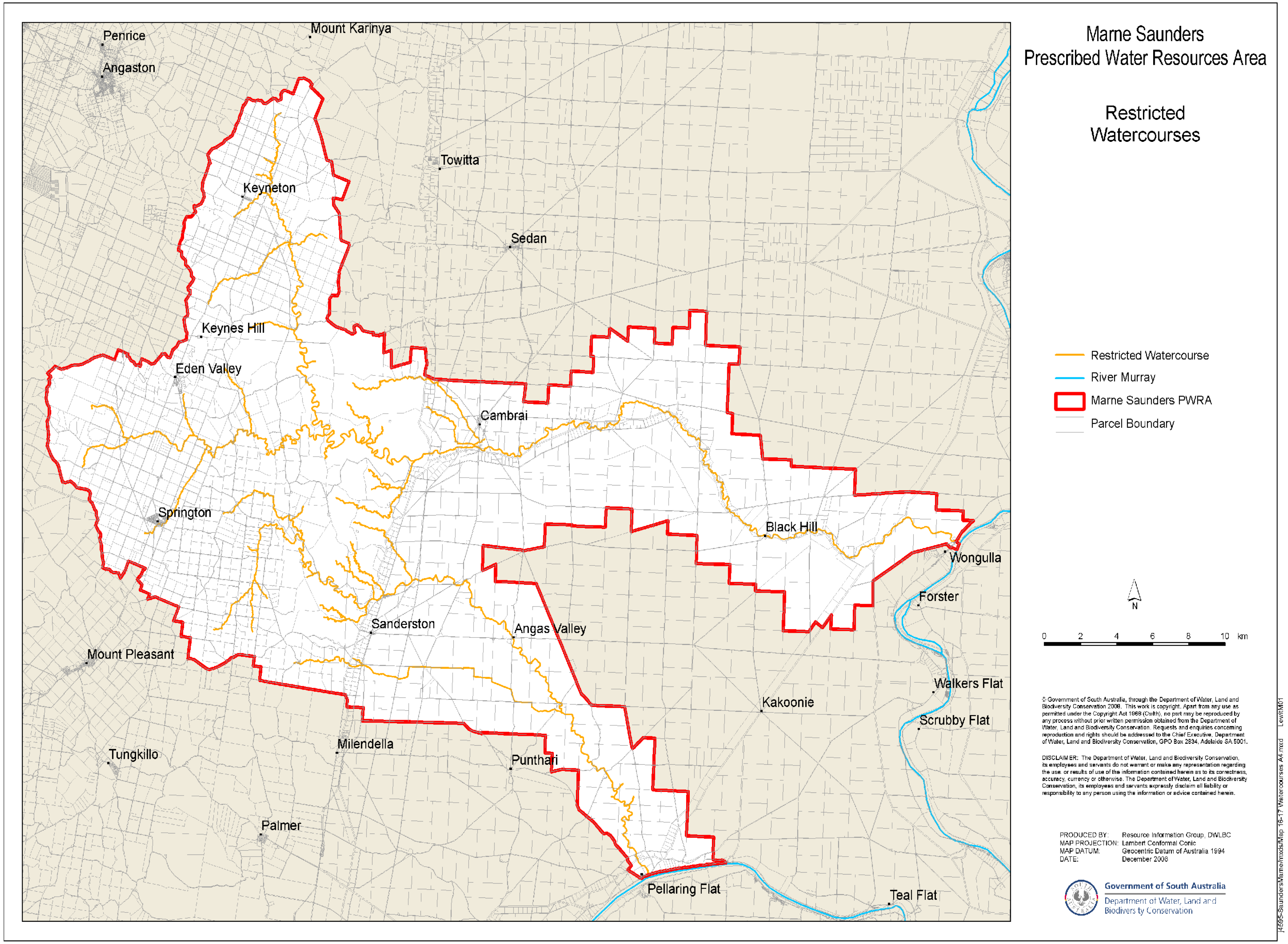


Figure 39 Marne Saunders PWRA restricted watercourses. This figure shows key features of GRO Plan 3/2009.

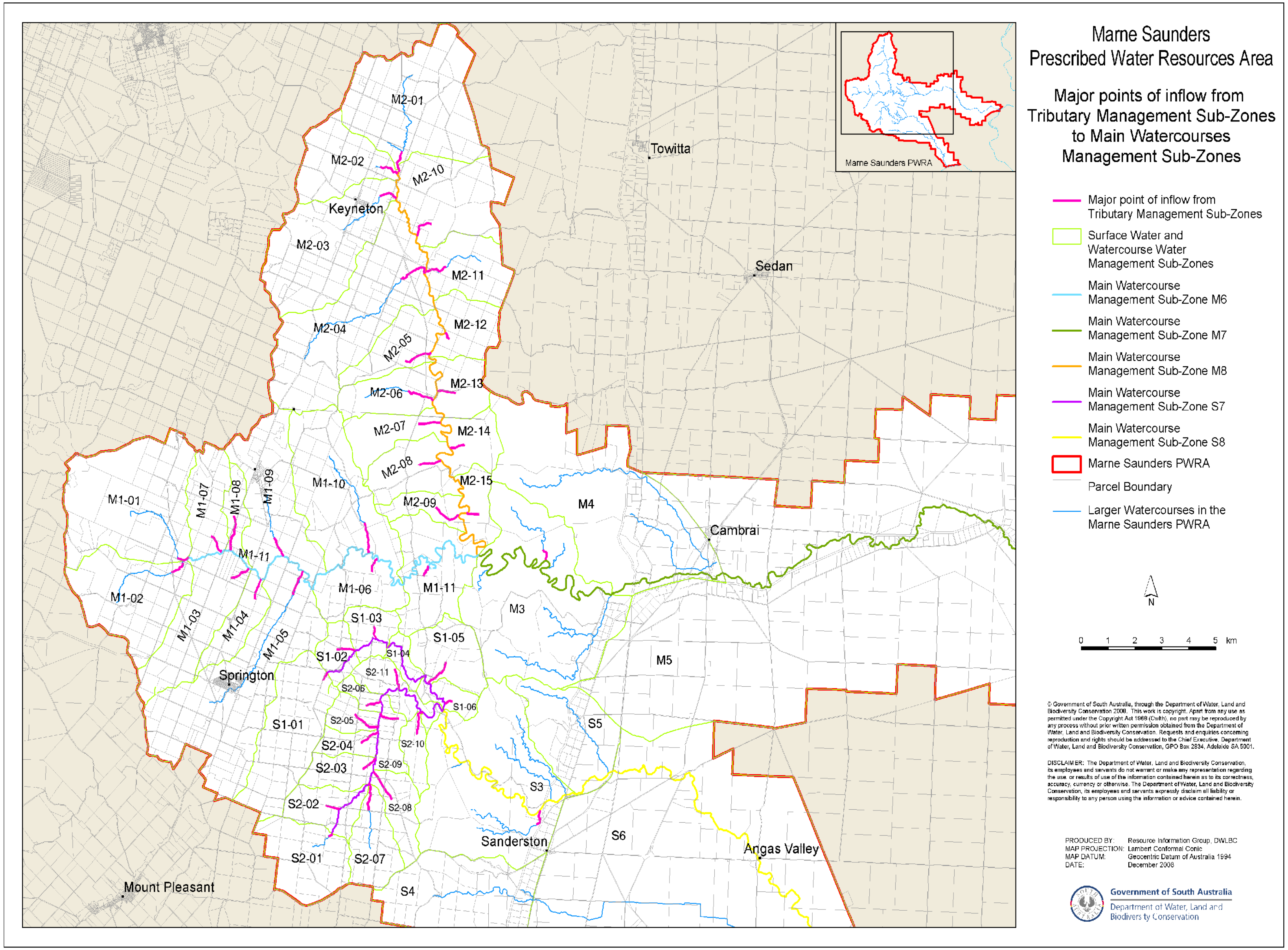


Figure 40 Major points of inflow from tributary management sub-zones to main watercourse management sub-zones. This figure shows key features of GRO Plan 2/2009.

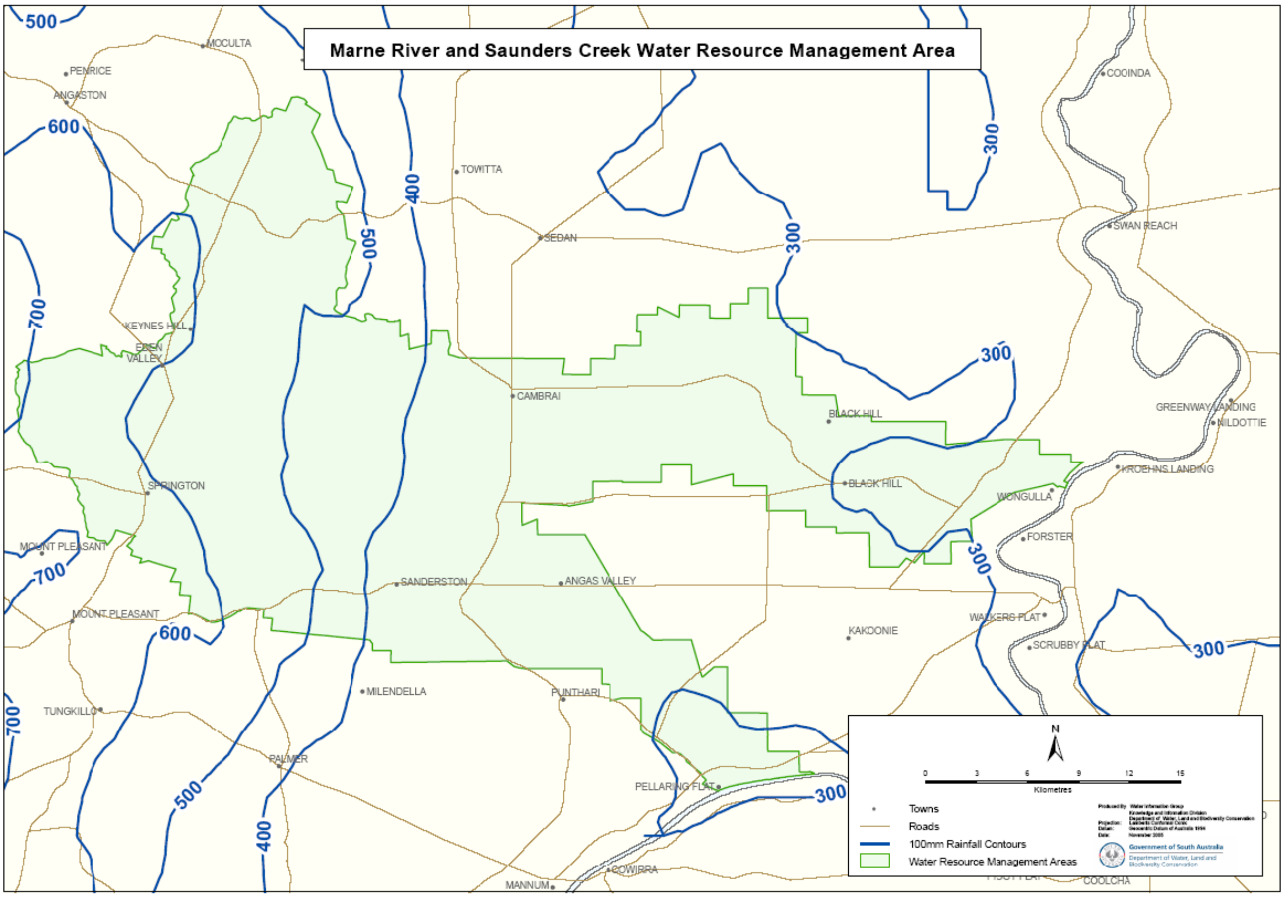


Figure 41 Average annual rainfall in the Marne River and Saunders Creek Water Resource Management Area.
Reproduction of Attachment 5 from with the Notice of Authorisation to take water in the *South Australian Government Gazette*, 16 March 2006, pages 906 - 912.

11.3 Commonly used abbreviations, acronyms and symbols

AS....................Australian Standard
DEW.................Department for Environment and Water
DEWNR............Department of Environment, Water and Natural Resources (former)
DWLBC.............Department of Water, Land and Biodiversity Conservation (former)
EPA..................Environment Protection Authority
GRO.................General Registry Office
ILUA..................Indigenous land use agreement
kL......................Kilolitre (1,000 litres)
km.....................Kilometre
km^2...................Square kilometre
L/s.....................Litres per second
m......................Metre
MACAI..............Mannum Aboriginal Community Association Incorporated
MAR..................Managed aquifer recovery
MGL..................Murray Group Limestone
Minister, the......The Minister responsible for the administration of the NRM Act
ML....................Megalitre (1,000,000 litres)
MSZ..................Management sub-zone
MSZ AL.............Management sub-zone allocation limit
MSZ CUL..........Management sub-zone consumptive use limit
MSZ DCL..........Management sub-zone dam capacity limit
MZ....................Management zone
MZ AL...............Management zone allocation limit
MZ DCL............Management zone dam capacity limit
MZ LDCT..........Management zone long-term dam capacity target
MTER...............Maximum theoretical enterprise requirement
N.......................Nitrogen
NATA...............National Association of Testing Authorities
NNAC...............Ngadjuri Nation Aboriginal Corporation
NRA..................Ngarrindjeri Regional Authority
NRM.................Natural Resources Management
NRM Act...........*Natural Resources Management Act 2004*
NTU..................Nephelometric Turbidity Unit
P.......................Phosphorus
Plan, the...........The Water Allocation Plan for the Marne Saunders Prescribed Water Resources Area
PWRA...............Prescribed Water Resources Area
SA MDB NRMB. South Australian Murray–Darling Basin Natural Resources Management Board
SW....................Surface water
SWL..................Standing water level
TDS..................Total dissolved solids
UGW.................Underground water
WC....................Watercourse water
WDE.................Water-dependent ecosystem
WR Act.............*Water Resources Act 1997*

11.4 Definitions and glossary

Terms used in sections 6 - 8 that are defined in the NRM Act shall have the definitions set out in the NRM Act. In addition, the following terms shall have the definitions set out below.

Term	Definition
Aboriginal	The term “Aboriginal” is used throughout this Plan instead of “Indigenous” as endorsed by the former SA Aboriginal State-wide Advisory Committee. “Aboriginal nations” is used throughout the Plan and is defined for the purposes of the Plan as a group or community of Aboriginal people who identify as descendants of the original inhabitants of the Plan area and may share a single common territory, or it may be located as a nation within another larger nation. The Aboriginal nation may include the native title holder or claimant body. All decisions and consultations about native title matters that impact on the Plan must be done with the native title body. An ILUA may provide that the native title holder or claimant is acknowledged as representing the nation on all matters dealt within the ILUA over all land and water within the ILUA area. Otherwise the representative body of the nation will be a body that demonstrates that it represents the members of the nation that hold the authority and responsibility with respect to Aboriginal culture and heritage for the specified area.
Aboriginal cultural heritage	Means Aboriginal objects, Aboriginal remains and Aboriginal sites that are protected under the *Aboriginal Heritage Act 1988*. It is an offence to damage, disturb or interfere with Aboriginal sites, objects or remains without the authorisation of the Minister or agreement of the Registered Aboriginal Representative Body. An Aboriginal object: means an object— (a) of significance according to Aboriginal tradition; or (b) of significance to Aboriginal archaeology, anthropology or history, and includes an object or an object of a class declared by regulation to be an Aboriginal object but does not include an object or an object of a class excluded by regulation from the ambit of this definition. Aboriginal remains: means the whole or part of the skeletal remains of an Aboriginal person but does not include remains that have been buried in accordance with the law of the State. An Aboriginal site: means an area of land— (a) that is of significance according to Aboriginal tradition; or (b) that is of significance to Aboriginal archaeology, anthropology or history, and includes an area or an area of a class declared by regulation to be an Aboriginal site but does not include an area or an area of a class excluded by regulation from the ambit of this definition.
Aboriginal Water Interest	Is used to describe native title rights and interests or other uses of water that are currently permitted under the NRM Act. It also includes aspirations to other legal interests in water that are not currently permitted under existing law including to the “cultural flow” as a separate and distinct entitlement. The term also describes the outcomes and objectives to the use and management of water that accords with the social, cultural and spiritual values of Aboriginal people as expressed by them.
Allotment	Has the same meaning as in the *Real Property Act 1886*.
Ambient underground water	The underground water that is present in the relevant aquifer, and may be the native underground water or mixed underground water.

Term	Definition
Aquifer	A saturated geological material that, when drilled into, can yield a useable quantity of underground water. Confined aquifer: An aquifer that is bound above and below by an impermeable confining bed. The pressure in a confined aquifer is usually greater than atmospheric pressure, resulting in water levels in wells rising above the top of the aquifer. Fractured rock aquifer: An aquifer where underground water is stored and moves through joints and fractures in the rocks. Sedimentary aquifer: An aquifer where underground water flows through the pore spaces within the sediments. Unconfined aquifer: An aquifer which has the watertable as its upper surface and which may be recharged directly by infiltration from the ground surface.
Artificial recharge allocation	An allocation granted in accordance with section 6.4.
Average adjusted winter runoff	The average depth or volume (as appropriate) of water modelled to run off an area from May to November under the “no dams” modelling scenario.
Baseflow	Water in a stream that results from underground water discharge to the stream. This discharge often maintains flows during seasonal dry periods and has important ecological functions.
Base water allocation	A water allocation that is not a water (holding) allocation, a rollover allocation or an artificial recharge allocation.
Catchment area	The catchment area of a particular point means all of the land, determined by natural topographic features, from which runoff has potential to naturally flow to that point.
Complying activity	A water affecting activity that does not require a water affecting activities permit because it meets all of the principles in section 8.1.
Connected roof area	The area of roof that drains (usually through gutters and downpipes) to water storage facilities. Where there are multiple connected roof areas on a property, the connected roof area for the property is the total of all connected roof areas for that property.
Consumptive use	In general, consumptive use is the use of water for private benefit consumptive purposes including irrigation, industry, urban and stock and domestic use. For the purposes of the principles of this Plan, consumptive use (CU) is the volume of surface water and watercourse water (excluding roof runoff (surface water)) estimated to be taken for consumptive purposes from a given area or location, determined in accordance with principle 63 f).
Credit year	The water use year in which not all of a base water allocation was taken, potentially giving rise to a rollover credit and/or a rollover allocation.

Term	Definition
Cultural flows	Described in paragraphs 30-31 of schedule 1 of the Murray–Darling Basin Plan. Indigenous uses includes use for cultural, social, environmental, spiritual and economic purposes. Many Indigenous people view water spiritually – people, land and rivers are inextricably connected. Indigenous economic interests include trading, hunting, gathering food and other items that alleviate the need to purchase similar items and the use of water to support businesses in industries such as pastoralism and horticulture. The environmental and cultural health of the Murray–Darling Basin is of paramount importance in serving these interests. The concept of cultural flows helps translate the complex relationship described above into the language of water planning and management. The following definition of cultural flows is currently used by the Northern Murray–Darling Basin Aboriginal nations and the Murray Lower Darling Rivers Indigenous nations: — Water entitlements that are legally and beneficially owned by the Indigenous nations and are of sufficient and adequate quantity to improve the spiritual, cultural, environmental, social and economic conditions of those Indigenous nations. This is our inherent right. — The provision of cultural flows will benefit Indigenous people in improving health, wellbeing and provides empowerment to be able to care for their country and undertake cultural activities.
Dam	A dam including but not limited to an off-stream dam and a turkey nest dam, but excluding turkey nest dams that only store water other than prescribed surface water and/or watercourse water from the Marne Saunders PWRA.
Dam – off-stream dam	A dam that is not constructed across a watercourse and is primarily designed to hold water from a source other than the catchment area of the dam. Other water sources may include, but are not limited to, underground water and water diverted or pumped from a watercourse and/or flow path that is not in the catchment area of the dam. Off-stream dams may capture a limited volume of surface water from the natural catchment area of the dam (up to 5% of its total capacity, determined on the basis of average adjusted winter runoff from the catchment area upstream of the dam).
Dam – turkey nest dam	An off-stream dam that does not capture any surface water from the catchment area upstream of the dam.
Date of adoption	The date that this Plan was adopted.
Diadromous	Species that travel between salt and fresh water.
Diversion structure	A dam, wall or other structure, object or device that will collect or divert water flowing in a watercourse or surface water flowing over land, including but not limited to a dam, weir, levee or pump.
Drawdown	A reduction in water level and/or pressure level in an aquifer as a result of the taking of underground water from that aquifer.
Ecosystem	A community of organisms, which may include humans, interacting with one another and including the physical, chemical and biological processes inherent in their interaction and the environment in which they live.
Engagement	Aboriginal 'engagement' is defined as any process that involves Aboriginal people in problem solving or decision making and uses community input to make better decisions (Commonwealth of Australia, 2016)

Term	Definition
Environmental asset	For the purposes of this Plan an environmental asset is a section of watercourse that supports water-dependent ecosystems that interacts with or is linked to a particular underground water aquifer. Environmental assets are marked with a green line in GRO Plans 54/2008, 55/2008 and 56/2008, with these plans indicating the aquifer that each asset is linked to. Figure 33, Figure 34 and Figure 35 respectively show key features of these plans at a reduced scale.
Environmental buffer zone	An environmental buffer zone is an area radiating from an environmental asset, and is linked to an aquifer or aquifers. The environmental buffer zones and the aquifers that they are linked to are shown in GRO Plans 54/2008, 55/2008 and 56/2008. Figure 33, Figure 34 and Figure 35 respectively show key features of these plans at a reduced scale.
Environmental stress limit	For the purposes of this Plan, the environmental stress limit means achieving a moderate or better environmental stress rating for all flow metrics, where the flow metrics and environmental stress ratings are described in section 3.6.
Environmental water provisions	Those parts of environmental water requirements that can be met at any given time. This is what can be provided at that time with consideration of existing users' rights, social and economic impacts.
Environmental water requirements	The water regime needed to sustain the ecological values of aquatic ecosystems, including their processes and biological diversity, at a low level of risk.
Extra safety net allocation	A particular type of allocation granted to an existing user pursuant to the Natural Resources Management Act (Marne Saunders Prescribed Water Resources Area- Reduction in Water Access Entitlements) Regulations 2009. These regulations grant existing users of surface water and watercourse water an allocation based on the lesser of their maximum theoretical enterprise requirements, dam capacity (where relevant), available runoff to their diversion structure, or share of the water available for licensed use within their management sub-zone consumptive use limit. Where the volume of this allocation is less than 50% of the maximum theoretical enterprise requirements (MTER), then the regulations provide that the existing user will be allocated 50% of MTER or their dam capacity (whichever is less). In this Plan, that allocation is referred to as the ***safety net allocation,*** comprised of two parts, being: • ***Foundation allocation*****:** the volume the existing user would have received if there was no safety net allocation (as described above); and • ***Extra safety net allocation*****:** the safety net allocation minus the foundation allocation.
Flow path	The natural preferential path or direction of surface water flow.

Term	Definition
Foundation allocation	A particular type of allocation granted to an existing user pursuant to the Natural Resources Management Act (Marne Saunders Prescribed Water Resources Area- Reduction in Water Access Entitlements) Regulations 2009. These regulations grant existing users of surface water and watercourse water an allocation based on the lesser of their maximum theoretical enterprise requirements, dam capacity (where relevant), available runoff to their diversion structure, or share of the water available for licensed use within their management sub-zone consumptive use limit. Where the volume of this allocation is less than 50% of the maximum theoretical enterprise requirements (MTER), then the regulations provide that the existing user will be allocated 50% of MTER or their dam capacity (whichever is less). In this Plan, that allocation is referred to as the ***safety net allocation,*** comprised of two parts, being: • ***Foundation allocation*****:** the volume the existing user would have received if there was no safety net allocation (as described above); and • ***Extra safety net allocation*****:** the safety net allocation minus the foundation allocation.
Fresh	Relatively short duration high flow events that remain within the stream channel.
Hydrogeology	The study of the underground water, which includes its occurrence, recharge and discharge processes and the properties of aquifers.
Hydrologically continuous	Two or more points on the landscape directly connected by the same flow path or watercourse.
Hydrology	The study of the characteristics, occurrence, movement and utilisation of water on and below the earth's surface and within its atmosphere.
Hyporheic fauna	Animals that are specialised for living in the wetted interstitial zone among sediments below and alongside rivers.
Indigenous land use agreement (ILUA)	A voluntary statutory agreement between a native title group or holder and the government made pursuant to Division 3 Subdivision of the *Native Title Act 1993* (Cth). Once registered an ILUA allows for the application of certain parts of the *Native Title Act 1993* (Cth) to be modified, for example the processes and effects of the future act provisions. It can also provide for compensation for extinguishment of native title and provide for the exercise of native title rights and interests.
Intensive farming	Has the same meaning as in the NRM Act, but excludes temporary feedlotting.
Key environmental asset	For the purposes of this Plan, a key environmental asset is a section of watercourse and a 50 m wide strip of surrounding land centred on that watercourse, that supports water-dependent ecosystems of key significance, that is marked as a purple line on GRO Plan 58/2008. Figure 36 shows key features of this plan at a reduced scale.
Key environmental buffer zone	An environmental buffer zone is an area radiating from a key environmental asset, and is linked to an aquifer or aquifers. The extent of the key environmental buffer zones and the aquifers they are linked to is shown in GRO Plans 60/2008 and 61/2008. Figure 37 and Figure 38 respectively show key features of these plans at a reduced scale.
Land division	A land division that requires approval under the *Development Act 1993* and also includes circumstances where contiguous allotments cease to be owned or occupied by the same person, and/or cease to be operated as a single unit for the purpose of primary production.
Main watercourse diversion structure	A diversion structure that may take water from a main watercourse management sub-zone.

Term	Definition
Main watercourse management sub-zone (or main watercourse MSZ)	In general, a surface water and watercourse water management sub-zone that represents the main watercourse which tributaries feed into, typically supporting a range of water-dependent ecosystems. Specifically, main watercourse MSZs are those with a type of "main watercourse" in column "Tributary or main watercourse" of Table 29. Main watercourse MSZs are shown in GRO Plan 1/2009. Figure 32 shows key features of this plan at a reduced scale. Water taken from the watercourse represented by the main watercourse MSZ is excluded from the adjacent tributary MSZs.
Major point of inflow	The major point of inflow from a tributary management sub-zone to a main watercourse management sub-zone. The major points of inflow from the tributary management sub-zones to the main watercourse management sub-zones are shown in GRO Plan 2/2009. Figure 40 shows key features of this plan at a reduced scale.
Managed aquifer recovery (MAR)	The process where water is artificially recharged into an aquifer for later recovery.
Management sub-zone (MSZ)	A specific part of a management zone. Boundaries of management sub-zones are shown in GRO Plans 28/2009 and 1/2009, and Figure 31 and Figure 32 show key features of these plans at a reduced scale. Key features are described in Table 29, including: • the management zone that the MSZ is part of (in column "Parent management zone"); and • the type of water resource and aquifer that the MSZ includes (in columns "Water resource" and "Aquifer") where relevant. Policies in this Plan relating to a management zone also apply to the management sub-zones that are part of it. Also see tributary MSZ and main watercourse MSZ.
Management sub-zone allocation limit (MSZ AL)	The maximum volume of water available for allocation from an underground water management sub-zone in a water use year, excluding rollover allocations and artificial recharge allocations. The volume of the MSZ AL is part of the volume of the management zone allocation limit (MZ AL) of the management zone that the management sub-zone is part of. The volume of the MSZ AL is not additional to the volume of the MZ AL of the management zone that the management sub-zone is part of. The volume of the MSZ AL for each relevant MSZ is given in column "Management sub-zone allocation limit" of Table 29.
Management sub-zone consumptive use limit (MSZ CUL)	The maximum volume of water available for consumptive use from a surface water and watercourse water management sub-zone in a water use year, excluding rollover allocations and roof runoff (surface water) allocations (where relevant). The MSZ CUL is determined in accordance with principles 63 and 65 in combination with column "Management sub-zone consumptive use limit" of Table 29.
Management sub-zone dam capacity limit (MSZ DCL)	The total volumetric capacity of dams in a management sub-zone that must not be exceeded when determining an application to erect, construct or enlarge a dam under section 8.5. The volume of the MSZ DCL for each relevant MSZ is given in column "Management sub-zone dam capacity limit" of Table 29.

Term	Definition
Management zone (MZ)	A part of the Marne Saunders Prescribed Water Resources Area as shown in GRO Plans 47/2008, 48/2008, 49/2008, 50/2008 and 51/2008. Figure 26, Figure 27, Figure 28, Figure 29 and Figure 30 respectively show key features of these plans at a reduced scale. A management zone includes the specified water resource(s) and aquifer (where relevant) as shown in columns "Water resource" and "Aquifer" of Table 28 that lie within that management zone's boundaries.
Management zone allocation limit (MZ AL)	The maximum volume of water available for allocation from a management zone in a water use year, excluding rollover allocations, artificial recharge allocations, roof runoff (surface water) allocations and extra safety net allocations (where relevant). The allocation limit for a management zone only applies to the water resource/resources and aquifer that the management zone is linked to, as defined in columns "Water resource" and "Aquifer" of Table 28 where relevant. The volume of the MZ AL for each MZ is given in column "Management zone allocation limit" of Table 28.
Management zone dam capacity limit (MZ DCL)	The total volumetric capacity of dams in a management zone that must not be exceeded when determining an application to erect, construct or enlarge a dam under section 8.5. The volume of the MZ DCL for each MZ is determined in accordance with principle 145.
Management zone long-term dam capacity target (MZ LDCT)	The long term target for dam capacity for a management zone that will provide enhanced environmental outcomes and better security of supply for users. The MZ LDCT for each MZ is given in column "Management zone long-term dam capacity target" of Table 28.
Mannum Aboriginal Community Association Incorporated (MACAI)	An Ngarrindjeri Regional Authority member organisation and an incorporated body that represents descendants of the ancestors who comprise some or all of the traditional owners of the Peramangk nation. Whilst Peramangk area is not subject to a native title claim, should one be made in the future then both MACAI and the claimants or holders of native title will be entitled to be consulted and dealt with in the Peramangk area about their respective responsibilities within the Peramangk nation.
Maximum diversion rate	The maximum rate (in litres per second) at which water may be diverted from a restricted watercourse, as determined in accordance with principles 73 - 75.
Maximum extraction rate	The maximum rate (in litres per second) at which water may be extracted from a point of taking endorsed on a licence. Types of maximum extraction rates that may apply include: • Maximum extraction rate from a well where its well buffer zone will overlap another well buffer zone, as determined in accordance with principles 40 - 42. • Maximum extraction rate from a well with a large allocation, as determined in accordance with principles 44 - 46.
Ngadjuri	Ngadjuri people assert shared traditional interests in the area of the Marne Saunders water allocation plan. Currently their interests are represented by Ngadjuri Nation Aboriginal Corporation (NNAC) who represents Ngadjuri nation in relation to those shared interests. Whilst the area is not subject to a native title claim, should one be made in the future then both NNAC and the claimants or holders of native title will be entitled to be consulted and dealt with in the area about their respective responsibilities within the Ngadjuri nation.

Term	Definition
Ngarrindjeri Regional Authority (NRA)	Ngarrindjeri governing organisation recognised by state and federal governments as the peak governing body for the Ngarrindjeri nation. The NRA Board includes representative from the Ngarrindjeri Native Title Holding Body, the Ngarrindjeri Heritage Committee and the Ngarrindjeri Tendi, as well as representatives from MACAI.
Ngartjis	Ngarrindjeri term for special animals (Ngarrindjeri Tendi Incorporated, Ngarrindjeri Heritage Committee Incorporated, Ngarrindjeri Native Title Management Committee, 2006).
Non-licensed consumptive use	Consumptive use of prescribed water resources for non-licensed purposes. Non-licensed purposes at the date of publication include: • domestic use; • provision of drinking water for stock that are not subject to intensive farming; and • purposes authorised by a notice under section 128 of the NRM Act in the area, which at the date of publication includes fire fighting; public road making; applying chemicals to non-irrigated crops or to control pests; use of up to 1,500 kilolitres per year of roof runoff for commercial (including irrigation), industrial, environmental or recreational purposes; and use under native title rights under some circumstances.
Off-stream dam	A dam that is not constructed across a watercourse and is primarily designed to hold water from a source other than the catchment area of the dam. Other water sources may include, but are not limited to, underground water and water diverted or pumped from a watercourse and/or flow path that is not in the catchment area of the dam. Off-stream dams may capture a limited volume of surface water from the natural catchment area of the dam (up to 5% of its total capacity, determined on the basis of average adjusted winter runoff from the catchment area upstream of the dam).
Operational well	A water well that has not been abandoned or backfilled. The SA Geodata database will be used as the primary source to identify the existence, location and status of water wells. Alternative information on the existence, location and status of water wells may also be considered by the Minister.
Peramangk	Aboriginal people who identify with the Country on the eastern side of the escarpment of the Mount Lofty Ranges. The Peramangk people share close relationships, culture and some language with the nations of the Kaurna to the west, Ngadjuri to the north, and Ngarrindjeri to the south. Whilst the Peramangk area is not subject to a native title claim should one be made in the future then both MACAI and the claimants or holders of native title will be entitled to be consulted and dealt with in the Peramangk area about their respective responsibilities within the Peramangk nation.
Point of taking	The point or location at which an allocation is taken or is to be taken.
Post-credit year	The water use year immediately following the water use year in which not all of a base water allocation was taken (the credit year), potentially giving rise to a rollover allocation.
Property	An allotment or contiguous allotments owned or occupied by the same person, persons or body and operated as a single unit. Allotments will be considered to be contiguous if they abut at any point, or are separated only by a road, street, lane, footway, court, alley, railway, thoroughfare, easement, right-of-way, watercourse, channel or a reserve or similar open space.
Recharge	The infiltration of water into an aquifer from the surface.

Term	Definition
Restricted watercourse	A watercourse marked as an orange line in GRO Plan 3/2009. Figure 39 shows key features of this plan at a reduced scale. Restricted watercourses have been identified as watercourses of third order and greater using the Strahler stream ordering system, and are subject to specific principles including maximum diversion rates and limitations on dam construction.
Riffle	Stream section with fast and turbulent flow.
Riparian	Relating to the area which adjoins, directly influences, or is influenced by a body of water.
Rollover allocation	An allocation granted in accordance with principles 47 - 52 and/or 82 - 89.
Roof runoff (surface water)	Water that runs off a roof after being precipitated.
Roof runoff (surface water) allocation	An allocation of roof runoff (surface water) granted in accordance with section 6.6 of this Plan
Runoff (R)	The depth of average adjusted winter runoff from an area (in mm), where "winter" means May to November inclusive. The value of runoff that relates to an area is determined in accordance with principle 63 g).
Safety net allocation	A particular type of allocation granted to an existing user pursuant to the Natural Resources Management Act (Marne Saunders Prescribed Water Resources Area- Reduction in Water Access Entitlements) Regulations 2009. These regulations grant existing users of surface water and watercourse water an allocation based on the lesser of their maximum theoretical enterprise requirements, dam capacity (where relevant), available runoff to their diversion structure, or share of the water available for licensed use within their management sub-zone consumptive use limit. Where the volume of this allocation is less than 50% of the maximum theoretical enterprise requirements (MTER), then the regulations provide that the existing user will be allocated 50% of MTER or their dam capacity (whichever is less). In this Plan, that allocation is referred to as the ***safety net allocation,*** comprised of two parts, being: • ***Foundation allocation*****:** the volume the existing user would have received if there was no safety net allocation (as described above); and • ***Extra safety net allocation*****:** the safety net allocation minus the foundation allocation.
Source	A specific point of taking and its associated water-taking infrastructure, such as a given well, diversion structure or roof.
Stream order	A method of classifying the size of a part of a watercourse, based on the hierarchy of connecting watercourse segments. The Strahler stream ordering system is used in this Plan. The most upstream part of a watercourse is a first order stream. Two first order watercourses join together to become a second order watercourse. Two second order watercourses join together to become a third order watercourse and so on. Arthur Strahler first proposed the approach in 1952 in an article in the Geological Society of America Bulletin. The network of watercourses is defined in the basis of current 1:50,000 topographic maps produced by the state government.
Stygofauna	Animals that live in underground water systems, including aquifers and caves.

Term	Definition
Temporary feedlotting	A practice where: • animals are confined to a small space or area; and • are fed by hand or mechanical means for less than six months of the year; and • total stock numbers on the property are equal to or less than the stock carrying capacity of the property. A temporary feedlot may operate for more than six months as a temporary practice for land management purposes during drought when rainfall is insufficient for normal farming practices to be conducted.
Threshold flow rate	The flow rate at or below which surface water or watercourse water must not be diverted or must be bypassed or otherwise returned around a diversion structure in accordance with principles 76 and/or 155. The threshold flow rate is determined in accordance with principle 77.
Tradition Country	'Country' is a non-Aboriginal term that recognises the connections, relationships, authority and responsibilities of particular Aboriginal nations (including native title holders and claimants where native title rights are concerned and or as described in an ILUA) to the living entities of land and sea. 'Sea Country' – the coasts and oceans – forms an integral part of 'Country' as the lands and seas are not considered separately. It has a markedly different meaning than the English language definition. For Aboriginal people they are a part of the living body of their Country, they are Country. Country is capitalised when used. Country also refers to area(s) that an Aboriginal person has rights and responsibilities for and where the Aboriginal person is a native title holder or claimant will include responsibilities according to the laws and customs that form the native title rights and interests. All parts of South Australia, the lands, waters, seas, sky and even metropolitan and townships are the Country of an Aboriginal nation
Tributary management sub-zone	A surface water and watercourse water management sub-zone with a type of "tributary" in column "Tributary or main watercourse" of Table 29. Tributary MSZs are shown in GRO Plan 1/2009. Figure 32 shows key features of this plan at a reduced scale. The water resources of a tributary MSZ exclude water taken from the watercourse represented by a main watercourse MSZ.
Turkey nest dam	An off-stream dam that does not capture any surface water from the catchment area upstream of the dam.
Water-dependent ecosystem	Those parts of the environment, the species composition and natural ecological processes, which are determined by the permanent or temporary presence of flowing or standing water. Water-dependent ecosystems include riparian vegetation, springs, wetlands, floodplains, estuaries, in-stream areas of watercourses, hyporheic fauna (in wetted sediments below and alongside watercourses) and stygofauna (living in aquifers).
Water-dependent ecosystem use	The use of water to maintain, rehabilitate or restore locally indigenous water-dependent ecosystems, habitats, communities or species for a purpose and in a manner accredited by the South Australian Murray Darling Basin Natural Resources Management Board. Water-dependent ecosystem use may include non-active environmental use (where water is retained in aquifers, surface waters and/or watercourses) and active environmental use including but not limited to activities such as watering naturally occurring habitat.

Term	Definition
Water (holding) allocation	A type of allocation previously available pursuant to the *Natural Resources Management Act,* until that Act was amended by the *Natural Resources Management (Water Resources and Other Matters) Amendment Act 2007*. This kind of allocation no longer exists under the NRM Act as amended. However, the transitional provisions (being regulation 47 of the *Natural Resources Management (General) Regulations 2005,* and Clause 5 of Schedule 1 to the *Natural Resources Management (Water Resources and Other Matters Amendment Act 2007*) still temporarily permit this Plan to determine a quantity of water to be included on a licence to achieve the same effect. Thus a reference to a water (holding) allocation in this Plan is an allocation which does not authorise the taking of water but enables the holder of the licence to make a request to the Minister to convert the allocation to a water allocation which may be taken. The relevant transitional provisions that permit this to happen only operate until a day designated by the Minister when the Minister is satisfied that the Plan has been amended to take into account the 2007 amendments. As of the date of adoption, the relevant transitional provisions expire in any event in 1 July 2011.
Water quality criteria	Has the same meaning as in the *Environmental Protection Act 1993* and any associated policy.
Water use year	The period between 1 July in any calendar year and 30 June in the following calendar year.
Well buffer zone	A circular area centred on an operational well. The well buffer zone is linked to the aquifer that the well takes water from. The radius of the well buffer zone is determined in accordance with Table 30.
Wetland	Has the same meaning as in section 3 (1) of the NRM Act, meaning an area that comprises land that is permanently or periodically inundated with water (whether through a natural or artificial process) where the water may be static or flowing and may range from fresh water to saline water and where the inundation with water influences the biota or ecological processes (whether permanently or from time to time) and includes any other area designated as a wetland— a) by an NRM Plan; or b) by a Development Plan under the *Development Act 1993*, but does not include— c) a dam or reservoir that has been constructed by a person wholly or predominantly for the provision of water for primary production or human consumption; or d) an area within an estuary or within any part of the sea; or e) an area excluded from the ambit of this definition (under the NRM Act) by the regulations. Aboriginal nations refer to freshwater wetlands as ‘nurseries’ in recognition of the important role these areas play in providing food and shelter for many types of animals, birds and fish (ngartjis). Submerged plants in these nursery areas are critical for food and shelter for animals and their young (DEWNR, 2017). The nurseries are regarded as the lungs of the system that cleanse the body (land).
Wild flooding	Flood irrigation where no adequate system such as land levelling or irrigation bays is used to ensure a controlled distribution of water.

12 References

ABWMC (Angas Bremer Water Management Committee) (2005) Watercourse diversion best management practice guidelines – vegetation health monitoring tool (draft).

Alcorn, M.R. (2005) Surface water assessment of the Upper Saunders Creek Catchment. Knowledge and Information Division, Department of Water, Land and Biodiversity Conservation. Unpublished draft report. Report DWLBC 2005/14.

Allen, R.G., Pereira, L,S., Raes, D. and Smith, M. (1998) Crop evapotranspiration – guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper 56. Food and Agriculture Organization of the United Nations. Rome.

ANZECC & ARMCANZ (Agriculture and Resource Management Council of Australia and New Zealand, and Australian and New Zealand Environment and Conservation Council) (2000) Australian and New Zealand guidelines for fresh and marine water quality. Volume 1, The guidelines. Agriculture and Resource Management Council of Australia and New Zealand, and Australian and New Zealand Environment and Conservation Council.

ARMCANZ & ANZECC (Agriculture and Resource Management Council of Australia and New Zealand, and Australian and New Zealand Environment and Conservation Council) (1996) National principles for the provision of water for ecosystems. Sustainable Land and Water Resources Management Committee, Subcommittee on Water Resources. Occasional Paper SWR No 3 July 1996.

Banks, E.W., T. Wilson and A. Love (2006) Groundwater recharge investigations in the Upper Marne River Catchment, South Australia. Department of Water, Land and Biodiversity Conservation. Report DWLBC 2007/19.

Barnett, S., W. Yan and D. Zulfic (2001) Marne River Catchment Groundwater Assessment. South Australia. Department for Water Resources. Report DWR 2001/09.

Barossa and Light Regional Development Board (2004) Wine Industry Impact Review.

Clarke, D. (2008) Future demand requirements in the Marne Saunders PWRA. Sinclair Knight Merz. Unpublished report to the South Australian Murray–Darling Basin Natural Resources Management Board.

Commonwealth of Australia (2016) Engage Early – Guidance for proponents on best practice Indigenous engagement for environmental assessments under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), Commonwealth of Australia.

Cottingham, P., G. Quinn, A. King, R. Norris, B. Chessman and C. Marshall (2005) Environmental flows monitoring and assessment framework, version 1.1. Technical Report. CRC for Freshwater Ecology, Canberra.

CSIRO (2007) Water availability in the Eastern Mount Lofty Ranges: summary of a report to the Australian Government from the CSIRO Murray–Darling Basin Sustainable Yields Project.

DEW (Department for Environment and Water) (in prep) South Australian Eastern Mount Lofty Ranges Water Resource Plan, Government of South Australia, Adelaide.

DEWNR (Department of Environment, Water and Natural Resources) (2017) 2015 updated Ecological Character Description for the Coorong, and Lakes Alexandrina and Albert Wetland Ramsar site. Government of South Australia, Adelaide.

Doeg, T. and M. van der Wielen (2007) Environmental Water Requirements of Saunders Creek, South Australia. Unpublished Report to the South Australian Murray–Darling Basin Natural Resources Management Board.

Dooley, T. And Henschke, C. (2000) Dryland salinity management within the Eastern Hills and Murray Plains LAP area. Report to the Eastern Hills and Murray Plains Catchment Group Inc. PIRSA Rural Solutions.

Drillhole Enquiry System. Online resource at:
https://des.pir.sa.gov.au/deshome.html

DWLBC (Department of Water, Land and Biodiversity Conservation) (2006) State Natural Resources Management Plan. Government of South Australia.

DWLBC surface water archive. Online resource at
http://e-nrims.dwlbc.sa.gov.au/swa/map.aspx

EPA (2009) Water quality monitoring sites: Marne River near Cambrai – water chemistry results. Online resources at:
http://www.epa.sa.gov.au/environmental_info/water_quality/water_quality_monitoring_sites/marne_river_near_cambrai
Accessed November 2009.

Hammer, M. (2004) The Eastern Mount Lofty Ranges Fish Inventory: Distribution and conservation of freshwater fishes of tributaries to the Lower River Murray, South Australia. Native Fish Australia (SA) Inc and River Murray Catchment Water Management Board.

Hammer, M. (2006). Review and 2005 performance of fish indicators for Environmental Water Requirements of the Marne River Catchment, South Australia. Unpublished report to South Australian Murray–Darling Basin Natural Resources Management Board. Aquasave Consultants, Adelaide.

Hammer, M. (2007a) Data summary and 2006 performance of fish indicators for Environmental Water Requirements of the Marne River Catchment, South Australia. Unpublished report to South Australian Murray–Darling Basin Natural Resources Management Board. Aquasave Consultants, Adelaide.

Hammer (2007b) Freshwater fish monitoring for threatened species and environmental water requirements in the Eastern Mount Lofty Ranges, South Australia. Unpublished report to South Australian Murray–Darling Basin Natural Resources Management Board. Aquasave Consultants, Adelaide.

Hammer, M (2008) EMLR fish monitoring 2008. Unpublished report to South Australian Murray–Darling Basin Natural Resources Management Board. Aquasave Consultants, Adelaide.

Harrington, G.A. (2004a) Hydrogeological Investigation of the Mount Lofty Ranges, Progress Report 4: Groundwater – surface water interactions in the Scott Creek, Marne River and Tookayerta Creek Catchments. Department of Water, Land and Biodiversity Conservation. Report DWLBC 2004/11.

Harrington, G.A. (2004b) Defining sources of groundwater for the Blackhill Springs, Lower Marne River, South Australia. Department of Water, Land and Biodiversity Conservation. Report DWLBC 2004/20.

Hyder Consulting (2007) Updating stream salinity curves for the catchments of the Eastern Mount Lofty Ranges. Unpublished report to the South Australian Murray–Darling Basin Natural Resources Management Board.

Jolly, I., Walker, G., Stace, P., van der Wel, B. And Leaney, R. (2000) Assessing the impacts of dryland salinity on South Australia's water resources. CSIRO Land and Water Technical Report 9/00.

Kawalec, R and S. Roberts (2005) Review of South Australian State agency water monitoring activities in the Eastern Mount Lofty Ranges. Department of Water, Land and Biodiversity Conservation. Report DWLBC 2005/44.

Keane, S. (2003) Land use and management mapping of South Australia. Part 4: Murray Darling Basin. Bureau of Rural Sciences Land Use Mapping Program.

Kotz, S., D. Thomas and S. Rixon (2000) Watercourse survey and management recommendations for the Upper Marne River Catchment. Environment Protection Agency, Department of Environment and Heritage.

Lang, P.J. and Kraehenbuehl, D.N. (2000) Plants of particular conservation significance in South Australia's agricultural regions - extract for MU region. Unpublished database. National Parks and Wildlife SA, Department for Environment, Heritage and Aboriginal Affairs

Lyne, V.D and M. Hollick (1979) Stochastic time-varying rainfall-runoff modelling. Hydrology and Water Resources Symposium, Perth. Institute of Engineers, Australia, pages 89 – 92.

McEvoy, P. (2008) Environmental water quality requirements. Draft unpublished report to the South Australian Murray–Darling Basin Natural Resources Management Board.

McMurray, D. (2003) Assessment of water use from farm dams in the Mount Lofty Ranges of South Australia. Department of Water, Land and Biodiversity Conservation. Report DWLBC 2004/02.

MREFTP (Marne River Environmental Flows Technical Panel) (2003) Environmental water requirements of the ephemeral Marne River system, South Australia. River Murray Catchment Water Management Board.

NHMRC (2004) Australian Drinking Water Guidelines 6. National Health and Medical Resources Council and Natural Resource Management Ministerial Council.

Ngadjuri (2018) accessed 30 May 2018; http://www.ngadjuri.com.au/country.html

Ngarrindjeri Tendi Incorporated, Ngarrindjeri Heritage Committee Incorporated, Ngarrindjeri Native Title Management Committee (2006) Ngarrindjeri Nation Yarluwar-Ruwe Plan: Caring for Ngarrindjeri Sea Country and Culture, Kungun Ngarrindjeri Yunnan (Listen to Ngarrindjeri People Talking). Ngarrindjeri Tendi Incorporated, Ngarrindjeri Heritage Committee Incorporated, Ngarrindjeri Native Title Management Committee.

Obswell. Online resource of data from observational wells at: https://obswell.pir.sa.gov.au/new/obsWell/MainMenu/menu

Savadamuthu, K. (2002) Impact of farm dams on streamflow in the Upper Marne Catchment. Resource Assessment Division, Department for Water Resources. Report DWR 02/01/0003.

Savadamuthu, K. (2005) Surface water allocation framework, Upper Marne. Unpublished DWLBC presentation material.

Savadamuthu, K. (2007) Impact Sustainable extraction limits for farm dams. Department of Water, Land and Biodiversity Conservation. DWLBC Technical Note 01/06.

SA MDB NRMB (2010 in prep) Stock and domestic water requirements in the Marne Saunders Prescribed Water Resources Area. Unpublished report by the South Australian Murray–Darling Basin Natural Resources Management Board.

Trevorrow, T (2010) video recording Murrundi Ruwe Pangari Ringbalin *River Country Spirit Ceremony: Aboriginal Perspectives on River Country*. YouTube, viewed February 2018. https://www.youtube.com/watch?v=GqrRfyVNqIo

Tucker, A. (2001) Water use of *Eucalyptus camaldulensis* (River Red Gums) along the Marne River, Eastern Mount Lofty Ranges. Honours Thesis. School of Biological Sciences, Flinders University.

Yan, W. and S.R. Barnett (2001) Marne River Catchment plains zone groundwater modelling. South Australia. Department for Water Resources. Report DWR 2001/010.

Zulfic, D. and S.R. Barnett (2002) Saunders Creek Catchment Groundwater Assessment. Resource Assessment Division, Department of Water, Land and Biodiversity Conservation. Report DWLBC 2002/01.