South East NRM Plan Water Affecting Activity Policy—Surface Water and Dams Technical Review

Julian Whiting and Kumar Savadamuthu
Department for Environment and Water

December 2018

DEW Technical report 2018/10

Government of South Australia
Department for Environment and Water

Department for Environment and Water

GPO Box 1047, Adelaide SA 5001

Telephone National (08) 8463 6946

International +61 8 8463 6946

Fax National (08) 8463 6999

International +61 8 8463 6999

Website www.environment.sa.gov.au

ISBN 978-1-925805-56-7

Preferred way to cite this publication

Whiting JP & Savadamuthu K (2018). *South East NRM Plan Water Affecting Activity Policy—Surface Water & Dams Technical Review,* DEW Technical report 2018/10, Government of South Australia, Department for Environment and Water, Adelaide.

Download this document at http://data.environment.ppf.env.sa.gov.au/Pages/default.aspx

Foreword

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

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

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

John Schutz
CHIEF EXECUTIVE
DEPARTMENT FOR ENVIRONMENT AND WATER

Acknowledgements

The authors wish to acknowledge the support of the following.

Department for Environment and Water staff:

- Ben Plush and Jonathan Phillips for spatial analysis assistance
- Dr Matt Gibbs and Volmer Berens for assistance with methodology, and for comments provided in reviewing this report

Natural Resources South East staff:

- Jennifer Schilling, Phil Elson and Jennifer Peterson for providing feedback throughout the project.

Contents

List of figures

List of tables

1 Introduction

1.1 Background and context

The current South East Natural Resources Management Plan (SE NRM Plan) was adopted in 2010 and includes Water Affecting Activity (WAA) policies related to surface water including:

- **Surface water policy areas**—The Region is demarcated into 13 Surface Water Policy Areas (SWPAs) based on rainfall and catchment characteristics.
- **Dam development limits**—Limits for development of surface water through farm dam development limits derived from rainfall-runoff relationships are provided for each SWPA.
- **Surface water diversion thresholds**—Diversion of surface water to off-stream storage is regulated through a threshold flow rate (75% of the median annual flow), below which water cannot be diverted.

Policies relating to the management of dams in the South East Region ('the Region') have been in place since the inception in 2003 of the South East Catchment Water Management Plan, which was later revised in 2010 with the adoption of the current NRM Plan.

As part of its review of the current NRM Plan, Natural Resources South East (NRSE) requested the Science and Information Group of DEW to undertake a technical review of:

- The methodology used for demarcating the 13 surface water policy areas (SWPAs) in the Region
- The methodology and data used to determine rainfall-runoff factors that define dam development limits
- The rationale behind all new capturing dams requiring low flow to be bypassed
- The scientific (hydro-ecological) basis, methodology and data used in developing the current Threshold Flow Rates (TFRs) (75% of median annual flows) for diverting/extracting water from watercourses and drains
- The methodology used for determination of Sustainable Diversion Limits (SDLs), to ensure consistencies in the methodology used for sections of the Region and sections of the SA Murray-Darling Basin region.

This technical review was delivered in two phases: Phase 1 involved a preliminary review of current farm dam policy in the South East NRM Plan, while providing for comparative purposes Water Affecting Activity (WAA) policy from other NRM regions and Water Allocation Plans across the State. Following the finalisation of Phase 1 in August 2016, a field visit and workshop were held involving DEW hydrologists, NRSE water planning staff and SE Water Conservation and Drainage Board staff, with the following scope of work for Phase 2 proposed:

- Review the boundaries of SWPAs in the existing SE NRM Plan with respect to modelled surface water catchment boundaries (e.g. Wood & Way, 2011) and related spatial data such as land use, soil type, etc.
- Propose new SWPA boundaries for the Region.
- Review rainfall-runoff relationships and broad trends in likely hydrological responses included in the existing NRM Plan, using extended hydrological data sets for the most recent years available and outputs from existing WaterCress models.
- Investigate appropriate threshold flow rates and water extraction rules for a designated part of the SE Region, as a case study that is agreed upon with NRSE.
- Provide recommendations on further work required to apply these methods to other parts of the Region e.g. monitoring to implement the policy and having a default position in the absence of other data.

1.2 Scope of work

This technical report represents the response of the Science and Information Group to Phase 2 of this technical review, and comprises:

- A spatial verification review, including the technical basis for the spatial extent of the SWPA boundaries
- A verification and validation of rainfall-runoff parameters for SWPAs
- Proposed changes to SWPA boundaries and the technical basis for the proposed changes
- The calculation of farm dam development limits across proposed SWPAs
- A case study of WAA diversion rules in the Drain K catchment
- A review of Morambro Creek Water Allocation Plan and the surface water technical investigations undertaken as part of developing this plan.

2 Surface Water Resources in the South East

2.1 Regional description

The natural hydrological pattern of the South East Region was for high rainfall events to flood lower gradient flats into an interconnected series of slowly draining wetlands. Most runoff from the Region is generated from the Lower South East and the cross-border catchments of the Morambro, Naracoorte and Mosquito Creeks, which have catchments rising in (relatively) higher areas of western Victoria. These cross-border catchments are significant sources of surface water for watercourses in the north-western parts of the Region that support many wetlands and water-dependent ecosystems (WDEs). As such, these watersheds act as 'headwaters' for much of the Region.

The natural system of permanent, seasonal and ephemeral wetlands has been heavily modified since European settlement by drainage schemes developed to manage runoff accumulated on the valuable agricultural soils of the flats. In the early stages of settlement drainage schemes were small scale, but as regional flooding problems persisted, the drainage became more extensive and a series of cross-country drains (e.g. Drain M and Blackford Drain) were built to convey floodwaters directly to the ocean. The SE drainage network now supports over 200 regulators for water conservation and adaptive management practices. Flood flows are increasingly diverted away from natural wetlands and waterways, depriving wetlands of the water that would naturally have filled them and it has lessened the flushing flows necessary for their continued health (Wood & Way, 2011). Land drainage has reduced significantly both the number of wetlands in a natural condition and greatly affected the frequency and duration of inundation to which the remaining wetlands have been subject in recent years (Sheldon, 2007).

The significant and interconnected development of drains across the Region has significantly altered the management of surface water resources, such that there is now more flexibility in the supply of water to meet operational decisions. Any increase in the abstraction of surface water resources from the Region (e.g. for farm dams) needs to be considered alongside environmental water requirements (EWRs) of such areas (if these are defined), and risks to other users of the surface water resources.

The groundwater resources and ephemeral surface water streams of the South East are closely related with the Tertiary Limestone Aquifer (TLA), the principal source of groundwater throughout the Region. The TLA varies between 300 m below surface level in the south, to less than 2 m below surface in the Upper South East. This close proximity makes the management of agricultural drainage and of groundwater-dependent ecosystems challenging. The removal of flood flows lowers the water table within the flatter regions, firstly by shallow surface water drains limiting the infiltration of standing water to groundwater and secondly by lowering the water table and decreasing the amount of water available to keep wetlands moist through dry periods.

Dryland farming is the dominant agricultural enterprise across the mixed land use of the South East. Irrigation, almost entirely from the TLA, is used for cropping and pasture and is widely and intensively used for vine growing.

2.2 Background to SWPAs

Wood & Way (2011) prepared DEWNR Technical Report 2011/21, *Basis for a regional flow management strategy for the South East of South Australia*. This report included the development of a series of rainfall-runoff models (using the WaterCress modelling platform) to describe patterns of surface water runoff generated from catchments, storages that included major wetland complexes (but not farm dams), and diversions through drain networks. Conceptual broad-scale models were developed for 17 surface water catchments, and calibrated to available streamflow records at downstream points.

Wood & Way (2011) recommended the partition of the Region into six coastal zones broadly representing 'bands within the long-term rainfall gradient' (i.e. isohyets), with regional rainfall-runoff (RR) factors derived for each.

These coastal zones (alongside four additional zones) formed the basis of SWPAs defined in the SE NRM Plan, with RR factors for each SWPA mainly corresponding to the zonal values presented in Wood & Way (2011). The existing SWPA boundaries are shown in Figure 2.1.

The three main cross-border catchments (Morambro, Naracoorte and Mosquito Creeks) have higher elevation changes than other surface water catchments in the Region, and consequently there is greater potential for on-stream (intercepting) dam development in these areas. These three catchments are defined as separate surface water policy areas (SWPAs) in the existing SE NRM Plan, with allowable farm dam capacity limits also specified for the two Morambro prescribed management areas that are located within the Morambro SWPA.

The Northern area of the Region has limited hydrological data and is characterised by minimal surface runoff and sparse watercourses. The SE NRM Plan defines a single SWPA across the north-easterly part of the Region, although only a small portion of this area has gauged streamflow data, from the Tatiara and Nalang watercourses. The area of the Region further north from the specified Tatiara–Nalang SWPA was not included as a SWPA in the existing NRM Plan. The western half of the Region was demarcated into six SWPAs, termed Regional Zones 'a' to f, which traverse a number of different surface water catchments.

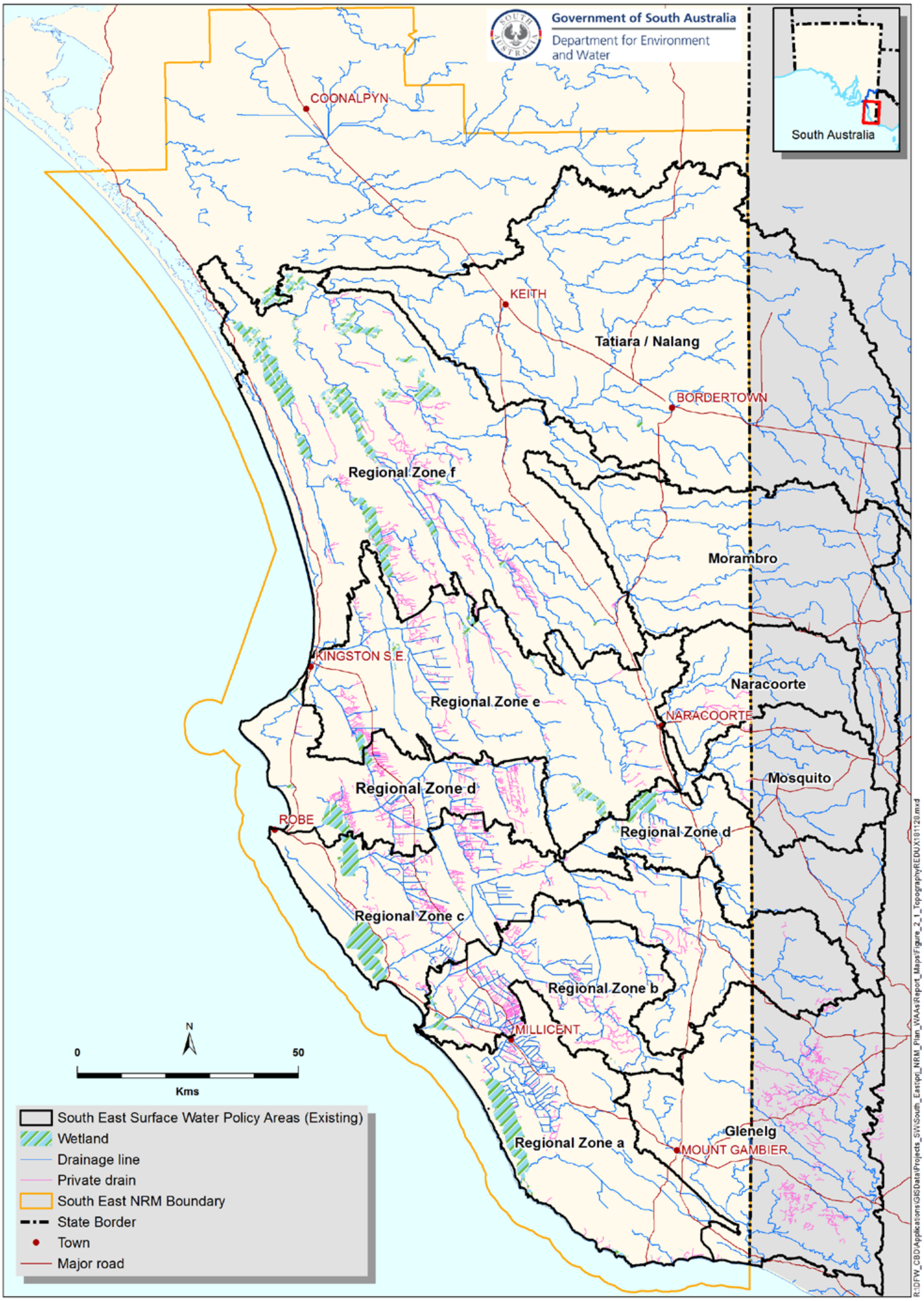

Figure 2.1 Existing SWPAs in the South East NRM Region

2.3 Relationship between surface water catchment boundaries and SWPAs

Wood & Way (2011) developed 17 conceptual rainfall-runoff models to describe hydrological responses across numerous catchments within the Region (Figure 2.2). Watercourses (and drains) across much of the Region are now highly altered from their pre-development state, and the interconnected nature of many of the watercourses means that there is not necessarily a close link between flows in gauged watercourses and underlying hydrological processes in the catchments.

A reliance on long-term rainfall gradients over an analysis of surface water behaviour (e.g. catchment boundaries) may lead to the grouping of areas with disparate hydrological responses, and variable risks that may result from an increased abstraction of surface water resources. The existing SWPA boundaries are presented in Figure 2.2 alongside the surface water catchment boundaries as modelled by Wood & Way (2011).

2.4 Analysis of existing SWPAs

The existing SWPA boundaries across the Region were assessed via a review of historical hydrological responses using relationships between continuous streamflow records and spatially-averaged rainfall from contributing catchment areas.

Surface water runoff was derived from daily flow data recorded at flow gauges within catchments for each relevant SWPA, with continuous daily flow records used where possible. Daily flows were aggregated to annual volumes, and these annual volumes were converted to annual runoff depths (in millimetres) from the contributing catchments.

For annual rainfall totals, the SILO patched-point dataset was used to derive daily rainfall for the period 1889–2016 at the locations of Bureau of Meteorology stations across the Region. These daily rainfall figures were aggregated using the Thiessen Polygon approach to derive a spatially-averaged daily rainfall series corresponding to the contributing catchments for each streamflow gauge. These daily rainfall series were also aggregated to annual periods.

Rainfall-runoff factors are dimensionless variables, derived as the ratio of surface water runoff (in millimetres) to total rainfall (in millimetres) for a specific catchment. For each flow record, the time series of annual runoff totals were ranked, and the median runoff year chosen. The rainfall-runoff factor for this median runoff year was then calculated using the annual catchment rainfall for that year

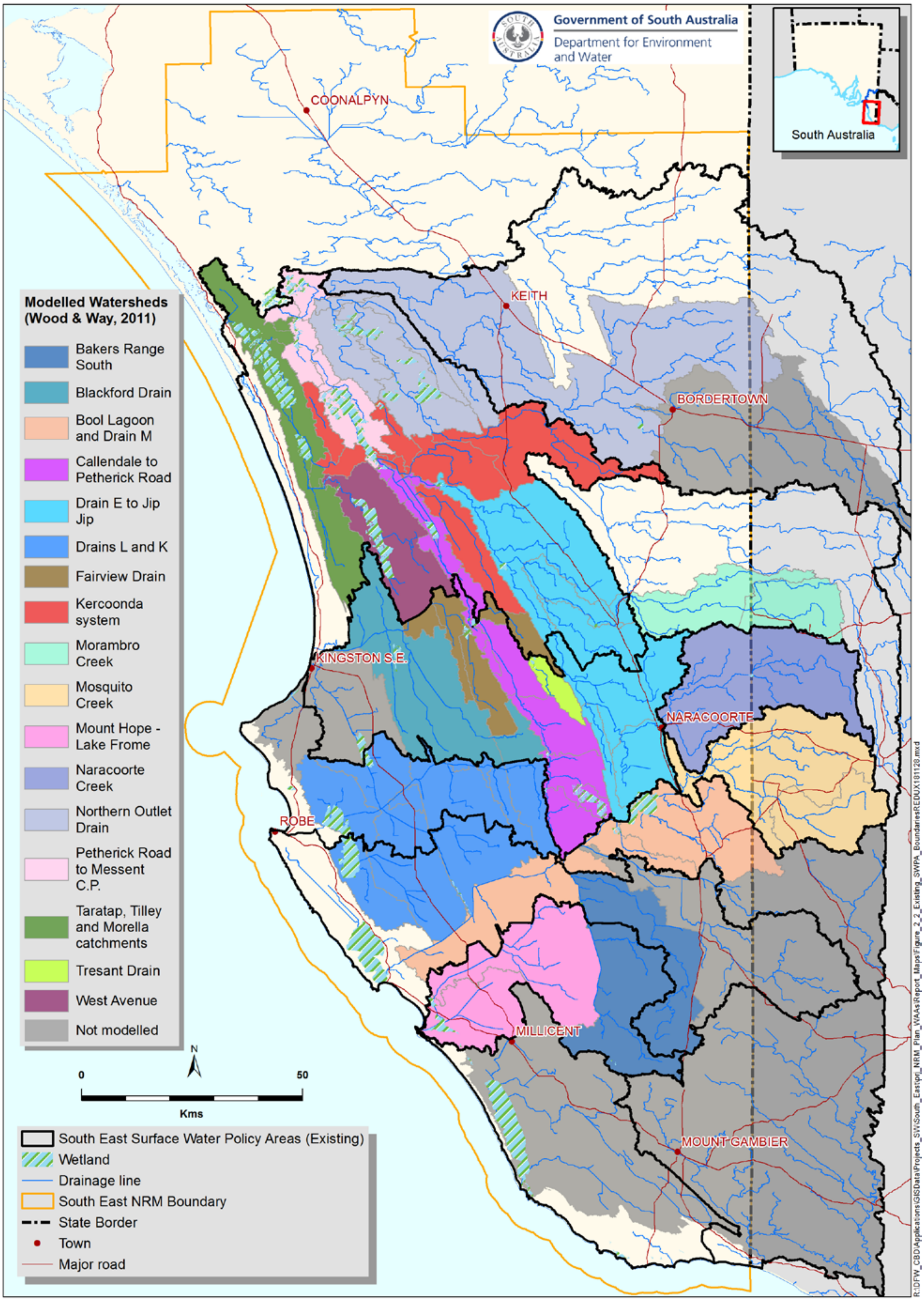

Figure 2.2 Existing SWPA boundaries alongside modelled catchment boundaries (Wood & Way, 2011)

2.5 Existing SWPAs

The methodology originally used to define SWPAs was reviewed, alongside the rainfall-runoff relationships that define allowable dam volumes using hydrological data sets that had been extended since the Wood and Way (2011) investigation. The SWPAs defined in the existing SE NRM Plan are further described in this section, with Appendix A showing SWPA boundaries alongside modelled catchments (from Wood & Way, 2011).

2.5.1 Regional Zone a

2.5.1.1 Description

Regional Zone a covers the watershed of Lake Bonney SE, as shown in Figure A.1, and is contained within the SE NRM regional boundary. Lake Bonney SE is a high-value coastal freshwater lake that has been subject to deteriorating water quality over recent decades, prompting the initiation of catchment management programs.

2.5.1.2 Data availability and analysis

Two flow monitoring gauges were previously maintained by DEWNR on the eastern boundary of Lake Bonney SE. Table 2.1 summarises data recorded at these gauges and shows that their respective sub-catchments have varying rainfall-runoff characteristics. The median year rainfall-runoff factors for these two gauges are both lower than the rainfall-runoff factor defined in the existing SE NRM Plan.

Table 2.1 Summary of historical rainfall-runoff relationships for two flow gauges in Regional Zone a

	A2390523 Stony Creek @ Woakwine Range	***A2390533 Drain 48 @ U/S Lake Bonney Rd Bridge***
Catchment area upstream of gauge	485 km^2	114.6 km^2
Proportion of existing SWPA represented by gauge	28.2%	6.7%
Flow period analysed	1974–2014 (41 years)	1977–2013 (37 years)
Average annual flow (average runoff)	4,745 ML (10 mm)	4,932 ML (43 mm)
Median annual flow (median runoff)	3,237 ML (7 mm)	3,773 ML (33 mm)
Average annual catchment – averaged rainfall for flow period	778 mm	758 mm
Median annual catchment – averaged rainfall for flow period	768 mm	753 mm
Rainfall-runoff factor for median runoff year	0.012	0.037

2.5.1.3 Issues and risks with current SWPA extent

The boundaries of the existing SWPA correspond to surface water catchment boundaries for watercourses that supply Lake Bonney SE (as described in Figure A.1). This definition of the SWPA extent is therefore appropriate to support the ongoing management of the water body. However, it is understood that flows recorded at the two gauges described in Table 2.1 reflect varying quantities of groundwater influx, rather than representing predominantly catchment runoff (per Wood & Way, 2011). As such, the definition of the underlying rainfall-runoff relationships for this zone will be enhanced through additional investigation of the contribution of groundwater resources to surface water flows.

2.5.2 Regional Zone b

2.5.2.1 Description

Regional Zone b includes the Mount Hope–Lake Frome catchment, and the western part of the Bakers Range South catchment, as shown in Figure A.2. Lake Frome is a high-value coastal wetland that is fed from a network of east to west flowing drains that are independent from other drain networks in the Region that tend to follow a south-east to north-west flow path. The terrain of the Mount Hope–Lake Frome watershed is generally flat with high rainfall and significant drain development. The Bakers Range South system lies to the east of the Mount Hope–Lake Frome catchment, with its catchment supplying the Bakers Range watercourse that flows north to join Drain M (which forms the northern boundary of the Mount Hope–Lake Frome catchment). The Bakers Range South watercourse is a major source of regional surface water flows.

2.5.2.2 Data availability and analysis

Table 2.2 provides a summary of the historical rainfall-runoff relationships for two streamflow gauges in Regional Zone b, which suggests a higher rainfall-runoff response when compared with Regional Zone a. These two gauges describe surface runoff from almost 80% of the existing SWPA.

Table 2.2 Summary of historical rainfall-runoff relationships for two flow gauges in Regional Zone b

	A2390513 Reedy Creek-Mt Hope Drain @ 7.2km NE South End	***A2390515 Bakers Range South Drain @ Robe-Penola Rd***
Catchment area upstream of gauge	538 km^2	493 km^2
Proportion of existing SWPA represented by gauge	40.2%	36.9%
Flow period	1972–2015 (44 years)	1973–92 (20 years)
Average annual flow (average runoff)	20,560 ML (38 mm)	18,925 ML (38 mm)
Median annual flow (median runoff)	17,141 ML (32 mm)	17,433 ML (35 mm)
Average annual catchment – averaged rainfall for flow period	716 mm	778 mm
Median annual catchment – averaged rainfall for flow period	710 mm	772 mm
Rainfall-runoff factor for median runoff year	0.046	0.043

2.5.2.3 Issues and risks with current SWPA extent

The two gauges summarised in Table 2.2 show that their contributing catchments generate similar surface responses to rainfall events. Like Lake Bonney SE in Regional Zone a, Regional Zone b includes a significant coastal wetland with high ecological value that is supplied from watercourses within this zone. The impact of development in this zone on the ecological health of Lake Frome will be a key driver to assessing water affecting activities in these catchments. However, approximately half of the SWPA draining to the Bakers Range South watercourse flows north, rather than to the coastal Lake Frome. As such, the diversion of water from this catchment will have risks to other environmental assets and may require different surface water management approaches.

2.5.3 Regional Zone c

2.5.3.1 Description

Regional Zone c includes the southern part of the Drain L watershed, the western part of the Bool Lagoon–Drain M catchment, the eastern part of the Bakers Range South catchment and most of the Drain C catchment, as shown in Figure A.3. The eastern extent of this zone crosses the State border, and hence the boundary of the SE Region.

Drain M is an artificially-constructed cross-country drain that is supplied from Bool Lagoon, the Bakers Range South drain, and runoff from its local catchment. Surface flows in Drain M either travel in a westerly direction to terminate at Lake George near Beachport, or are diverted northwards out of Drain M via the Callendale Regulator to flow through other watercourses.

The Drain L catchment terminates at Lake Hawdon North and Lake Hawdon South near Robe, which are significant coastal wetlands. The southern part of the Drain L catchment contains a network of drains that are not connected to other watercourses in the region (like Mount Hope–Lake Frome), and are separated from Drain M to the south.

There is significant forestry development in the eastern portion of Regional Zone c, which has a localised impact on surface water runoff. Included in this zone is the Drain C catchment, which is 'effectively non-yielding' (Wood & Way, 2011), and fails to produce flow when other creeks in the immediate area are flowing, likely a result of extensive forestry operations and its internal drainage characteristics.

2.5.3.2 Data availability and analysis

Table 2.3 provides a summary of historical rainfall-runoff relationships within Regional Zone c, which shows that the Bray Drain catchment provides higher runoff than Wilmot Drain, both of which are located within the Drain L watershed. Although the gauge for Wilmot Drain (A2390527) is located within Regional Zone d, its contributing catchment is within Zone c. Both flow gauges show rainfall-runoff factors (for median runoff years) that exceed the 0.040 value defined in the current SE NRM Plan. A review of previously calibrated WaterCress models for the Drain L catchment showed rainfall-runoff factors close to 0.080.

Streamflow gauge A2390516, located at the downstream end of Drain C, has a contributing catchment within Regional Zone c. However, there is very little streamflow data recorded at this location. As such, it cannot be used to investigate the variability of rainfall-runoff processes in this zone.

Although there is a gauge at the downstream end of Drain M (A2390512) that provides significant flow data, the flow in this drain is influenced by releases from Bool Lagoon, the level of which is dependent upon inflows from other watercourses such as Mosquito Creek. As such, it was considered that this streamflow gauge would not provide a clear representation of rainfall-runoff relationships for the southern part of the zone, which is the contributing local catchment for Drain M.

Table 2.3. Summary of historical rainfall-runoff relationships for two gauges in Regional Zone c

	A2390504 Bray Drain @ Site B	***A2390527 Wilmot Drain @ 9.2km from Drain L***
Catchment area upstream of gauge	276 km^2	271 km^2
Proportion of existing SWPA (within the SE Region) that is represented by gauge	11.1%	10.9%
Flow period	1976–88 (13 years)	1973–89 (17 years)
Average annual flow (average runoff)	24,123 ML (87 mm)	13,781 ML (51 mm)
Median annual flow (median runoff)	15,785 ML (57 mm)	12,777 ML (47 mm)
Average annual catchment – averaged rainfall for flow period	643 mm	651 mm
Median annual catchment – averaged rainfall for flow period	627 mm	641 mm
Rainfall-runoff factor for median runoff year	0.099	0.068

2.5.3.3 Issues and risks with current SWPA extent

Regional Zone c includes the surface water catchment of a number of different major watercourses. Drain M is the primary source of freshwater to the coastal Lake George, and Bray Drain and Wilmot Drain supply Lake Hawdon, which has high ecological value. Drain C in the eastern part of Zone c was developed to remove surface water and saline groundwater to improve the utility of the surrounding agricultural land. As such this existing zone covers areas of variable environmental quality and surface response, which will in turn have different surface water management demands.

2.5.4 Regional Zone d

2.5.4.1 Description

As shown in Figure A.3, Regional Zone d includes the northern part of the Drain L catchment, the eastern part of the Drain M catchment (including the local catchment for Bool Lagoon) and the eastern part of the low-yielding Drain C catchment.

2.5.4.2 Data availability and analysis

Regional Zone d is typified by variable rainfall-runoff responses. The northern parts of the Drain L catchment (which are independent from the interconnected drain systems to the north, and separated from Drain M) show higher yields than the local catchment of Bool Lagoon. Surface water inflows to Bool Lagoon are available for Drain M to flow westerly to the sea, or north through other watercourses. Previously calibrated WaterCress models for the Bool Lagoon catchments showed rainfall-runoff factors of approximately 0.010. As noted with Regional Zone c, there is anecdotal evidence (Wood & Way, 2011) that Drain C has even lower yields. Table 2.4 summarises the rainfall-runoff responses for Drain K and Drain C. There are no surface water gauges at which runoff from the local catchment of Bool Lagoon are recorded.

Drain K shows a much lower rainfall-runoff coefficient than adjacent watercourses Wilmot Drain or Bray Drain (in Regional Zone c) However, Drain K was assessed over a longer period that had lower average rainfall than the data summarised in Table 2.3. When the rainfall-runoff calculation for Drain K was repeated over a shorter 1972–1988 period (to be consistent with data analysed in Table 2.3), a slightly higher rainfall-runoff factor of 0.032 was observed. Although higher, this rainfall-runoff factor was still lower than the adjacent Bray Drain or Wilmot Drain, suggesting slightly different catchment responses in the northern part of the Drain L catchment.

The Drain C flow data was assessed over two periods (1978–89 and 2005–14), as no data was recorded between 1989–2004. These 22 years of data showed low flows in this drain, with significant periods of zero flow.

Table 2.4. Summary of historical rainfall-runoff relationships for two gauges in Regional Zone d

	A2390510 Drain K @ U/S Princes Highway	***A2390536 Drain C @ U/S Coonawarra***
Catchment area upstream of gauge	489 km^2 (489 km^2 in SE region)	149 km^2 (41 km^2 in SE region)
Proportion of existing SWPA (within the SE Region) that is represented by gauge	24.5%	2.3%
Flow period	1972–2013 (42 years)	1978–89, 2005–14 (22 years)
Average annual flow (average runoff)	12,114 ML (25 mm)	297 ML (2 mm)
Median annual flow (median runoff)	9,082 ML (18 mm)	8 ML (0.1 mm)
Average annual catchment – averaged rainfall for flow period	603 mm	615 mm
Median annual catchment – averaged rainfall for flow period	608 mm	626 mm
Rainfall-runoff factor for median runoff year	0.028	<0.001

2.5.4.3 Issues and risks with current SWPA extent

Regional Zone d has areas of disparate surface water management needs, with the western half of the zone supplying Lake Hawdon North (through Drain L), most of the eastern half supplying Bool Lagoon, and a small area of the 'effectively non-yielding' Drain C catchment included. These areas have variable catchment responses, and it may be more appropriate to collate areas with similar rainfall-runoff relationships and likely surface water management impacts.

2.5.5 Regional Zone e

2.5.5.1 Description

As shown in Figure A.4, Regional Zone e includes a number of different surface water catchments and has a large interconnected network of drains. In general, surface water yields decrease from west to east across the zone. This zone includes the southern part of Drain E catchment, the Tresent Drain catchment, the southern part of the Bakers Range watercourse catchment, most of the Fairview Drain catchment, Blackford Drain catchment and the Kingston Main Drain catchment. Blackford Drain is the most significant surface water system in this zone, but unlike Drain M or the Drain L system to the south, which supply Lake George and Lake Hawdon respectively, this cross-country drain flows directly to the sea and is therefore not a source of fresh inflows to a coastal wetland.

2.5.5.2 Data availability and analysis

The southern catchments of the Blackford Drain flow north-westerly, then west in the main Blackford Drain. A review of existing Watercress models reveals rainfall-runoff factors of 0.020–0.050 for contributing catchments.

The Fairview Drain was constructed as a groundwater-intercepting drain, and can deliver saline groundwater into Blackford Drain for disposal to the ocean, and fresher water into Bakers Range watercourse. Tresent Drain is a small closed catchment draining surface runoff to Fairview Swamp, and a review of previous WaterCress models suggests that this catchment is lower-yielding than the Blackford Drain catchments.

The southern part of the Drain E catchment (north of Bool Lagoon) is also relatively low-yielding, and inflows from Naracoorte Creek are important components of total flow. The Kingston Main Drain in the west of the zone is ungauged, and Wood & Way (2011) were unable to construct a WaterCress model to describe its flows.

The Bakers Range watercourse flows north-westerly through numerous wetland complexes and can carry surface runoff from its own contributing catchment, and flows provided into it from watercourses to the south. Flows can also be diverted from this watercourse in numerous places. It is therefore unlikely that an analysis of flows at the Petherick Road gauge (A2390556) would provide a clear description of runoff from the catchment of the Bakers Range watercourse within Regional Zone e).

The interconnected nature of the drains and watercourses in Regional Zone e make the identification of rainfall-surface water relationships difficult. Table 2.5 summarises the rainfall-runoff relationship for the Blackford Drain, using streamflow recorded at the downstream gauge A2390506. Flows recorded at this gauge represent runoff from the Blackford Drain catchment (756 km^2), with potential contributions from the Fairview Drain (and Bakers Range watercourse flows) from diversions at the Keilira regulator (A2390564). As it is unknown what part of the historical streamflow record represents periods of Fairview contribution to the Blackford, it was assumed that the entire flow record reflected runoff from only the Blackford Drain contributing catchments.

The Fairview Drain represents an additional catchment area of 310.2 km^2. If it was assumed that the Fairview Drain was continually connected to the Blackford Drain, the flow volumes recorded at the A2390506 gauge would correspond to lower runoff depths, such that the rainfall-runoff factor for the median flow year would reduce from 0.040 to 0.032.

2.5.5.3 Issues and risks with current SWPA extent

The existing SWPA includes some complex surface water interactions, with its western extent (predominantly the Blackford Drain catchment) typified by artificial drainage for removal of surface water from agricultural land and the eastern areas including some significant on-stream wetlands. The existing SWPA therefore has areas of variable risks associated with increased surface water abstraction, and it might be more appropriate to link areas with similar risk profile in a SWPA. Although rainfall-runoff relationships for the Blackford Drain can be interpreted from streamflow data, this catchment reflects less than 30% of the total area of the SWPA, and there is less certainty regarding appropriate rainfall-runoff factors for the remaining area of the SWPA.

Table 2.5. Summary of historical rainfall-runoff relationship for Blackford Drain in Regional Zone e

	A2390506 Blackford Drain @ Amtd 4.0km
Catchment area upstream of gauge	836.4 km^2
Proportion of existing SWPA represented by gauge	29.8%
Flow period	1972–2016 (45 years)
Average annual flow (average runoff)	19,933 ML (24 mm)
Median annual flow (median runoff)	18,851 ML (23 mm)
Average annual catchment – averaged rainfall for flow period	558 mm
Median annual catchment – averaged rainfall for flow period	567 mm
Rainfall-runoff factor for median runoff year	0.040

2.5.6 Regional Zone f

2.5.6.1 Description

As shown in Figure A.5, Regional Zone f consists of numerous watercourses that are supplied from the south-east, and a review of previously-calibrated WaterCress models suggest that surface water catchments in this zone generally provide lower yields than areas to the south. This zone includes the Taratap Drain–Tilley Swamp catchment, West Avenue catchment, the northern part of the Bakers Range watercourse catchment, the Kercoonda system, the northern part of Drain E catchment, the Northern Bakers Range catchment (north of Petherick Rd) and the Northern Outlet Drain catchment.

2.5.6.2 Data availability and analysis

The Kercoonda system is supplied from a network of drains designed primarily for shallow groundwater interception, although some of these will also intercept surface runoff that would normally flow into the Bakers Range watercourse. The Bakers Range watercourse, north of the Fairview Drain crossover, has a series of important wetlands but also has low-yielding catchments. The West Avenue catchment also includes some important wetlands and is a closed catchment, with drains that intercept both surface runoff and saline groundwater.

The interconnected nature of the watercourse and drains in this zone, together with potential interactions with groundwater resources, provide uncertainty about the use of historical flows recorded at streamflow gauges in the zone to estimate underlying rainfall-runoff relationships.

2.5.6.3 Issues and risks with current SWPA extent

The existing SWPA encompasses an area with consistent land use and surface water management issues. Given the flat topography of the area covered by this existing SWPA, water affecting activities such as farm dam development are less likely than other parts of the Region. Although there are some important wetlands in this area, many of the natural watercourse flow paths are now heavily modified due to the development of drains to remove surface flood flows and drain saline groundwater.

2.5.7 Naracoorte

2.5.7.1 Description

Naracoorte Creek, the major waterway within the Naracoorte SWPA (shown in Figure A.6), is an important cross-border watercourse that supplies the Drain E system (including the Marcollat watercourse), which supplies numerous high-value wetlands. It has a catchment bordered by Mosquito Creek to the South and Morambro Creek to the North, and it has slightly higher rainfall than the Morambro Creek catchment. The existing SWPA corresponds to the surface water catchment of Naracoorte Creek.

2.5.7.2 Data availability and analysis

Table 2.6 provides a summary of the historical rainfall-runoff relationship for Naracoorte Creek, recorded at the Naracoorte town gauge (A2390542) at the downstream end of the SWPA. These flow data are not expected to represent any contribution from groundwater. These data therefore suggest that this catchment provides much lower surface runoff than some of the south-westerly SWPAs.

Table 2.6. Summary of historical rainfall-runoff relationship for the Naracoorte SWPA

	A2390542 Naracoorte Ck @ Naracoorte
Catchment area upstream of gauge	910 km^2 (465 km^2 in SE Region)
Proportion of existing SWPA (within the SE Region) that is represented by gauge	100%
Flow period	1985–2014 (30 years)
Average annual flow (average runoff)	4,511 ML (5 mm)
Median annual flow (median runoff)	1,471 ML (2 mm)
Average annual catchment – averaged rainfall for flow period	525 mm
Median annual catchment– averaged rainfall for flow period	528 mm
Rainfall-runoff factor for median runoff year	0.003

2.5.7.3 Issues and risks with current SWPA extent

The existing SWPA corresponds directly to the surface water catchment of Naracoorte Creek. Given that this watercourse is an importance source of fresh water for surface water systems flowing in a north-westerly direction across the flatter parts of the Region, the existing SWPA boundaries are appropriate.

2.5.8 Morambro

2.5.8.1 Description

Morambro Creek is a significant cross-border stream, and the only prescribed watercourse in the Region. The existing Morambro SWPA boundary shown in Figure A.6 matched the initial interpretation of spatial information regarding the watershed for Morambro Creek. Wood & Way (2011) noted that the Northern part of the SWPA (within the Little Desert Conservation Park) fails to contribute surface runoff due to its sandy topography with interdunal hollows that collect rainfall for percolation and evaporation. As a result, Wood & Way (2011) proposed that the actual watershed boundary associated with the Morambro Creek (as measured at gauging station A2390531) was much smaller than previously proposed.

2.5.8.2 Data availability and analysis

Table 2.7 summarises the historical rainfall-runoff relationship for the Morambro SWPA, with streamflows measured at the A2390531 gauge at the downstream end of the existing SWPA boundary.

Figure 2.3 and Figure 2.4 show a comparison between the percentage of areas that correspond to both soil waterholding capacity classifications and the surface soil texture classifications respectively for the Morambro Creek catchment area and the remainder of the existing Morambro SWPA, termed 'Morambro North'. These comparisons were generated from a review of spatial data sets and indicate that the Morambro North area has a higher proportion of surface sand, and therefore a lower waterholding capacity, when compared with the Morambro Creek surface water catchment. Both waterholding capacity and soil texture characteristics will contribute to different rainfall-runoff relationships across the two areas.

Table 2.7. Summary of historical rainfall-runoff relationship for the Morambro SWPA

	A2390531 Morambro Ck @ Bordertown-Naracoorte Rd Bridge
Catchment area upstream of gauge	567 km^2 (301 km^2 in SE Region)
Proportion of existing SWPA (within the SE Region) that is represented by gauge	32.3%
Flow period	1977–2016 (40years)
Average annual flow (average runoff)	3,089 ML (6 mm)
Median annual flow (median runoff)	502 ML (1 mm)
Average annual catchment – averaged rainfall for flow period	499 mm
Median annual catchment – averaged rainfall for flow period	499 mm
Rainfall-runoff factor for median runoff year	0.002

2.5.8.3 Issues and risks with current SWPA extent

There are no surface water data corresponding to runoff from the Morambro North area, however Figure 2.3 and Figure 2.4 show that an analysis of soils information can provide insight into the rainfall-runoff relationships for this area. These spatial data appear to support the view of Wood & Way (2011) that the Morambro North area is lower-yielding than the watershed of the Morambro Creek, and suggest that it could be appropriate for Morambro North to be separated from the Morambro Creek watershed, from a surface water management perspective.

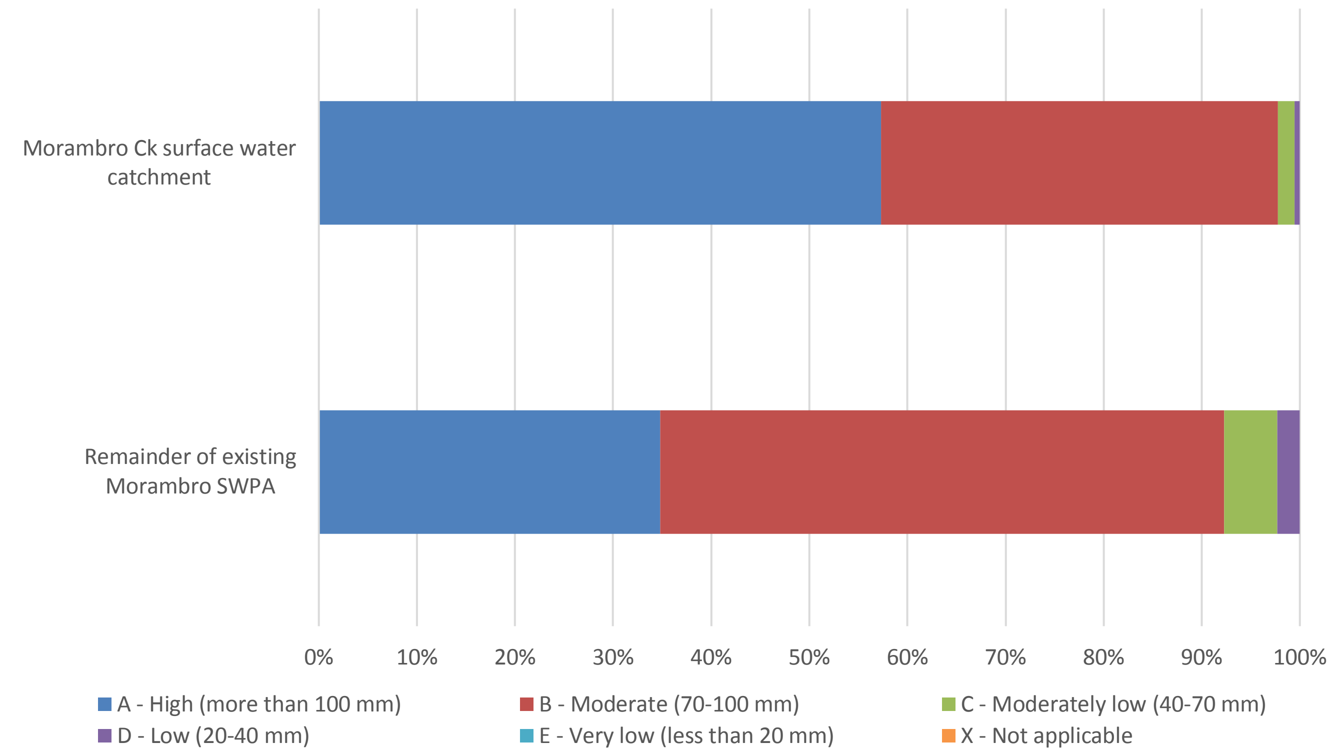

Figure 2.3. Proportions of the watershed of Morambro Creek and of the remainder of the existing Morambro SWPA (termed 'Morambro North') that correspond to various soil waterholding capacity classifications

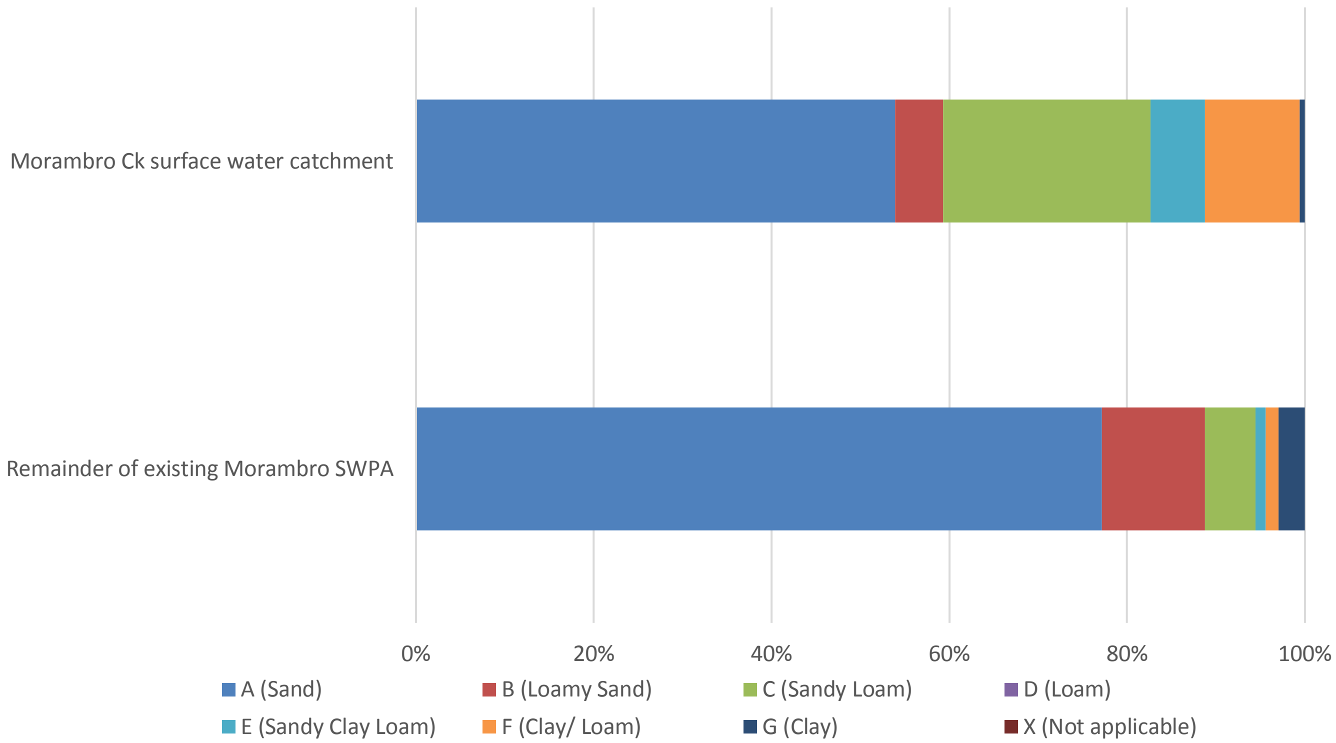

Figure 2.4. Proportions of the watershed of Morambro Creek and of the remainder of the existing Morambro SWPA (termed 'Morambro North') that correspond to various surface soil texture classification

2.5.9 Mosquito

2.5.9.1 Description

Mosquito Creek is the primary source of inflow to the ecologically significant Bool Lagoon and Hacks Lagoon. The Mosquito Creek catchment includes two major streams, shown in Figure A.6, with a long-term flow gauge (A2390519) located after their junction. The existing SWPA corresponds to this surface water catchment.

2.5.9.2 Data availability and analysis

Table 2.8 summarises the historical rainfall-runoff relationship from the Struan gauge (A2390519) at the downstream end of the Mosquito SWPA. These data show that Mosquito Creek has the highest yield of the three major cross-border watercourses, and also suggests that the catchment surface provides a higher runoff response than either the Mosquito Creek or Morambro Creek catchments.

2.5.9.3 Issues and risks with current SWPA extent

The existing SWPA corresponds directly to the surface water catchment of Mosquito Creek. Given that this watercourse is the primary source of fresh water to the ecologically-significant Bool Lagoon and Hacks Lagoon, the existing SWPA boundaries are appropriate.

Table 2.8 .Summary of historical rainfall-runoff relationship for the Mosquito SWPA

	A2390519 *Mosquito Creek @ Struan*
Catchment area upstream of gauge	1002 km^2 (192 km^2 in SE Region)
Proportion of existing SWPA (within the SE Region) that is represented by gauge	100%
Flow period	1972–2016 (45 years)
Average annual flow (average runoff)	20,679 ML (21 mm)
Median annual flow (median runoff)	12,467 ML (12 mm)
Average annual catchment – averaged rainfall for flow period	593 mm
Median annual catchment – averaged rainfall for flow period	581 mm
Rainfall-runoff factor for median runoff year	0.022

2.5.10 Tatiara–Nalang

2.5.10.1 Description

The existing Tatiara–Nalang SWPA covers a significant area of the north-eastern part of the Region, as shown in Figure A.7, and extends beyond the watersheds of the Tatiara and Nalang Creeks into the Mallee area. These two watercourses have significant cross-border catchments, although yields from these watersheds are low, with few flow events having been recorded.

2.5.10.2 Data availability and analysis

Table 2.9 summarises the historical rainfall-runoff responses of this SWPA, with streamflow measured at three separate gauges. Two of these gauges are on Nalang Creek, with the flow record of the upstream gauge (A2390535) ceasing in 1993 prior to the establishment of the downstream gauge A2390562. These data suggest that these catchments generate low runoff, with many periods of zero flow. As a result, median flow years correspond to very low runoff, leading to a low median-year rainfall-runoff factor.

Table 2.9. Summary of historical rainfall-runoff relationships for three gauges in the Tatiara–Nalang SWPA

	A2390534 Tatiara Creek @ Bordertown	***A2390535 Nalang Creek @ Olive Bank***	***A2390562 Nalang Creek @ Allendale***
Catchment area upstream of gauge	818 km^2 (219 km^2 in SE region)	179 km^2 (109 km^2 in SE region)	336 km^2 (266 km^2 in SE region)
Proportion of existing SWPA (within the SE Region) that is represented by gauge	5.6%	2.8%	6.8%
Flow period	1978–2014 (37 years)	1978–93 (16 years)	1995–2013 (19 years)
Average annual flow (average runoff)	2,375 ML (3 mm)	1,334 ML (8 mm)	696 ML (2 mm)
Median annual flow (median runoff)	374 ML (1 mm)	541 ML (3 mm)	59 ML (0.2 mm)
Average annual catchment – averaged rainfall for flow period	458 mm	488 mm	431 mm
Median annual catchment – averaged rainfall for flow period	449 mm	496 mm	416 mm
Rainfall-runoff factor for median runoff year	0.001	0.007	<0.001

2.5.10.3 Issues and risks with current SWPA extent

The measurement of surface runoff in these watersheds, and characterisation of their hydrological processes, is complicated by topographic features that include runaway holes. Wood & Way (2011) noted that these two watercourses have significant ecological value, and therefore future expansion of farm dam development could pose a risk to these resources.

Figure 2.5 and Figure 2.6 compare the percentage of areas that correspond to both soil waterholding capacity classifications and surface soil texture classifications respectively for the surface water catchments of: the Tatiara and Nalang Creeks; the remainder of the existing Tatiara–Nalang SWPA; the Morambo Creek; , and the remainder of the Morambro SWPA. A review of these spatial data reveals that 68% of the Tatiara–Nalang SWPA that is north of the surface water catchments has 'sand' as the dominant surface soil texture category, which is much different than the soil texture of the watersheds of these creeks. In addition, the waterholding capacity of this northern Mallee area is much lower than these other areas. The combination of sandy soils, low watertable and lower rainfall would suggest that little surface runoff would be expected across the Mallee district. Farm dams in this area are likely to be for opportunistic interception, and less likely to pose a risk to WDEs or groundwater recharge than in other areas of the Region.

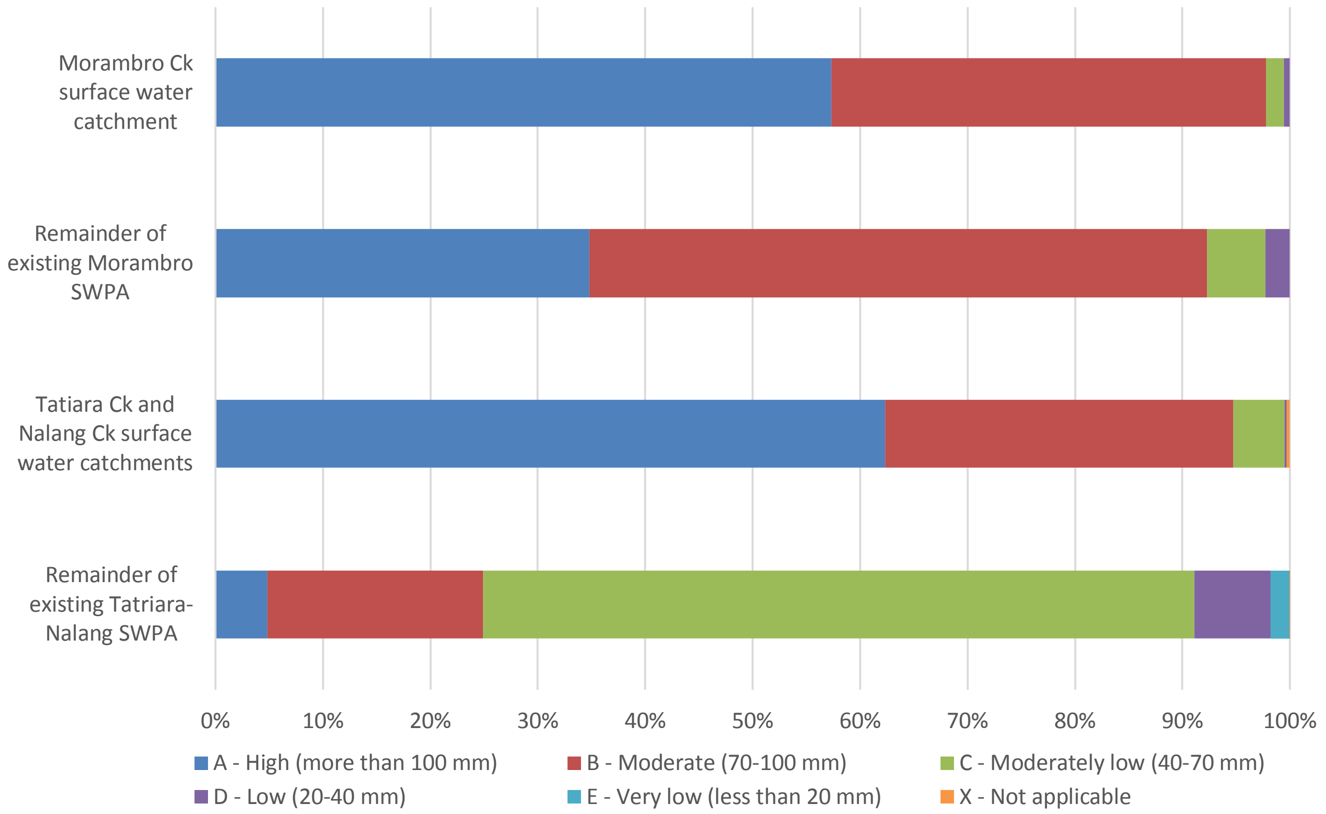

Figure 2.5. Proportions of the Morambro and Tatiara–Nalang SWPAs by soil waterholding capacity classification

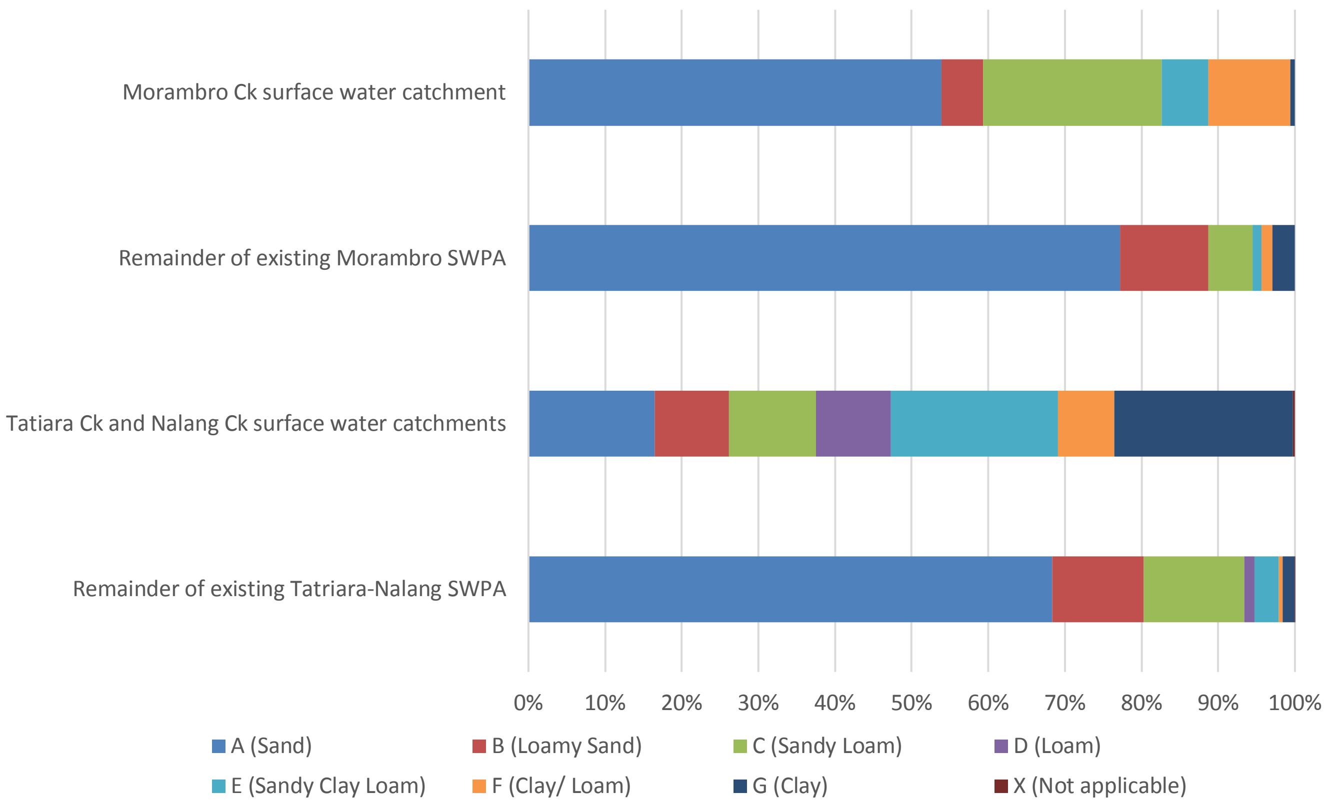

Figure 2.6. Proportions of the Morambro and Tatiara–Nalang SWPAs by surface soil texture class

2.5.11 Glenelg

2.5.11.1 Description

The Glenelg SWPA is defined across the southern part of the Region (adjacent to Regional Zone a), with surface water generally flowing in a south-easterly direction towards the Glenelg River.

2.5.11.2 Data availability

There are no reliable surface water gauge data to inform the rainfall-runoff relationship in this zone. As a result, spatial soil data from both this area and the adjacent Bakers Range South catchment (which has a reliable streamflow gauge) were analysed to infer potential rainfall-runoff relationships. Figure 2.7 and Figure 2.8 compare the percentages of these two areas that correspond to soil waterholding capacity classifications and surface soil texture classifications respectively. These results indicate that the Bakers Range South watershed has a similar soil profile to the Glenelg SWPA, which may lead to a similar rainfall-runoff response in this zone.

2.5.11.3 Issues and risks with current SWPA extent

The Glenelg SWPA covers an area of the SE Region that drains surface flows in a south-easterly direction. This is in contrast to areas directly to the north, which drain either north or northwest, or the surface water catchment of Lake Bonney SE, which drains south-westerly towards this coastal lake. The SWPA is therefore a potential source of surface water supply to the lower reaches of the Glenelg River, which is mostly located within western Victoria, although there are no streamflow gauges from which to record likely catchment surface responses to rainfall events. A review of spatial information can suggest that surface flow data from adjacent zones can be used to infer potential rainfall-runoff relationships in the Glenelg SWPA. Field investigations to better classify the ecological characteristics of this zone will assist in determining the relationship between surface flows and environmental requirements.

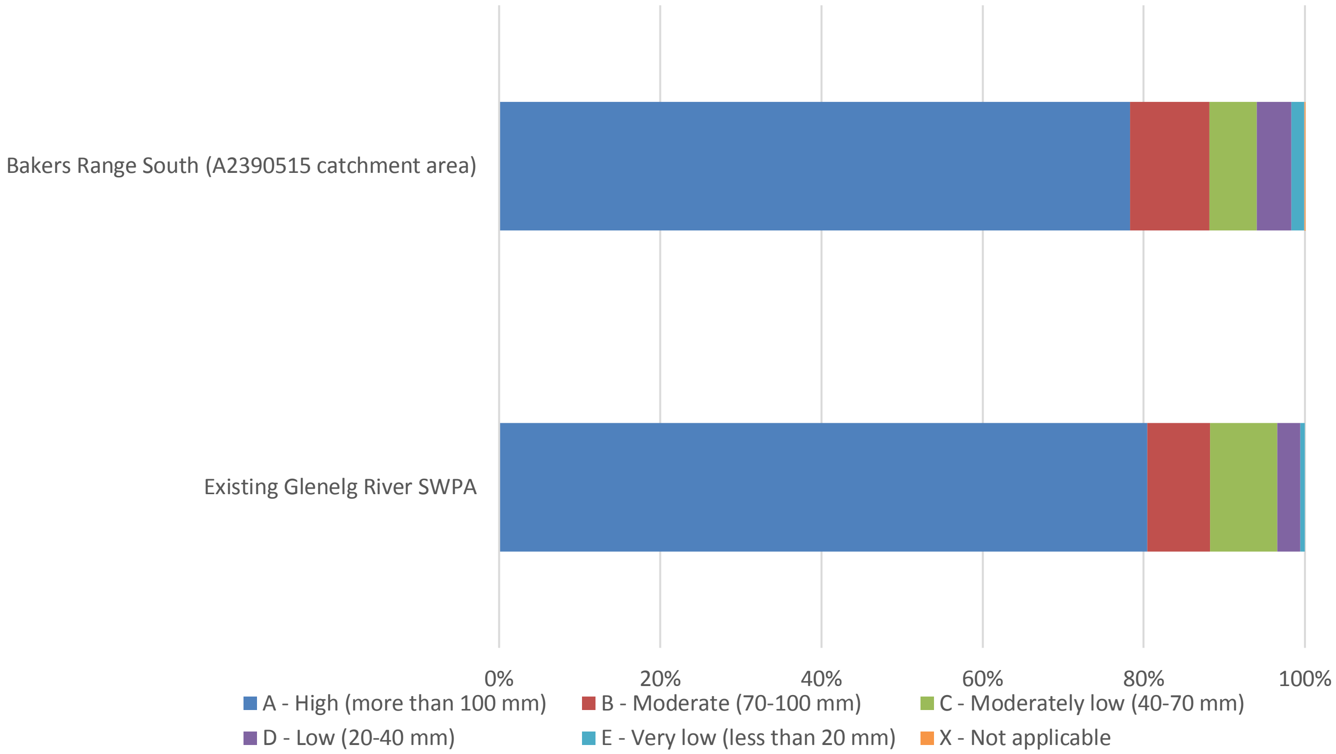

Figure 2.7. Proportions of the existing Glenelg SWPA and the catchment of the Bakers Range South watercourse by soil waterholding capacity classification

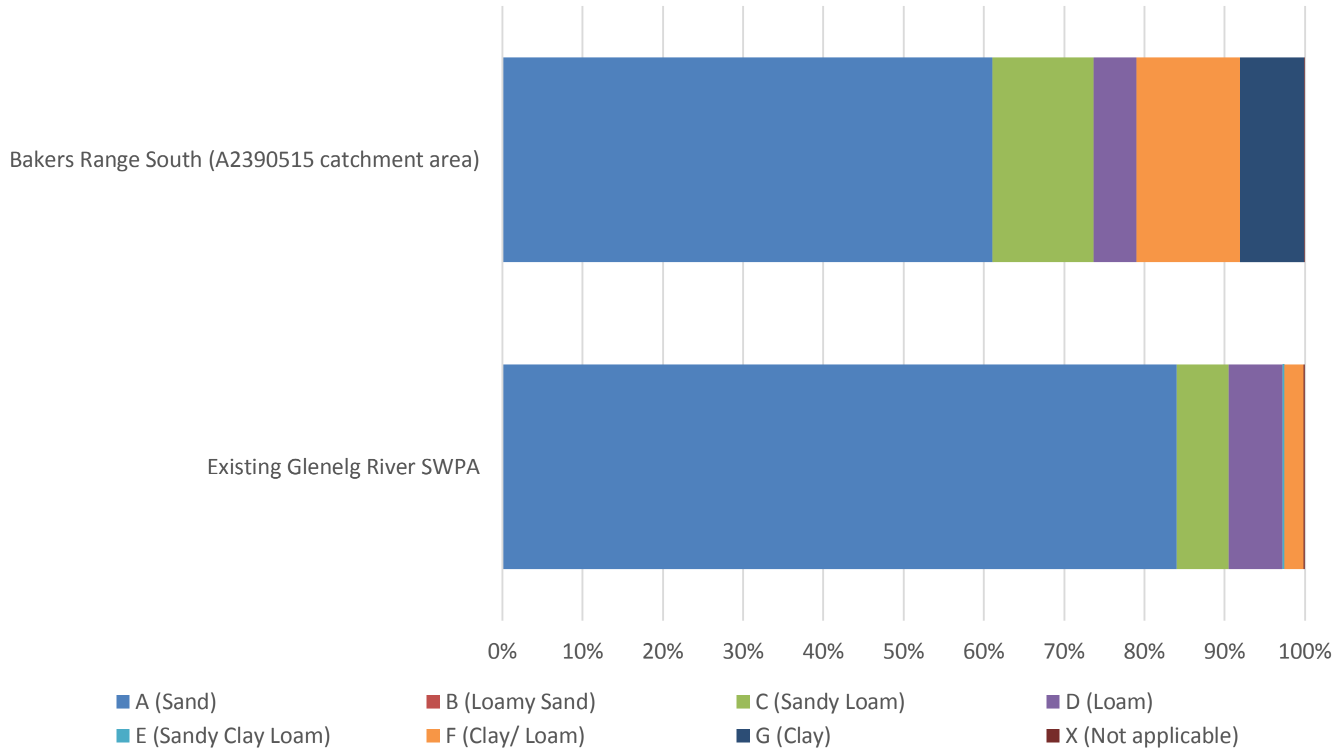

Figure 2.8. Proportions of existing Glenelg SWPA and the Bakers Range South catchment by surface soil texture class

3 Proposed SWPAs

3.1 Methodology used to identify proposed SWPAs

The issues and risks associated with the existing SWPAs, as described in Section 2, were reviewed alongside topographic information for the Region, historical rainfall-runoff relationships and broader surface water management issues to propose new SWPAs.

3.2 Summary of proposed SWPAs

Following review of existing SWPAs, it is proposed that the Region is divided into 12 SWPAs, as shown in Figure 3.1. These proposed SWPA boundaries are compared with the modelled watersheds as defined by Wood & Way (2011) in Figure 3.2, and compared with the existing SWPAs in Figure 3.3. The relationship between the boundaries of the proposed SWPAs and the boundaries of existing SWPAs is further described in Table 3.1.

Table 3.1. Relationship between the spatial extents of proposed SWPAs and existing SWPAs

Proposed SWPA	Spatial relationship to existing SWPAs	Area (km^2)	Proposed rainfall-runoff factor
Glenelg	Same extent as the existing Glenelg SWPA	1,012	0.040
Lake Bonney	Same extent as the existing Regional Zone a	1,720	0.040
Drain C	Area covers the watershed of Drain C, split across the existing Regional Zone c and Regional Zone d	538	0.001
South Western	Area covers the existing Regional Zones b, c and d, minus the area that contributes surface flows to Drain C	5,291	0.050
Mosquito	Same extent as the existing Mosquito SWPA	192	0.022
Naracoorte	Same extent as the existing Naracoorte SWPA	465	0.003
Morambro	Area covers the watershed of Morambro Creek, located within the existing Morambro SWPA	301	0.002
Morambro North	Area represents the difference between the existing Morambro SWPA and the proposed Morambro SWPA	852	0.001
Tatiara–Nalang	Area is limited to the watersheds of Tatiara and Nalang Creeks, located within the existing Tatiara–Nalang SWPA	516	0.001
Flats–Drains	Area covers the existing Regional Zone e and Regional Zone f	7,362	0.040
Murray-Darling Basin	Area represents the northern part of the SE Region, also enclosed by the boundary of the Murray-Darling Basin	1,658[a]	0.001
Mallee	Area represents the north-eastern part of the Region that is not covered by other SWPAs, including the northern part of the existing Tatiara–Nalang SWPA	6,941	0.001

[a] Total farm dam volume for the proposed Murray Darling Basin SWPA will be a negotiated volume.

Five of the 12 proposed SWPAs for the Region (as shown in Figure 3.1) represent areas from which total yield was calculated using historical streamflow gaugings. Table 3.2 summarises the derivation of rainfall-runoff factors for these five SWPAs using historical flow data and area-averaged rainfall data for the surface water catchment of each gauge, derived from the daily SILO patched point data set using the Thiessen polygon method. The rainfall-runoff factors were then calculated as the ratio between the median annual runoff for the gauged period (median annual flow divided by the contributing catchment area upstream of the gauging site), and the area-averaged rainfall in the median runoff year. Appendix B summaries some of these hydrological data. In the remaining eight SWPAs, rainfall-runoff factors cannot be defined from observed hydrological data, and these need to be estimated through other approaches.

Table 3.2. Derivation of rainfall-runoff factors for selected SWPAs with surface runoff represented by single gauge

Proposed SWPA	Flow gauge (period of assessment)	Median annual flow for period, Q_m (ML)	Median annual runoff for period, R_m (mm)	Annual rainfall in year of median annual runoff, P_m (mm)	Rainfall-Runoff factor (R_m/P_m)
Tatiara–Nalang	A2390534 *Tatiara Creek @ Bordertown* (May 1978 – Apr 2014)	374	0.5	449	0.001
Morambro	A2390531 *Morambro Creek @ Bordertown-Naracoorte Rd Bridge* (May 1977 – Apr 2016)	501.7	0.9	469	0.002
Naracoorte	A2390542 *Naracoorte Creek @ Naracoorte* (May 1985 – Apr 2014)	1,471	1.6	534	0.003
Mosquito	A2390519 *Mosquito Creek @ Struan* (May 1972 – Apr 2016)	12,467	12.4	576	0.022
Flats–Drains	A2390506 *Blackford Drain @ Amtd 4.0km* (May 1972 – Apr 2016)	18,851	22.5	560	0.040

The proposed SWPAs are further described in the following sections.

3.2.1 Glenelg SWPA

The existing Glenelg SWPA covers the only area of the SE region that drains in a south-easterly direction, and therefore is a catchment that potentially contributes surface runoff to the Glenelg River in western Victoria. This characteristic supports maintaining this area as a distinct SWPA. A review of spatial information showed a potential similarity between the surface soil behaviour of this ungauged zone and the surface water catchment area of the gauged Bakers Range South watercourse, immediately to the north of this zone. As such, with the latter showing a rainfall-runoff factor for a median flow year of 0.043, it is proposed that the rainfall-runoff factor of 0.040 that is defined in the existing SE NRM Plan be retained.

3.2.2 Lake Bonney SWPA

It is proposed to retain the watershed of Lake Bonney SE as a distinct SWPA since it is a contained area (i.e. its watercourses are not supplied from outside the catchment boundaries), and it supplies a high-value ecological asset of the Region. Uncertainties about hydrological responses across the Lake Bonney SE watershed make the calculation of rainfall-runoff factors, and therefore the definition of allowable dam volumes for the SWPA difficult. As a result, it is proposed that the rainfall-runoff factor of 0.040 is retained from the existing Regional Zone a. Future definition of EWRs for Lake Bonney SE, and the resumption of surface water monitoring in the area, would help to define appropriate limits on surface water abstraction for farm dams in this zone.

3.2.3 Drain C SWPA

As noted previously in discussion of existing Regional Zones c and d, the Drain C catchment is understood to be much lower-yielding than adjacent catchments. Forestry comprises approximately 29% of the total area of the proposed Drain C SWPA, which is significantly higher than other SWPAs, other than Glenelg (33%), and is a contributing factor to this lower yield. It is proposed that its catchment area is defined as a separate SWPA, due to the different rainfall-runoff relationships displayed when compared to nearby SWPAs, and the fact that the Drain C is not a source of fresh water to a key ecological site.

Although Drain C has two historical surface water monitoring sites, the downstream gauge (A2390516 Drain C @ Balma Carra) has gauged flow data for only a 5-year period (1974–8), and an upstream gauge (A2390536 Drain C @ Coonawarra) has 19 years of data split across two periods (1979–88 and 2005-13). An analysis of the limited surface flow data available for this proposed SWPA suggested that an estimate of median annual runoff for this catchment related to a rainfall-runoff factor of less than 0.001. However, with significant uncertainty about rainfall-runoff relationships in this proposed SWPA from a lack of gauged flow data, a rainfall-runoff factor of 0.001 is proposed.

3.2.4 South Western SWPA

It is proposed that the surface watersheds of the Drain L catchment, the Mt Hope–Lake Frome catchment, the Bakers Range South catchment and the Drain M catchment are aggregated to a single SWPA. This area has been termed the South Western SWPA, and encompasses the surface water catchments of watercourses that flow in a south-westerly direction to supply major coastal waterbodies (Lake Hawdon, Lake George and Lake Frome) from a comparatively higher rainfall area of the Region. As previously described, Bakers Range South watercourse flows north, rather than in a south-westerly direction towards the coast. Historically, flow from the Bakers Range South catchment would have continued northward along the Bakers Range Watercourse; however, this pathway was interrupted with the construction of Drain M. It is now a contributing catchment for Drain M flows.

Across larger areas, there will be inherent variability in rainfall-runoff relationships, such that higher rainfall areas may be under-allocated from the use of a constant dam capacity value, and lower rainfall areas may be over-allocated. This zone remains outside the boundaries of the interconnected surface drains further north, and as such, includes contained surface water runoff areas. Although there are no streamflow monitoring stations in this proposed SWPA that are currently gauged, until recently at least five watercourses provided continuous flow records across a number of years. The historical streamflow data for surface water catchments in this proposed zone show similar rainfall-runoff relationships. A rainfall-runoff factor of 0.050 is proposed that is an approximate average of the rainfall-runoff factors for the five gauges, which range from 0.028-0.099. Historical streamflows in Bray Drain and Wilmot Drain revealed rainfall-runoff factors that are higher than 0.050; however, it should be noted that these were derived over a shorter (and wetter period).

3.2.5 Mosquito SWPA

Mosquito Creek is one of the three major watercourses with cross-border catchments that are significant sources of fresh water to supply wetlands and other environmental assets of the SE Region. It is proposed that the existing boundaries of the Mosquito SWPA, which match the boundaries of the surface water catchment for the watercourse, are retained. A review of recent streamflow data proposes a rainfall-runoff factor of 0.022 for this SWPA, a slight reduction from the 0.028 factor defined in the existing SE NRM Plan.

3.2.6 Naracoorte SWPA

In a similar manner to the Mosquito SWPA, it is proposed that the existing boundaries of the Naracoorte SWPA are retained, as they correspond to the surface water catchment of this watercourse. A review of the most recent streamflow data for Naracoorte Creek proposes a rainfall-runoff factor of 0.003 for this SWPA, compared with 0.002 as defined in the current SE NRM Plan.

3.2.7 Morambro SWPA

As described in Section 2.5.8, the existing Morambro SWPA extends beyond the surface water catchment of Morambro Creek (which is similar to the Morambro Water Allocation Plan area), to include significant areas to the north. A review of spatial data sets suggests that this northern zone will be lower-yielding due to a different surface soil profile, and it is therefore proposed that the boundaries of the Morambro SWPA are reduced to the local surface water catchment boundaries for Morambro Creek. A review of the most recent streamflow data for Morambro Creek suggests that a rainfall-runoff factor of 0.002 is adopted for this SWPA, a reduction from 0.007 as used in the existing SE NRM Plan.

It should be noted that the proposed extent of the Morambro SWPA is similar to, but not identical to the Morambro Prescribed Area, as described in the Water Allocation Plan for the Morambro Creek and Nyroca Channel Prescribed Watercourses (SENRMB, 2006), with the latter extending further west than the boundary of the proposed SWPA.

3.2.8 Morambro North SWPA

The area that represents the difference between the existing Morambro SWPA and the proposed SWPA boundary is an area that has been termed 'Morambro North', and it is proposed that this is classified as a distinct SWPA. This area is predominantly sandy, and there is anecdotal evidence that it is 'non-yielding' from a surface water perspective. A rainfall-runoff factor of 0.001 (representing runoff of 0.5 mm for an annual rainfall of 500 mm) is proposed for this SWPA, even though this value likely overstates the underlying rainfall-runoff relationship.

3.2.9 Tatiara–Nalang SWPA

The existing Tatiara–Nalang SWPA extends beyond the water surface catchment areas for the Tatiara and Nalang Creeks to include northern areas that have lower rainfall, and much lower surface response to rainfall events. The Tatiara and Nalang Creeks have cross-border catchments and supply ecologically-significant watercourses. As a result, there are benefits to retaining this area as a separate SWPA with a view towards classifying EWRs for these watercourses. It is proposed that the boundaries of the Tatiara–Nalang SWPA are reduced to match those of the surface watersheds, due to the absence of surface water data in the northern part of the existing Tatiara–Nalang SWPA boundary. The western boundary of the SWPA is proposed to include the outlet of Poocher Swamp (on Tatiara Creek), and gauge A2390562 (Allendale) on Nalang Creek. Therefore, the boundaries of the proposed SWPA represent the surface water catchments of the Tatiara and Nalang Creeks upstream of these two boundary points, which were identified using a Digital Elevation Model.

There are a number of significant swamp areas, including runaway holes, downstream (to the west) of this proposed SWPA and prior to Riddoch Highway, although it is uncertain whether these sites are entirely surface water or groundwater dependent. A potential westerly extension of this SWPA towards Riddoch Highway would increase the catchment area to include significant areas that are currently ungauged. This increases the uncertainty relating to rainfall-runoff relationships.

The Tatiara Creek has a longer continuous record (1978–2014) than Nalang Creek, with gauged data for the upstream gauge of the latter (A2390535 Olive Bank) only available for 1978–92 and data from a downstream gauge (A2390562 Allendale) available for 1995–2012. Consequently, the data for A2390534 (Tatiara Creek @ Bordertown) was used to derive the surface flow characteristics for the entire Tatiara–Nalang SWPA. As a result, a rainfall-runoff factor of 0.001 is proposed for this smaller Tatiara–Nalang SWPA. Although the rainfall-runoff factor for an upstream gauge of the Nalang Creek was slightly higher (0.007), this was calculated over a shorter and wetter period, and the streamflow record for the downstream gauge on this watercourse showed a much lower rainfall-runoff factor that was below 0.001.

3.2.10 Flats–Drains SWPA

The areas of Regional Zones e and f are proposed to be aggregated to a single SWPA termed Flats–Drains SWPA. This zone has consistent topography and is dominated by a complex system of drains that allow removal of surface water and generally saline groundwater flows. A large array of flow regulating structures enables the interconnection of flows originating from different parts of this SWPA. However, the interconnectivity of these drain systems, together with the uncertainty regarding surface water-groundwater interactions in many parts of this SWPA impedes the estimation of underlying rainfall-runoff relationships.

Further complicating the characterisation of surface water response within the proposed Flats–Drains SWPA is the contribution of flows from watercourses with upstream catchments, including the Naracoorte and Morambro Creek SWPAs. These upstream catchments can contribute varying quantities of flow into the watercourses and drain systems of the lower SWPA.

The A2390506 gauge at the downstream end of Blackford Drain represents the most useful surface water gauge in this zone, as it has a relatively long daily flow record, and more certainty regarding its contributing catchment. A review of the rainfall-runoff relationship for the Blackford catchment shows a rainfall-runoff factor for a median flow year that is consistent with the value used in the existing SE NRM Plan, of 0.040, and this is proposed for the Flats–Drains SWPA.

3.2.11 Murray-Darling Basin SWPA

Small areas of the northern part of the Region that were not classified in a SWPA in the existing SE NRM Plan, are also located within the boundaries of the Murray-Darling Basin (MDB). Water affecting activities in this area may have implications for the development of policies for the broader MDB region. As a result, it is proposed that the part of the Region that also lies within the MDB boundary should be defined as a separate SWPA to enable close alignment on WAA policies, in particular, in relation to farm dam capacity limits. There are no streamflow gauges in this area, and surface runoff is expected to be negligible. As noted previously, a minimum value of 0.001 is proposed for the rainfall-runoff factor of this SWPA.

3.2.12 Mallee SWPA

A large section in the north of the Region is not included within the boundaries of existing SWPAs, primarily because there are no significant watercourses in this northern area, and therefore there are no flow data from which to inform an understanding of underlying hydrological processes. In order to propose SWPAs that enclosed the entire Region, various spatial datasets were analysed to understand the likely rainfall-runoff relationships in the northern area, which closely matches the extent of the Mallee NRM Sub-region as developed by NRSE. As shown in Figure 2.5 and Figure 2.6, the combination of sandy soils, low watertable and lower rainfall suggests that little surface runoff would be expected across the Mallee district. Farm dams in this area are likely to be for opportunistic interception, and less likely to pose a risk to WDEs or groundwater recharge than in other areas of the Region. It is proposed that a new Mallee SWPA is described to cover the area that was previously outside the extents of the SWPA boundaries, including the northern part of the existing Tatiara–Nalang SWPA. A rainfall-runoff factor of 0.001 was chosen for this region (representing runoff of 0.4 mm for annual rainfall of 400 mm), even though this value likely overstates the underlying rainfall-runoff relationship.

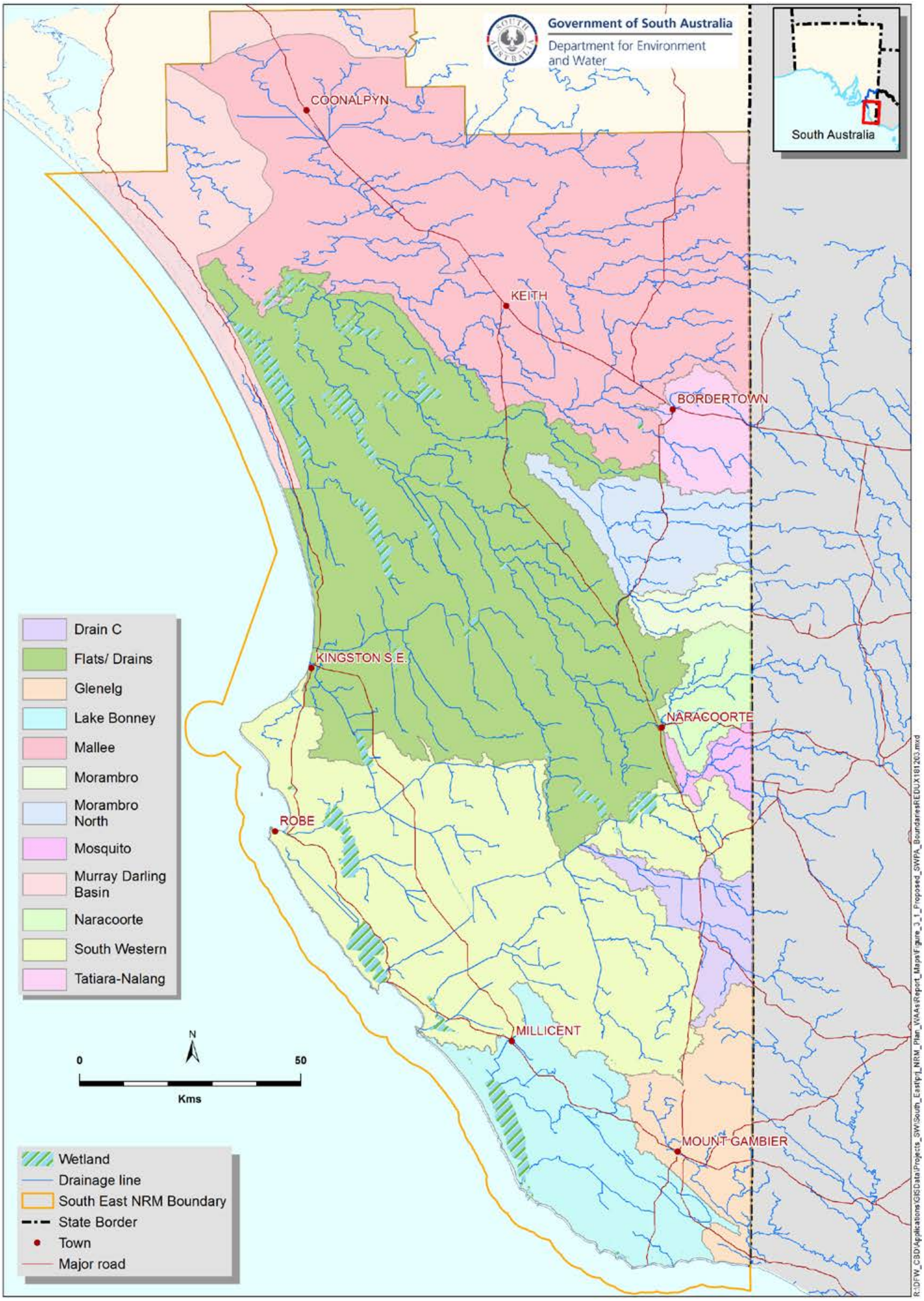

Figure 3.1 Proposed SWPA boundaries

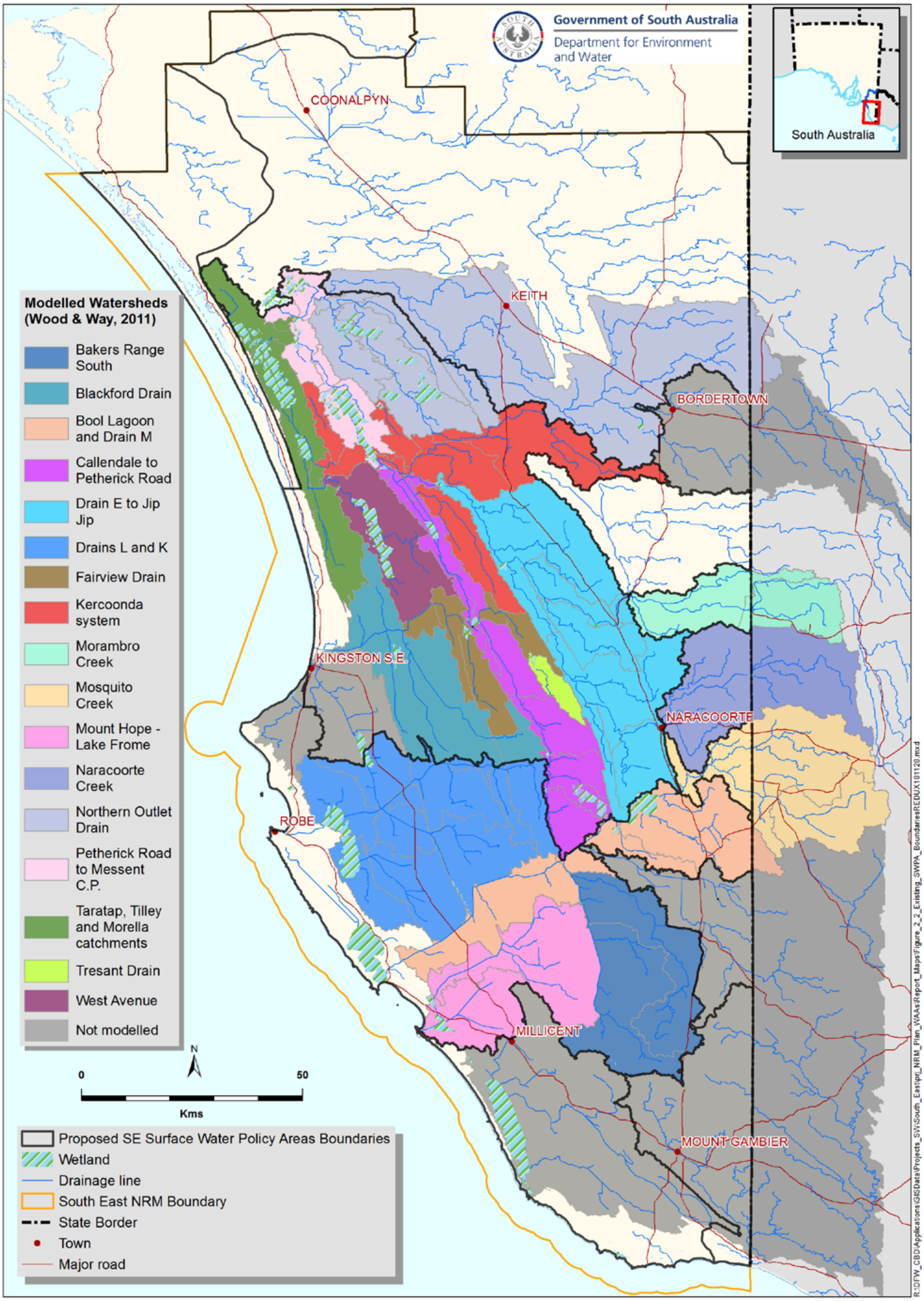

Figure 3.2 Proposed SWPA boundaries (black lines) alongside modelled watershed boundaries (Wood & Way, 2011)

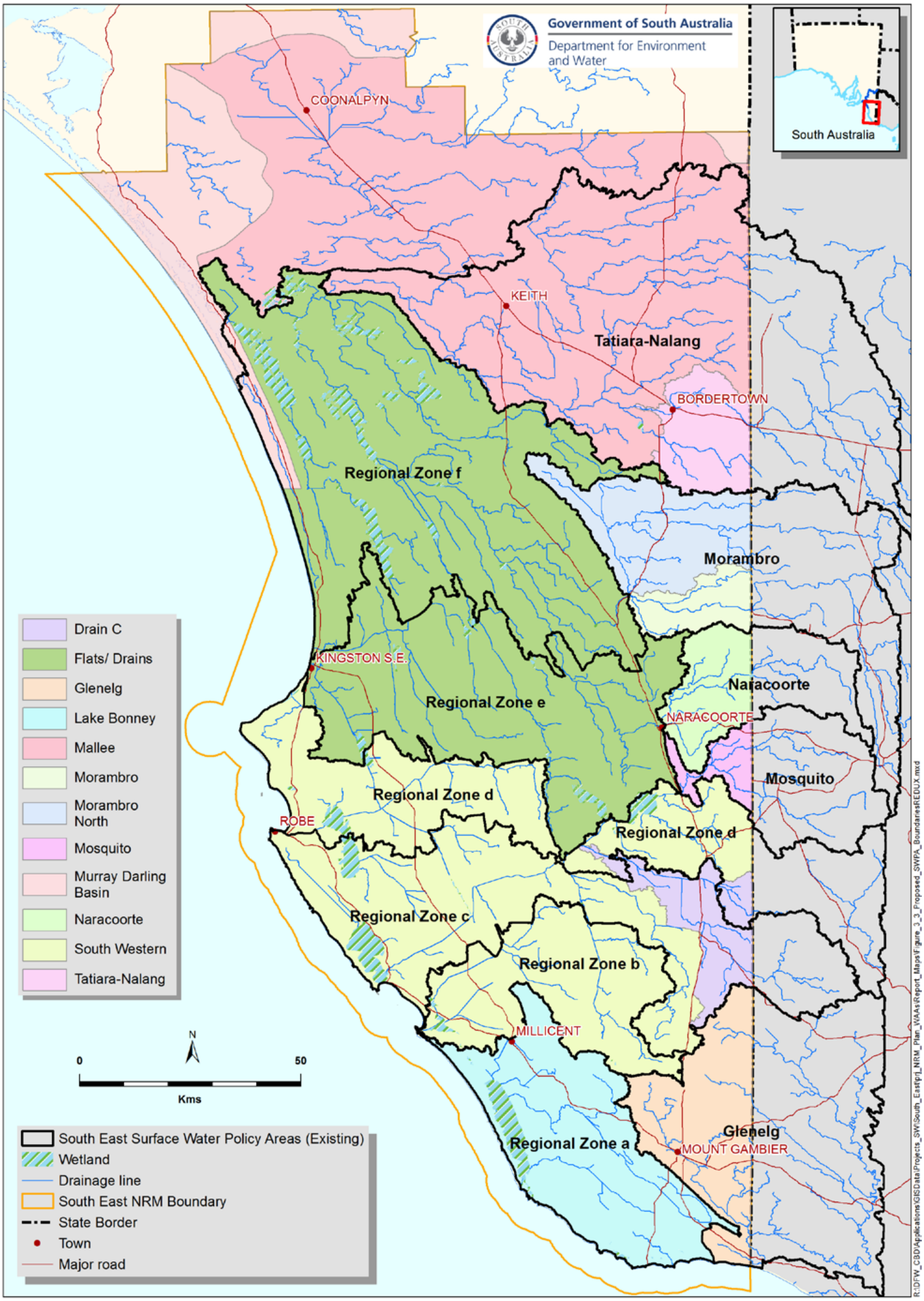

Figure 3.3 Proposed SWPA boundaries (coloured) alongside existing SWPA boundaries

4 Limits on surface water capture, diversion and use

4.1 Background

Different regions of South Australia have experienced significant development of surface water resources since the late 1970s. Across the Mt Lofty Ranges (MLR), the Fleurieu Peninsula, the Mid-North and Kangaroo Island, this development generally included the construction of runoff/surface water-capturing farm dams in the hilly terrain (headwaters) of catchments, with direct extractions and diversions from watercourses that are draining through flatter sections of catchments.

In the South East, dominant water issues relate to draining excess surface and groundwater from the landscape through the construction of a series of drain networks and introduction of plantation forestry. The construction of capturing dams is less prominent when compared to other parts of the State.

4.2 Limits for surface water use

A Water Use Limit (WUL) is a general description for the maximum annual volume of surface water and watercourse water that is permitted to be taken in a surface water management zone, such as a SWPA in the SE Region. WULs are generally defined as a proportion of the surface water resource capacity, which is the total volume of surface water runoff at the downstream end of a surface water management zone. The surface water resource capacity is the runoff that would flow over land if there were no dams or forestry development in that zone. WULs are set to ensure sufficient flows for WDEs, underground water recharge and system losses, as well as for downstream users.

4.2.1 Statewide policy guidelines – the '25% Rule'

A statewide policy framework has been developed to protect the consumptive needs of existing surface water users, to reduce further degradation of water-dependent ecosystems and to manage resources in a sustainable manner. This policy framework was informed from water resource investigations undertaken in the catchments of the MLR and the Mid-North region (Clare Valley) to assess the impacts of development. Based on the outcomes of these investigations, the State NRM Plan 2006 (prepared under the *NRM Act 2004*) presented a broad state wide policy framework to manage surface water resources outside of prescribed areas or areas that had a water allocation plan.

The State NRM Plan 2006 (DWLBC, 2006) defines a standard approach in defining surface WULs as:

'*Outside prescribed areas, and until there is additional information, 25% of median annual adjusted catchment yield should be used as an indicator of the sustainable limit of the catchment surface water and watercourse water use. 'Adjusted' is defined as the annual catchment discharge with the impact of dams removed*' (Appendix 2 of the State NRM Plan 2006).

As such, 25% of the catchment yield should provide an *indication* of the sustainable use limit of available surface water resources until additional information becomes available. Investigations undertaken at a similar time in eastern states of Australia (e.g. Nathan *et al*., 2002; SKMCRC, 2002; SKM, 2003) defined sustainable surface water use limits in a similar manner.

In areas of South Australia where estimated water use exceeded the 25% limit, further detailed investigations were undertaken to assess the risks of developments to existing water users, including risks to water dependent ecosystems. Based on these investigations and risk assessments, water resources in high risk areas have been prescribed and water allocation plans developed to manage resources in a sustainable manner. The Western and Eastern MLR regions, Clare Valley, Barossa Valley, and Morambro Creek in the SE Region are some of the areas where surface water resources have been prescribed and water allocation plans prepared.

4.2.2 25% used but not 75% to pass!

The allocation of 25% of median annual catchment yield for consumptive use does not imply that 75% of median annual catchment yield is available to pass downstream. When 25% of median runoff is allocated:

- Another 25% of the captured catchment runoff can be expected to be lost from farm dams to evaporation and seepage.
- Less than the median catchment yield will actually be available for half of the time, as a result of normal climatic fluctuations and variability. This will be exacerbated by farm dam development, which tends to capture a greater proportion of the runoff when conditions are dry.
- A significant portion is effectively inaccessible as it can be expected to occur in a small number of relatively large events that cannot be harvested.

4.2.3 Existing method in SE NRM Plan – using 25% of recorded yield

The existing SE NRM Plan uses an assumption that total farm dam capacity for each SWPA is limited to 25% of the average annual yield from the SWPA. The 25% proportion appears to be derived from a default position presented in the State NRM Plan 2006 (DWLBC, 2006), which states that the limit for *surface water use*, not limit for dam capacity, in areas outside of prescribed areas, should be calculated as 25% of annual *adjusted* yield.

There appears to be two different issues with the methodology in the current SE NRM Plan; the first being whether to define limits for surface water use as 25% of *adjusted* yield or to use 25% of *recorded yield*, and the second being whether the 25% rule remains a limit for *water use* or as a limit for *dam capacity*. This section addresses the first issue, with the definition of dam capacity limits discussed in Section 4.3.

The existing SE NRM Plan does not propose the calculation of *adjusted* yield, rather the use of recorded yield. The calculation of water use limits using the assumptions outlined in the existing SE NRM Plan relies upon rainfall-runoff factors, as described in Section 3.2, to estimate surface yield from area-averaged rainfall across the proposed SWPAs, particularly in parts of the Region in which gauged hydrological data are limited.

For the proposed Tatiara–Nalang, Morambro, Naracoorte and Mosquito SWPAs, rainfall-runoff factors were calculated as the ratio of median annual runoff from historical streamflow data to the annual area-averaged rainfall in the median runoff year. In addition, these SWPAs represented surface water catchment areas, such that spatially-averaged rainfall across the SWPA represented rainfall that contributed to surface runoff as measured at streamflow gauges. Consequently, the calculation of surface water use limits for these four SWPAs used the median annual area-averaged rainfall for the periods over which historical streamflows were available (shown in Table 3.2).

For the other eight SWPAs, rainfall-runoff factors were estimated and not derived from historical streamflow data. As such, the calculation of the surface water use limits for these SWPAs using this approach relied upon the product of these estimated rainfall-runoff factors and the average annual rainfall (aggregated across each policy area) for a common 40-year period (1977–2016). Area-averaged rainfall was calculated for each SWPA using the SILO patched point rainfall dataset and the Thiessen Polygon approach.

Table 4.1 summarises the calculation of surface water use limit ('Recorded WUL') for each SWPA as 25% of surface yield, calculated as the product of annual area-average rainfall, rainfall-runoff factor and policy area. These calculations show a total water use limit for the Region of 102,582 ML. This total includes 597 ML for the Mosquito Creek SWPA, although the current SE NRM Plan indicates that there is no further dam development permitted in this area. The remaining water use limit of 101,985 ML represents a slight reduction from the total *dam capacity* limit for the Region of 102,434 ML as provided in the existing Plan.

Table 4.1. Surface Water Use Limits (WULs) for proposed SWPAs assuming 25% of recorded yield

Proposed SWPA	Policy area (km^2)	Annual area rainfall (mm)		Rainfall Runoff factor	Allowable volume (ML/ha)	'Recorded WUL' (ML)
		Median (P_m)	Average (1977–2016)			
Tatiara–Nalang	516	448.8		0.001	0.0011	59
Morambro	301	468.8		0.002	0.0023	67
Naracoorte	465	533.8		0.003	0.0040	188
Mosquito	192	576.4		0.022	0.0317	597
Mallee	6,941		433.4	0.001	0.0011	752
Murray-Darling Basin	1,658		454.4	0.001	0.0011	188
Morambro North	852		474.9	0.001	0.0012	101
Lake Bonney	1,720		730.8	0.040	0.0731	12,570
Drain C	538		618.3	0.001	0.0015	83
South Western	5,291		647.5	0.050	0.0809	42,824
Flats–Drains	7,362		515.6	0.040	0.0516	37,958
Glenelg	1,012		710.9	0.040	0.0711	7,194
					Total=	102,582

4.2.4 Proposed method for South East – using 25% of adjusted yield

As described previously, the State NRM Plan 2006 (DWLBC, 2006) presents a default position for water use limits being 25% of the annual yield adjusted to include the impacts of existing on-stream or capturing dams, watercourse extractions and plantation forestry. Appendix C provides a discussion about how adjusted annual catchment yield (i.e. yield adjusted for the effects of farm dam, authorised diversions/extractions and forestry development) can be determined in terms of the breadth of hydrological data available for an area.

The calculation of median annual adjusted yield, which is used in many applications of the 25% rule, usually requires the development of catchment scale rainfall-runoff models with explicit representation of farm dams, watercourse extractions and plantation forestry, together with the associated data collection, to calculate the hydrological impacts of current extractions. The development of such models across the SE Region will require significant resources.

As stated in Appendix C, the process undertaken to calculate water use limits (WULs, as an alternative term for 'sustainable use limits') for gauged/ungauged catchments or sub-catchments that do not have a rainfall-runoff model would be as described in Eq. 1:

Adjusted WUL (ML) = 0.25 X [Median annual recorded flow (ML) + IFD (ML) + IWC (ML) + IPF (ML)] Eq.1

Where: IFD (ML) = estimated impact of farm dams on streamflow

IWC (ML) = annual water extracted/diverted from watercourses

IPF (ML) = estimated impact of plantation forestry on surface water

Previous investigations (e.g. McMurray, 2004) have estimated that the impact of existing farm dams on streamflows (IFD) in the Mt Lofty Ranges was approximately 50% of the total farm dam volume within the catchment. Plantation forestry in the Mt Lofty Ranges and Kangaroo Island have been estimated to reduce potential surface runoff by 85%.

In order to calculate the WUL for each policy area, it was necessary to estimate the three parameters IFD, IWC and IPF as shown in Eq. 1. The procedure described in Appendix D was used to analyse spatial data to estimate the total surface area of farm dams (and therefore the total storage volume) in each proposed policy area, and the total coverage of forestry. Table 4.2 summarises farms dam development, forestry and watercourse extraction within each proposed SWPA, alongside estimated total farm dam volume and total plantation forestry coverage for the Region.

It should be noted that for the four SWPAs with cross-border catchments, rainfall-runoff relationships were calculated using the entire catchment areas. Water Use Limits for these SWPAs were however calculated using only the surface water catchment area within South Australia. Streamflow records that were used to calculate rainfall-runoff relationships account for the impact of development within the Victorian portion of these catchments; however, the farm dam volumes and areas of forestry development within Victoria were unavailable and therefore not used for calculating adjusted water use limits within South Australia.

The South East Water Conservation and Drainage Board (SEWCDB) authorises the take and use of water from drainage channels and associated water management works under its control. The SEWCDB has issued eight permits for the Authorised Take and Use of Water (ATUW) in the Region, with all of these located in the Eight Mile Creek area, which is within the proposed Lake Bonney SWPA. There are also two permits for extractions from Drain 56 (near Millicent), also in the proposed Lake Bonney SWPA, which are based on the historical use of the water at these sites. In addition, the SEWCDB has issued one licence for the diversion of water from Drain M, slightly upstream of Lake George (in the proposed South Western SWPA), and another for environmental flow releases from Drain E (in the proposed Flats–Drains SWPA).

Table 4.2. Estimated farms dam, watercourse extraction/diversions and plantation forestry development

Proposed SWPA	Farm dam development		Authorised annual extractions/diversions (ML)	Plantation forestry (ha)
	No. of dams	Total estimated volume (ML)		
Tatiara–Nalang	976	798		19
Morambro	430	509		32
Naracoorte	449	777		212
Mosquito*	112	139		401
Mallee	6,232	7,503		240
Murray-Darling Basin	279	358		30
Morambro North	2,378	1,906		1,244
Lake Bonney	318	620	1,380	31,294
Drain C	250	435		15,375
South Western	1,251	1,865	775	60,679
Flats–Drains	2,539	3,118		10,705
Glenelg	197	423		33,585
SE Region total	**15,411**	**18,451**	**2,155**	**153,816**

The data provided in Table 4.2 were used to calculate a WUL for each proposed SWPA using Eq.1, which required median annual recorded flow as input. As catchment-scale rainfall-runoff models have not been developed for the Region, median annual yields were estimated using median rainfall-runoff factors for Tatiara–Nalang , Mosquito, Naracoorte and Morambro SWPAs (the four SWPAs in which gauged flow data are available), and median annual rainfall and the total contributing catchment areas as shown in Table 4.2. For the remaining SWPAs, an average annual yield was calculated using the rainfall-runoff factors and average rainfall (1977–2016) shown in Table 4.2, and contributing catchment areas. In each of these eight SWPAs, except for the cross-border Drain C, the total catchment area corresponded to the total policy area (constrained by the State border) as shown in Table 4.3.

Table 4.3 shows the calculation of the WULs for each SWPA assuming 25% of adjusted yield, with a total WUL of 113,903 ML for the Region that is 11,321 ML higher than the 'unadjusted' WULs calculated in Table 4.1. If the impact of farm dams across the Region was assumed to be 100% of the total farm dam capacity instead of 50%, then the IFD variable would increase by 9,226 ML across the region, and the estimate of total WUL would increase by 2,151 ML (or 1.9%).

It is proposed that these adjusted WULs represent a more appropriate description of limits on water use in the Region than the 25% of calculated (or unadjusted) surface yield. The adjusted WULs are consistent with the default position of the State NRM Plan 2006 by accounting for the impacts of existing farm dams, watercourse extractions and plantation forestry on potential surface yield.

Table 4.3. Surface Water Use Limits for proposed SWPAs assuming 25% of adjusted yield

Proposed SWPA	Contributing Area (km^2)	Annual yield (ML)		Annual runoff (mm)	IPF (ML)	IFD (ML)	IWC (ML)	WUL (ML)	(Adjusted WUL – Recorded WUL) (ML)
		Median	Average						
Tatiara–Nalang	818	374		0.46	0	399	-	122	+63
Morambro	567	502		0.89	0	255	-	100	+34
Naracoorte	910	1,471		1.62	3	389	-	238	+50
Mosquito	1,002	12,465		12.44	42	70	-	602	+5
Mallee	6,941		3,008	0.43	1	3,752	-	1,690	+938
MDB	1,658		753	0.45	0	179	-	233	+45
Morambro North	852		405	0.47	5	953	-	341	+240
Lake Bonney	1,720		50,279	29.23	7,776	310	1,380	14,936	+2,366
Drain C	1,069		661	0.62	81	218	-	121	+38
South Western	5,291		171,296	32.38	16,698	933	775	47,425	+4,601
Flats–Drains	7,362		151,834	20.62	1,877	1,559	-	38,817	+859
Glenelg	1,012		28,777	28.44	8,118	212	-	9,277	+2,082
SE Region total								**113,903**	**+11,321**

Where IPF = estimated impact of plantation forestry on surface water
IFD = estimated impact of farm dams on streamflows
IWC = annual volume extracted/diverted from watercourses
WUL = Water Use Limit for the Proposed SWPA, as defined in Appendix C
MDB = Murray-Darling Basin

4.3 Development limits for surface water catching dams

4.3.1 Statewide default policy – the '50% rule'

The 25% rule in the State NRM Plan 2006 (DWLBC, 2006) evolved from a '50% rule' as presented in the State Water Plan 2000 (DWR, 2000). To ensure that all surface water was equitably shared, the 50% rule required that half the runoff from any property should pass to downstream users, leaving a maximum of 50% of the runoff to be captured for use. Due to the lack of inflow during dry years, unharvestable spills occurring in large events and wet years, evaporation and seepage, experience showed that approximately half of this volume could then be reliably accessed from farm dams every year, giving rise to the 25% rule.

4.3.2 Morambro Creek Water Allocation Plan (WAP) 2006

The Morambro WAP defines limits for the development of catching dams at both management and allotment scales, as the product of the area of management zone or allotment and a Maximum Dam Capacity Factor of 0.05 ML/ha (5 mm runoff depth).

A 2004 review of hydrological investigations undertaken to inform the Morambro Creek WAP (Cresswell, 2004) indicated that long-term mean annual runoff for Morambro Creek was assumed to be 11.5 mm, with median annual runoff of 5 mm. It was unclear whether the Maximum Dam Capacity Factor of 5 mm was calculated as 50% of the mean annual runoff (11.5 mm), but if this was the case, it should be noted that mean annual flows were used in preference to median annual flows as defined in the State NRM Plan 2006. Cresswell (2004) demonstrated that the median annual flow for Morambro Creek was approximately one-third the mean annual flow, and therefore recommended the use of the larger flow rate (mean annual flow) to more adequately balance the environmental and economic needs for water.

4.3.3 Proposed methodology for dam capacity limits in the SE Region

Two options are presented to the SE Region for use as interim methodologies for the definition of development limits for capturing dams until further local-scale investigations are completed:

Option 1: The total capacity limit for catching dams within a SWPA is defined as '50% of annual adjusted yield', as recommended in the State NRM Plan 2006, and used widely across other regions in the State. This option assumes that dams are generally over-sized, constructed to a capacity that is much higher than the long-term runoff generated from their upstream area, and therefore will not fill-and-spill on an annual basis.

Option 2: The total capacity limit for catching dams within a SWPA is defined as '25% of annual adjusted yield', to be adopted as a precautionary and conservative measure. This option assumes that dams are not over-sized, and will fill-and-spill more often than in under Option 1.

As discussed previously, the 25% rule for surface water use limit and the 50% rule for dam capacity limit were developed from investigations primarily undertaken in the Mt Lofty Ranges. It is recognised that the landscape and hydro-geological features of catchments and farm dam characteristics in the SE Region differ from those in Mt Lofty Ranges catchments. This highlights uncertainties regarding the applicability of this methodology to the SE Region, and therefore the options presented above should be considered as an interim measure until further investigations are undertaken to:

- Validate existing farm dam surface area to volume relationship(s) that are specific to the landscape features and hydro-geological conditions of the SE Region. This will improve the understanding of the type, geometry and characteristics of dams built in the region, increase the confidence in selecting a methodology to estimate farm dam volumes, and provide better understanding of the impacts of catching dams on surface water resources.
- Develop rainfall-runoff models with explicit spatial representation of farm dams for areas with currently high farm dam development (and for areas where there is a high likelihood of large-scale development of catching dams) to better quantify the impact of farm dams on surface runoff.
- Based on the results of these investigations, re-assess and validate the assumptions used in the derivation of the 25% rule and the 50% rule in order to better reflect the hydro-geological characteristics and the ecosystem functions in the SE Region.

4.4 Threshold flow rates (TFRs) for watercourse diversions

Threshold flow rates (TFRs) set a minimum rate, such that watercourse flows below a TFR are intended to be diverted around catching dams (using Low Flow Bypass (LFB) mechanisms), or left in-stream for the case of water being diverted directly from watercourses. TFRs are generally set following detailed site investigations to relate watercourse flow rates with flow depth and characterisation of WDEs, such as ensuring the provision of sufficient depth of flow to maintain core aquatic habitat (refugia) and promote plant reproduction during key flow periods (e.g. VanLaarhoven, 2010).

4.4.1 Statewide default policy – 10th percentile exceedance daily flows

The water management framework outlined in the State NRM Plan 2006 assumes that if surface water development is limited to the surface WULs of a catchment (from the 25% rule), a range of flows including medium-sized and larger flow events would be available for capture or diversion at downstream locations. Since the development of the State NRM Plan 2006, preliminary investigations on the flow requirements of WDEs mainly in catchments of the Mt Lofty Ranges and the Mid-North (e.g. VanLaarhoven and van der Wielen, 2012) identified the importance of low flows in maintaining healthy WDEs (mainly in-stream permanent pools).

The *10th percentile exceedance daily flow rate* was derived as a suitable hydrological metric to meet the low flow requirements of typical in-stream WDEs observed in MLR catchments. A TFR equal to the *10th percentile exceedance daily flow rate* indicates that flow rates will exceed this value for around 10% of the time (around 36 days) during a year on average. This metric is termed 'TFR_L' in this report, to indicate its intent to address the low flow requirements of in-stream WDEs without accounting for the medium and high-flow requirements of other WDEs, including inland, terminal and coastal waterbodies (lakes, wetlands and swamps), and floodplain WDEs.

The *10th percentile exceedance daily flow rate* has been adopted as the default TFR for new dams and watercourse extractions in non-prescribed areas across the State where detailed investigations on flow requirements of local WDEs have not been undertaken. In such cases, flows below the TFR_L are to be either diverted around catching dams (using LFB mechanisms), or left in-stream in the case of water being diverted directly from watercourses.

4.4.2 Eastern and Western Mt Lofty Ranges Water Allocation Plans (2013)

Detailed investigations (e.g. VanLaarhoven and van der Wielen, 2012) on WDEs and their flow requirements in the eastern and western Mt Lofty Ranges (EMLR and WMLR) catchments were undertaken during the development of their Water Allocation Plans (SAMBDNRMB, 2013; AMLRNRMB, 2013). These investigations demonstrated that by limiting the total water use within the WMLR to 25% of the mean annual adjusted yield (and 20% in the EMLR), the low-flow requirements for WDEs were better expressed using the *20th percentile exceedance non-zero daily flow rate* metric. This alternative TFR accounts for the ephemeral nature of watercourses in the MLR, that do not flow throughout the year, and therefore the TFRs were calculated only for the flowing period.

4.4.3 Morambro Creek Water Allocation Plan (2006)

The Morambro Creek Water Allocation Plan (SENRMB, 2006) defines diversion rules (or TFRs) for 'Taking of Water' from the prescribed watercourse (Section 16, page 41) in two components; Component A described the 'base' component of the allocation, with Component B describing the 'flood flow' allocation. The rules for watercourse diversions were developed from detailed investigations of the different WDEs within the prescribed area, and their flow requirements (REM, 2003). The rules for take (or diversion) comprise three elements:

- Cockatoo Lake must be 80% full;
- Water can only be diverted when flows exceed 230 L/s (20 ML/d) (the TFR for the watercourse); and
- When flows are above the TFR, the maximum amount of water that can be taken at any location on the prescribed watercourse cannot exceed 50% of flow at that location.

Assessment of streamflow records from Morambro Creek for 1985–2003 (Cresswell, 2004) showed that flows above this TFR occur 27 days in a year on average (an average of 7% of days, or the *7^{th} percentile exceedance daily flow rate*). This is comparable to a TFR_L of the 10^{th} percentile exceedance daily flow rate that was described previously as having been developed as a default statewide approach.

The rules for take for the Component B allocation (flood diversion) comprise four elements:

- 4,300 ML must have passed (spilled from) the Jip Jip weir gauging station in the water use year;
- Cockatoo Lake must have filled to capacity during the water use year;
- Water can only be diverted when flows exceed 1,200 L/s (100 ML/d) (TFR_H for the watercourse); and
- When flows are above TFR_H, the maximum amount of water that can be taken at any location on the prescribed watercourse cannot exceed 50% of flow above 1,200 L/s passing that location.

An assessment of streamflow records from Morambro Creek for 1985–2003 (Creswell 2004) showed that the spill at Jip Jip exceeded 4,300 ML in 5 of the 19 years, with an average diversion of 139 ML/d available under the Component B licence across the 19 years.

4.4.4 Proposed methodology for TFRs for watercourse diversions in the SE Region

The fundamental purpose of defining TFRs is to provide equitable sharing of runoff generated across a landscape or watercourse flows between upstream and downstream users, including the environment. The *10^{th} percentile exceedance daily flow rate* has been used across the State as a default TFR_L to address the low flow requirement of WDEs in non-prescribed areas.

The TFR_L for the Morambro Creek Prescribed Area (*7^{th} percentile exceedance daily flow rate*):

- was derived from detailed eco-hydrological investigations within the prescribed area
- closely approximates the statewide default TFR_L metric (*10^{th} percentile exceedance daily flow rate*).

Note that the actual flow rate for the 7^{th} percentile is a higher value than the flow rate of the 10^{th} percentile.

As a result, the SE Region may consider the following recommendations with regards to defining TFRs:

- Consider using the 10^{th} percentile exceedance daily flow rate as an interim TFR_L to address low-flow requirements of WDEs. In this case, flows below TFR_L would not be captured by new dams in the headwater section (with higher slopes and greater rainfall) of the Region, or diverted from watercourses by new diversion points, with a clear statement of the assumptions and limitations of using this TFR_L across the region.
- A clear pathway to undertake future field investigations to locate, and assess, the current health and water requirements of local WDEs is developed, including:
    - The low flow requirements of WDEs to validate the interim TFR_L; and
    - The medium and high-flow requirements (TFR_{MH}) for other WDEs including inland, terminal and coastal waterbodies (lakes, wetlands and swaps), and floodplain WDEs.

As an initial stage of this future work pathway, it is also recommended that a review of investigations related to WDEs (and their flow requirements) within the SE Region be undertaken, with a focus on investigations already completed such as the one undertaken as part of developing the Morambro Creek WAP (i.e., Creswell, 2004). A comprehensive review of this information will inform whether regionally-appropriate TFRs can be derived from previous studies, or whether further specific investigations are warranted. This will produce more reliable estimates of TFRs for the SE Region.

5 Exploration of methodology used to define water use limits and threshold flow rates based on environmental water requirements: Drain L case study

5.1 Background

The classification of SWPAs, and related farm dam capacity limits (based on an equitable share of calculated yields) for each SWPA are key components of the Water Affecting Activity policies for the SE Region. Part Four of the existing SE NRM Plan provides total farm dam capacity limits for SWPAs, but does not provide limits for on-stream (capturing) farm dams separate from limits for off-stream (diversion) dams. Due to the topography of the Region, it is more likely that on-stream (capturing) dams will be located in the cross-border catchments that are key sources of surface water resources to the Region.

The existing SE NRM Plan also provides some policy details regarding the management of farm dams, and rules for surface water capture or watercourse extractions to off-stream dams. For example, Section 4.4.4.4 of the existing SE NRM Plan states the following:

> '*Any on-stream dam must be sited or constructed to enable low flows to by-pass the dam*' (Point 1).

and

> '*Structures designed to capture and deliver water to an off-stream dam must be designed, installed and operated to facilitate the capture of water to commence when 75% of the median annual flow record is reached at the specified gauging station* (see Table 4, column H)' (Point 4).

The Plan does not provide a clear definition of 'low flows' in Point 1, and it is uncertain whether the Plan implies that on-stream dams need to have the facility to bypass all flows until the time that 75% of the median annual flow from the catchment has passed a relevant gauging site.

The policy for off-stream diversions as outlined in Point 4 is consistent with commentary provided in Appendix F of Wood & Way (2011), as follows:

> '*The question has been raised about when water should be taken, given the identified priority in the State NRM Plan that environmental water requirements be met. The State Plan allows the allocation of 25% of median runoff, with the corollary that 75% of runoff is for environmental purposes. It is proposed that taking of water for storage should occur once 75% of median flow has passed a recorder site. This means that in years where flows are small all water will be used for environmental purposes and none will be available for abstraction. It also ensures that water is only available late in the season once wetlands and waterways have been thoroughly wetted. In the South East, as in many hydrological systems, annual flows vary greatly and the median flow rarely occurs, it is usually greatly exceeded or is not reached at all.*'

The current SE NRM Plan includes rules for sharing water resources that appear conservative from a consumptive point of view. The Plan does not outline a position regarding rates at which surface flows can be diverted, with no discussion of TFRs or maximum diversion rates. Once 75% of median annual flows have passed a specified gauging site, there is then no limit on the rate at which diversions can occur to an off-stream dam.

The technical investigations undertaken for the Drain L catchment and the Morambro Creek Water Allocation Plan were reviewed as part of this study to:

- Gain further understanding of the policies developed for managing surface water resources in those areas
- The science underpinning the policies, i.e. the hydrological and hydro-ecological assessments undertaken to develop policies and define limits and rules related to farm dam development, diversions and extractions from watercourses and drains, and threshold flow rates for the above extractions
- The relevance and applicability of those policies (or the policy framework) for other areas in the Region.

5.2 Drain L catchment

The classification of environmental water requirements (or EWRs) within a particular surface water zone will enable the specification of more sustainable WAA policies for that zone, rather than relying on generic Region-wide policies. The Drain L catchment, which supplies surface waters to a group of coastal wetlands that have high ecological significance, provided an example of a surface water zone in the Region which the EWRs of downstream water bodies have been established. The timing and magnitude of diversions from the Drain L catchment were then reviewed, to analyse how these EWRs impact management policies for diversions out of the watercourses.

As stated previously, the Drain L catchment is a high-yielding area with a significant network of drains that are independent from drains in other parts of the Region. Drain L flows into and through the Lake Hawdon system (consisting of North and South Lakes) and then flows into the series of four connected coastal Robe lakes prior to ocean discharge. The construction of Drain L converted Lake Hawdon North to a 'flow-through' system (with the bed excavated for the drain channel), whereby Lake Hawdon North now acts as a floodplain, filling only in high-flow events when the channel spills out of its banks. Upstream of Lake Hawdon, Drain L takes flows from Drain K and Wilmot Drain in the northern part of the watershed, with Bray Drain receiving surface runoff from the southern part of the catchment and flowing directly into Lake Hawdon South. The North and South parts of Lake Hawdon are permanently connected.

The Drain L catchment was the subject of some extensive review by DEWNR in 2014, during the feasibility stage of the South East Flows Restoration Project (SEFRP). The DEWNR technical report *Investigations to inform diversion rules for the South East Flows Restoration Project in the Drain L catchment* (Taylor *et al*., 2014) was reviewed to determine the extent of understanding of EWRs for Lake Hawdon, and how these can influence rules for watercourse extractions from off-stream farm dams.

5.2.1 Summary of 2014 DEWNR Technical Report (Taylor *et al.*, 2014)

The 2014 report summarised a series of investigations to inform diversion rules for the SEFRP from the Drain L catchment. Diversions of surface water from this catchment, in a northerly direction to the Coorong South Lagoon, were previously being considered in the feasibility stage of the SEFRP. The investigations summarised in the 2014 report included:

- A characterisation of the Lake Hawdon inundation regime via remote sensing
- A review of the ecological character of Lake Hawdon and the Robe lakes (including the specification of an Ecologically Ideal Hydrograph, or EIH)
- Hydrodynamic modelling of the Robe lakes (and implications for upstream diversions)
- The specification of diversion rules for the Drain L catchment subject to downstream EWRs.

The EIH represented the downstream EWR for this catchment and is shown in Figure 5.1. The specification of diversion rules involved the development of a calibrated rainfall-runoff model for catchments contributing to Lake Hawdon, and a lake-storage model to assess resultant water levels in Lake Hawdon against the EIH.

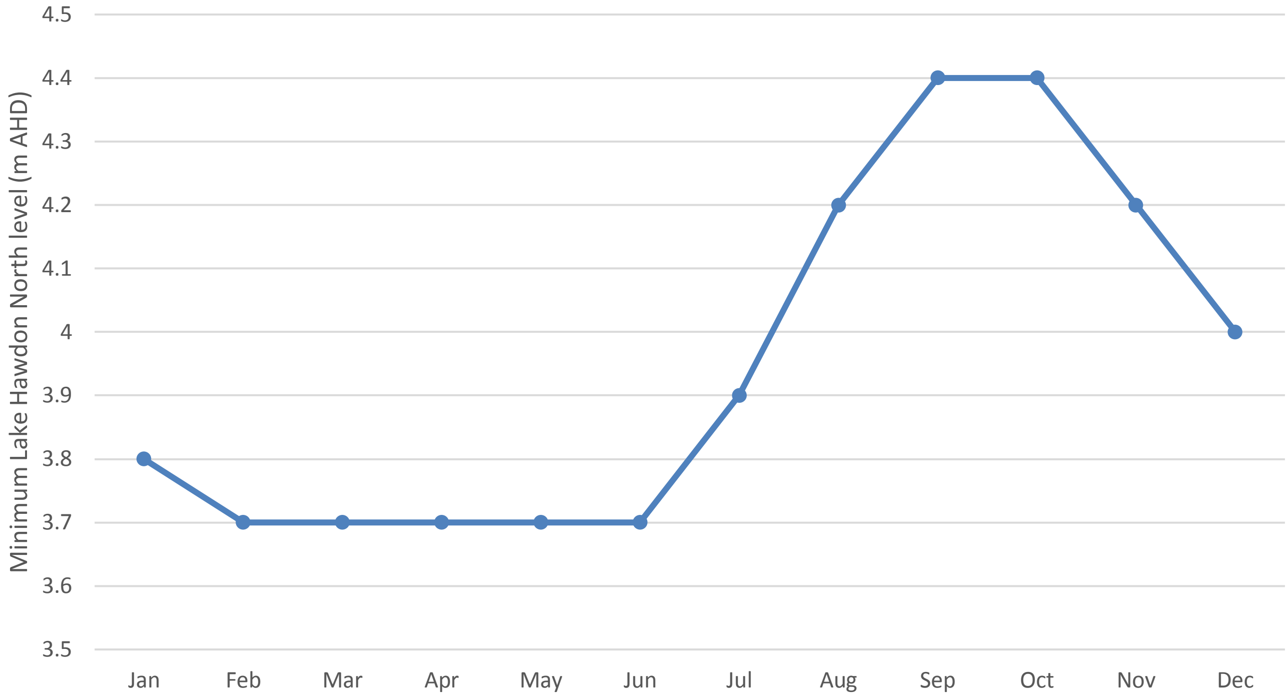

Figure 5.1. Ecologically ideal hydrograph (EIH) for Lake Hawdon North (Taylor *et al.*, 2014)

The premise for these investigations was that diversions out of the catchment may occur from specified locations on Drain L and Wilmot Drain for an augmented SEFRP. The theoretical diversion of significant volumes of water from the system would result in a reduction in the frequency, depth and duration of inundation events in Lake Hawdon, given the existing requirement for high flows in Drain L for inundation to occur.

To prevent a modified flow regime from impacting the ecological character of the Lake Hawdon wetland, the construction of a regulator structure across Drain L at the outlet of Lake Hawdon was also investigated in order to facilitate inundation events at lower flow rates.

A range of different diversion scenarios were assessed at these upstream locations to identify suitable rates that would ensure that the EIH for Lake Hawdon North was met at the same frequency as under current conditions. In addition, the design of a low flow bypass culvert within the regulator structure was investigated to ensure that sufficient flows were provided through the regulator to the Robe lakes to maintain current water quality and levels.

The investigation assumed an optimal maximum diversion rate of 250 ML/d from Drain L and Wilmot Drain to Coorong South Lagoon (which had been established from previous analyses), and analysed minimum flow rates (i.e. threshold flow rates) in Drain L and Wilmot Drain that are required before diversions could occur.

5.2.2 Key outcomes of the 2014 DEWNR Technical Report (Taylor *et al.*, 2014)

The catchment area contributing to the nominated diversion points was 554 km^2; however, there was a catchment area of 1087 km^2 downstream of the diversion points that would continue to contribute to the Drains, and then flow unimpeded to Lake Hawdon.

The modelling undertaken for this 2014 investigation indicated that a minimum flow rate before diversions can occur from Drain K or Wilmot Drain (i.e. TFRs) was not required, as the downstream catchment was sufficient to generate the low flow requirements of Lake Hawdon North.

There are no permanent level monitoring gauges in Lake Hawdon, although a network of temporary gauges was installed as part of the investigations captured in the 2014 report. As a result, historical water levels were simulated in the eWater Source model, and these suggested that the EIH (as shown in Figure 5.1) was met in 8 years out of 20 years since 1991 (a frequency of 40% of years).

A 100 ML/d low flow bypass (culvert) in a proposed downstream regulator that allowed a flow of 100 ML/d to the Robe lakes was sufficient to maintain downstream salinity targets, and still enable the EIH of Lake Hawdon to be met at the same frequency as historical records. This suggested that the current ecological character of these wetlands could be maintained even with the diversion of significant volumes of water from the catchment.

The historic frequency of meeting the EIH was also achieved when diversions were permitted all year as opposed to only being permitted in the wet months (June–November).

5.2.3 Proposed approach to analyse impacts of technical report findings on the current Water Affecting Activities policy investigation

The results from this 2014 investigation have clear implications for the consideration of rules around diversions for farm dams in this catchment. Due to the generally flat topography of the Drain L catchment, it is likely that there are more off-stream (diversion) dams constructed, or likely to be constructed, than on-stream (capturing) dams. Therefore, the impact of farm dam diversions in this catchment on the flow regimes of Lake Hawdon and the terminal Robe lakes can be investigated in a similar manner to the proposed diversions for the Coorong South Lagoon.

Unlike the investigations described in the 2014 Technical Report (Taylor *et al.*, 2014), the impact of farm dam diversions would need to be analysed under 'current' conditions, without a regulator being located on the downstream end of Lake Hawdon. The rainfall-runoff and lake storage models developed and calibrated for the 2014 investigation would need to be reinvestigated to simulate historical flows into Lake Hawdon without a regulator, in order to determine the volume and timing of 'surplus' flows—the portion of the flow regime that is theoretically available for farm dam diversion after EWRs of the system have been met.

At present, the SE NRM Plan presents a generic approach for the whole Region that states that diversions to off-stream dams can only occur once 75% of the median annual flow has passed a specified gauging point. The EWRs of the Lake Hawdon system at the downstream end of the system are assumed to reflect variations in minimum levels held within the water body, as described by the EIH (as shown in Figure 5.1) developed for the 2014 Technical Report. There is the potential to develop management rules for this catchment that relate the timing and magnitude of farm dam diversions to this EIH, rather than to the generic 75% of median annual flow policy. A potential revised approach could include diversions to off-stream dams being permitted only after the EIH is deemed to have been met (likely to be following the maximum level of 4.4 m AHD in Lake Hawdon North having been reached in September and onwards), although as previously noted the current frequency of the EIH being met is only 8 years in 20 rather than every year.

The application of this off-stream dam diversion policy relies upon a well-maintained monitoring program that provides the ability to accurately gauge flow rates at a nearby site. In addition, there is a need to be able to relate flows in the drains to levels in Lake Hawdon, in order to determine how flows in the contributing watercourses relate to the defined EWRs—for example, by defining the flow rates at which Lake Hawdon commences to fill.

At present, there is a lack of flow and level monitoring in this catchment. There are no operating level gauges in Lake Hawdon, which will hinder the ability to determine in real time how flows from the catchment have contributed to meeting the EIH, and how this will be impacted by farm dam diversions. In addition, the primary flow gauges (A2390510 Drain L, A2390527 Wilmot Drain and A2390504 Bray Drain) upstream of Lake Hawdon are not currently being monitored, and so there is no mechanism to determine flow rates in order to define threshold flow rates in watercourses that must be met before diversions could be permitted.

There is the potential to take advantage of the fact that EWRs have been defined for a terminal wetland system in the Drain L catchment to develop rules around timing and magnitude of diversions for off-stream dams in this catchment that emulate rules used to manage Cockatoo Lake in the prescribed Morambro Creek system.

6 Conclusion and recommendations

Surface Water Policy Area (SWPA) boundaries

This investigation has proposed a new set of twelve SWPAs for the SE Region. The boundaries of these proposed SWPAs were defined from analysing the flows from various surface water catchments across the Region, spatial information for the Region and from an assessment of the operation and connectivity of the various drain systems. Four of the proposed SWPAs have boundaries that are unchanged from the existing SE NRM Plan.

Rainfall-Runoff factors

Rainfall-runoff factors were derived for each proposed SWPA to derive runoff in terms of area-averaged rainfall. These factors were calculated as the ratio between the median annual observed runoff (for five SWPAs) and the corresponding area-averaged rainfall, or estimated through other approaches. Rainfall-runoff factors were used to derive Water Use Limits for each SWPA.

Surface Water Use Limits

Limits for surface water use were calculated for each of the proposed SWPAs using recent gauged streamflow data (where available), although an understanding of underlying rainfall-runoff relationships across many parts of the Region was constrained by a lack of historical streamflow data.

Surface water use limits were calculated through two approaches. The first of these approaches represented the methodology included in the existing SE NRM Plan by using 25% of the estimated *unadjusted* annual yields for each SWPA (Method A). The second approach, consistent with the State NRM Plan 2006, used 25% of the estimated *adjusted* yields for each SWPA to calculate water use limits (Method B). Yields in Method B were adjusted to account for the impacts of existing farm dam development, plantation forestry and authorised extractions/diversions on recorded yields. The second approach is considered technically more robust, as it accounts for the impacts of existing development on catchment yield.

Catching dam development limits

The current SE NRM Plan calculates dam development limits as 25% of the estimated unadjusted annual catchment yield, although there is limited documented scientific or technical basis for describing dam development limits with this metric. Furthermore, the SE NRM Plan does not specify if this limit is only applicable to catching dams or for off-stream and/or Turkeys Nest dams as well.

The State NRM Plan 2006 recommends 25% of median annual adjusted yield as the metric for calculating the limit for surface water use (the 25% rule), outside of prescribed areas, and until further information is available. The State NRM Plan's 25% rule evolved from the State Water Plan (DWR, 2000) 50% dam development limit rule (the 50% rule). A commonly-used approach to the definition of catching dam development limits in other non-prescribed areas of the State is twice the water use limit.

Therefore, and until further detailed investigations on localised farm dam characteristics (including geometry, position in the landscape, construction details and type of water use) are undertaken, the SE Region could adopt either (i) 25% of the estimated adjusted yield, or (ii) 50% of the estimated adjusted yield as an interim metric for the calculation of Catching Dam Development Limits. The first option is more conservative from a development perspective, and the second option is consistent with default statewide policy. Table 6.1 summarises the total dam capacity limits for each proposed SWPA that are calculated from using these two approaches, alongside the estimated current dam capacities in each proposed SWPA.

Table 6.1. Comparison of the capacity limits for on-stream dams for proposed SWPAs calculated using different assumptions, against estimated current dam capacities

Proposed SWPA	Dam capacity limit (ML)			Estimated current dam volume per SWPA (ML)
	Using 25% of recorded yield (Method A)	Using 25% of adjusted yield (Method B)	Using 50% of adjusted yield	
Tatiara–Nalang	59	122	244	798
Morambro	67	100	201	509
Naracoorte	188	238	476	777
Mosquito	597	602	1,205	139
Mallee	752	1,690	3,380	7,503
Murray-Darling Basin	188	233	466	358
Morambro North	101	341	681	1,906
Lake Bonney	12,570	14,936	29,872	620
Drain C	83	121	241	435
South Western	42,824	47,425	94,851	1,865
Flats–Drains	37,958	38,817	77,635	3,118
Glenelg	7,194	9,277	18,553	423
SE Region total	**102,582**	**113,903**	**227,806**	**18,451**

Threshold flow rates (TFRs)

The current SE NRM Plan defines TFRs as 75% of the median annual flow record, with diversions from watercourses only permitted above these rates. This definition was derived from the State NRM Plan 2006 that defined consumptive use limits as 25% of median annual runoff, such that the remaining 75% of median annual runoff was to be allocated for environmental purposes. Further investigations are required to determine whether this is an appropriate approach to establish a region-wide TFR metric.

The hydrological metric used in non-prescribed areas across the State to address the low flow requirements of in-stream WDEs that are observed in the Mt Lofty Ranges (TFR_L) is the *10^th^ percentile exceedance daily flow rate*. More recent detailed hydro-ecological investigations undertaken to inform the EMLR and WMLR Water Allocation Plans have refined this default metric to the *20th percentile exceedance non-zero daily flow rate*. The TFR_L used in the Morambro Creek Water Allocation Plan equates to the *7th percentile exceedance daily flow rate*, with a ‘high flow’ TFR to meet the WDE flow requirements of larger inland and terminal/coastal water bodies including lakes, swamps and wetlands, and floodplain ecosystems (TFR_H). As a result, the SE Region could consider using the *10th percentile exceedance daily flow rate* as a reasonable interim TFR to address the low flow requirements of in-stream WDEs (TFR_L), with a future pathway to undertake further investigations on flow requirements of local WDEs to refine/validate TFR_L and develop threshold flow rates (TFR_{MH}) related to medium and high flow requirements of larger WDEs.

Table 6.2 provides a summary of the limits, options for hydrological metrics used to define each limit, the policy context (in relation to the statewide and other regional policy guidelines) and some of the assumptions and limitations in adopting a particular methodology (or metric). Comparative confidence levels for the applicability of each methodology (or metric) to the hydroecological conditions of the South East are also provided.

Table 6.2. Methodology options for establishing limits for surface water capture, diversion and use

Limits	Proposed metric	Policy context	Assumptions and Limitations	CCL [a]
Surface WUL	25% of median annual adjusted yield	• Consistent with State (and interstate) policy guidelines and other regions	• Developed for catchments and WDEs typical of the MLR • Morambro Creek WAP uses similar metric • Considered technically more robust than using recorded yield	H
Catching Dam Development Limit	OPTION 1: 50% of median annual adjusted yield	• Consistent with State policy guidelines and other regions	• Developed for catchment conditions and farm dam characteristics typical to the WMLR	H
	OPTION 2: 25% of median annual adjusted yield	• Policy in current SE NRM Plan • Conservative from a development perspective	• Assumes different dam characteristics (geometry, construction and use) in comparison to Option 1	M
	OPTION 3: 30% of annual yield	• Policy in current SA MDB NRM Plan	• Developed for catchment conditions and farm dam characteristics typical to the EMLR	M
Threshold Flow Rates	TFR_L – Low flow requirements of in-stream WDEs; applicable to new catching dams and watercourse extractions/diversions			
	OPTION 1: 10th percentile exceedance daily flow rate	• Consistent with State policy guidelines • Closer to TFR_L (7th percentile) in the Morambro Creek WAP	• Assumes WDEs and their low flow requirements are similar to those of the EMLR and WMLR, and Morambro Prescribed Area	M
	OPTION 2: 20th percentile exceedance non-zero daily flow rate	• Policy in EMLR and WMLR WAPs	• Based on detailed eco-hydrological investigations undertaken as part of WAP development	M
	OPTION 3: 75% of median annual flow	• Policy in current SE NRM Plan • Conservative approach from a development perspective	• Assumes '25% (of flow) use limit' to mean 75% has to flow through • Limited technical basis	L
	TFR_{MH} - Surrogate for WDEs medium and high flow requirements—yet to be established.			

[a]CCL – Comparative Confidence Level (shown as High, Medium or Low)

The following key recommendations are presented following this investigation:

- Total farm dam limits for SWPAs in the Region are recommended to be calculated from the Water Use Limit (WUL) approach to account for the current impacts of farm dams, watercourse diversions and plantation forestry on potential surface water yields.
- A broad-scale risk assessment be undertaken across the SE Region to identify key ecosystems, their current health status and to quantify their surface water requirements. This will help to determine the risk of over- or under-allocating water for consumptive purposes. Until such information is available, and without gauged hydrological data, it is difficult to assess the suitability of farm dam capacity limits for many areas. Recommendations regarding the timing of watercourse diversions will be a possible outcome from this risk assessment process.
- The analysis of the Drain L catchment and the Morambro Creek WAP showed that the definition of EWRs can provide an opportunity to derive rules concerning sustainable surface water and watercourse diversions, and the required threshold flow rates. These areas were chosen for analysis as they are two of the few parts of the Region in which EWRs have been clarified. EWRs are generally described in terms of measureable hydrologic metrics that correspond to key ecologically-relevant parts of the flow regime including flow season, frequency, duration and magnitude (Savadamuthu *et al*., 2011), although recent trends in EWR development have shown a move toward ecological response models. A firm understanding of local hydrology, ecology and geomorphology is therefore required to understand the impact of varying flow conditions on aquatic ecosystems. With only a small number of surface water flow monitoring gauges currently operating, in the first instance eco-hydrological modelling to inform EWRs in other parts of the Region will need to be directed towards monitored zones.
- Appendix C provides a discussion of how the 25% rule can be applied in different catchment areas, depending on the level of hydrological information available. The development of catchment scale rainfall-runoff models, together with the associated data collection that would be required to calculate the hydrological impacts of farm dams across the Region will require significant resources. Natural Resources SE may need to consider whether the development of calibrated rainfall-runoff models is necessary for the ongoing application of the 25% rule in the Region.
- The existing SE NRM Plan includes a number of Water Affecting Activity policies that impose requirements for a well-resourced and extensive monitoring program. The existing Plan requires median annual flows to be identified (and real-time flows to be determined) at gauging sites that are not currently being monitored. It is understood that in recent years, many monitoring sites have been closed across the Region, and a lack of current flow data negatively impacts the management of these policies. As such, a review and rationalisation of surface water monitoring across the Region is recommended.
- A review of the spatial coverage of farm dams across the Region should be undertaken, including on-ground investigations. In addition, a detailed study of the geometry and operation of farm dams across the Region will help to determine whether the assumptions relating dam surface area to volume, and total impact on catchment runoff, which were derived from the Mt Lofty Ranges catchments (McMurray, 2007) are valid for the SE Region.
- A local analysis of the impact of plantation forestry in the SE Region on potential surface yield should occur to help determine the suitability of using an assumption of forestry accounting for an 85% reduction in surface runoff from otherwise cleared land, which has been previously developed from plantations in Kangaroo Island and the Mt Lofty Ranges.

7 References

Adelaide & Mt Lofty Ranges Natural Resources Management Board (2013). *Water Allocation Plan for the Western Mount Lofty Ranges*, Government of South Australia, through the Adelaide and Mount Lofty Ranges Natural Resources Management Board.

AMLRNRMB – see Adelaide & Mt Lofty Ranges Natural Resources Management Board.

Cresswell, D. (2004). *Draft – Surface Water Assessment of the Morambro Creek Catchment*, Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Adelaide.

Department of Environment, Water and Natural Resources (2011). *Work Procedure – Digitising hydrologic features, Version 5 (Unpublished)*, Government of South Australia through Department of Environment, Water and Natural Resources, Adelaide.

Department of Water, Land and Biodiversity Conservation (2006). *State Natural Resources Management Plan 2006*, Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Adelaide.

Department of Water, Land and Biodiversity Conservation (2007). *Sustainable limits of surface water use in South Australia: Factsheet 81*, Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Adelaide.

Department of Water Resources (2000). *State Water Plan 2000*, Government of South Australia, through Department for Water Resources, Adelaide.

DEWNR – see Department of Environment, Water and Natural Resources.

DWLBC – see Department of Water, Land and Biodiversity Conservation.

DWR – see Department of Water Resources.

McMurray, D. (2004). *Assessment of water use from farm dams in the Mount Lofty Ranges, South Australia*, DWLBC Report 2004/02, Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Adelaide.

Nathan R. J., Doeg T. and Voorwinde L. (2002). *Towards defining sustainable limits to winter diversions in Victorian catchments*. Australian Journal of Water Resources, IEAust, 5(1): pp. 49–60.

Resource and Environmental Management (REM) (2003). *Morambro Creek Resource and Ecological Assessment: Stage One Report*, prepared for the South East Catchment Water Management Board.

SAMDBNRMB – see South Australian Murray-Darling Basin Natural Resources Management Board.

Savadamuthu, K., van der Wielen, M., Alcorn, M.R. & Vanlaarhoven, J. (2011). *Hydro-ecological modelling to establish sustainable extraction limits in unregulated catchments*, in Proceedings of the 19th International Congress on Modelling and Simulation (MODSIM 2011), pp 4113-4119

SENRMB – see South-East Natural Resources Management Board.

Sinclair Knight Merz (2003). *Sustainable Diversions Limit Project Estimation of Sustainable Diversion Limit Parameters over Winterfill Periods in Victorian Catchments*. The State of Victoria, through the Department of Sustainability and Environment, January, ISBN 0 74106 605 0.

Sinclair Knight Merz and Cooperative Research Centre for Freshwater Ecology (2002). *Sustainable Diversions Limit Project. Recommendations for Sustainable Diversions Limits over Winterfill Periods in Unregulated Victorian*

Catchments. The State of Victoria, through the Department of Natural Resources and Environment, January, ISBN 0 7311 5016 3.

SKM – see Sinclair Knight Merz.

SKMCRC – see Sinclair Knight Merz and Cooperative Research Centre for Freshwater Ecology.

South Australian Murray-Darling Basin Natural Resources Management Board (2013). *Water Allocation Plan for the Eastern Mount Lofty Ranges*, Government of South Australia, through the South Australian Murray-Darling Basin Natural Resources Management Board.

South-East Natural Resources Management Board (2006). *Water Allocation Plan for the Morambro Creek and Nyroca Channel Prescribed Watercourses including Cockatoo Lake and the Prescribed Surface Water Area*, Government of South Australia, through the South East Natural Resources Management Board.

Taylor, B., Gibbs, M., Hipsey, M., Lewis, M., Sharath, I., Brookes, J., Nicol, J., Clarke, K., Dalby, P., Clark, M. & Bice, C. (2014*). Investigations to inform diversion rules for the South East Flows Restoration Project in the Drain L catchment*, Government of South Australia, through Department of Environment, Water and Natural Resources, Adelaide.

VanLaarhoven, J. (2010). *Environmentally sustainable extraction limits for the Western Mount Lofty Ranges Prescribed Water Resources Area*, DFW Technical Report 2010/01, Government of South Australia, through Department for Water, Adelaide.

VanLaarhoven, J. & van der Wielen, M. (2012). *Assessment of the needs of water dependent ecosystems for the Eastern Mount Lofty Ranges Prescribed Water Resources Area*, Government of South Australia, through Department for Water, Adelaide.

Wood, G. & Way, D. (2011). *Development of the Technical Basis for a Regional Flow Management Strategy for the South East of South Australia*, DFW Report 2011/21, Government of South Australia, through Department for Water, Adelaide.

8 Appendices

A. Existing SWPAs with streamflow gauging station catchments

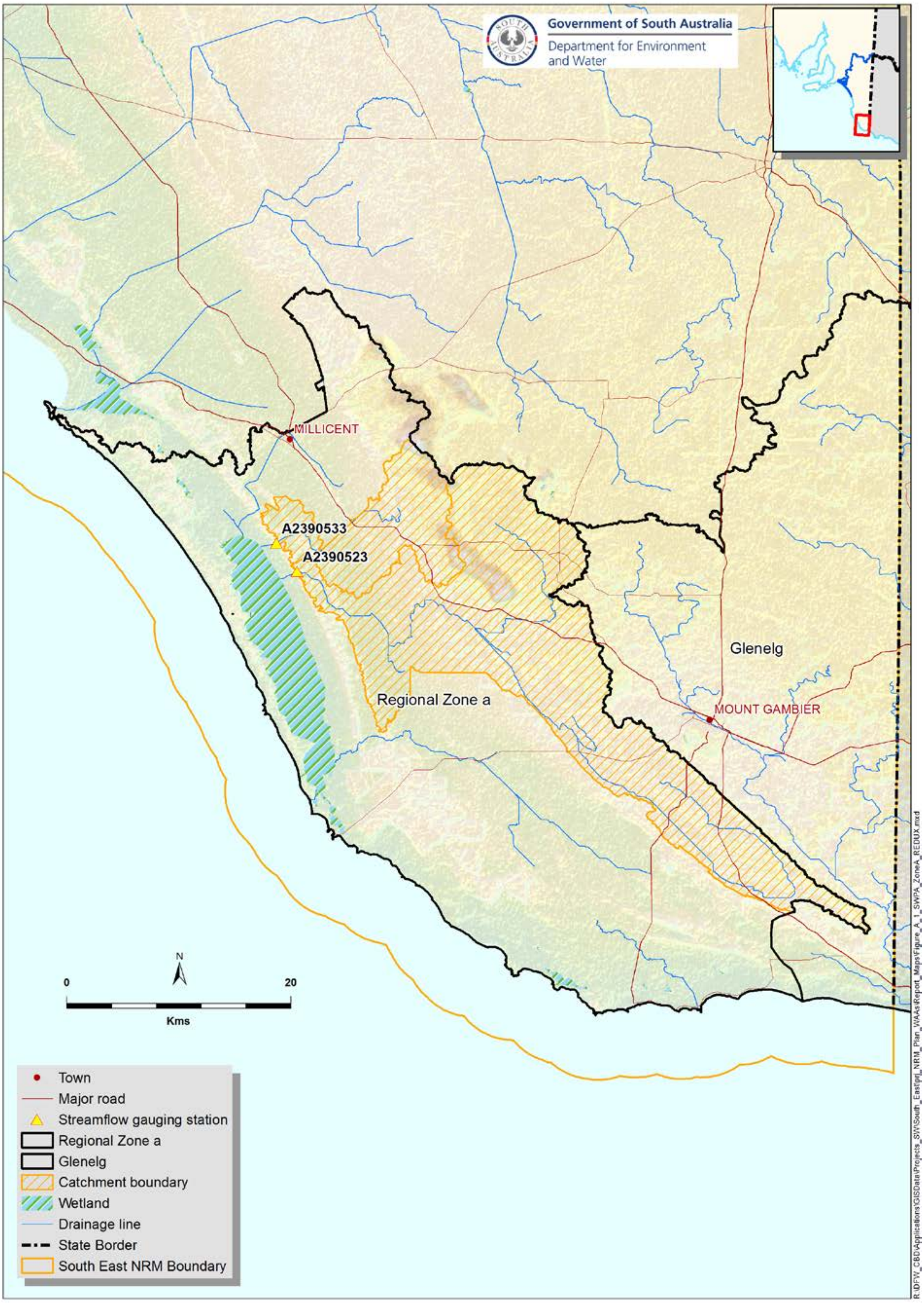

Figure A.1 Existing Regional Zone a SWPA and Glenelg SWPA

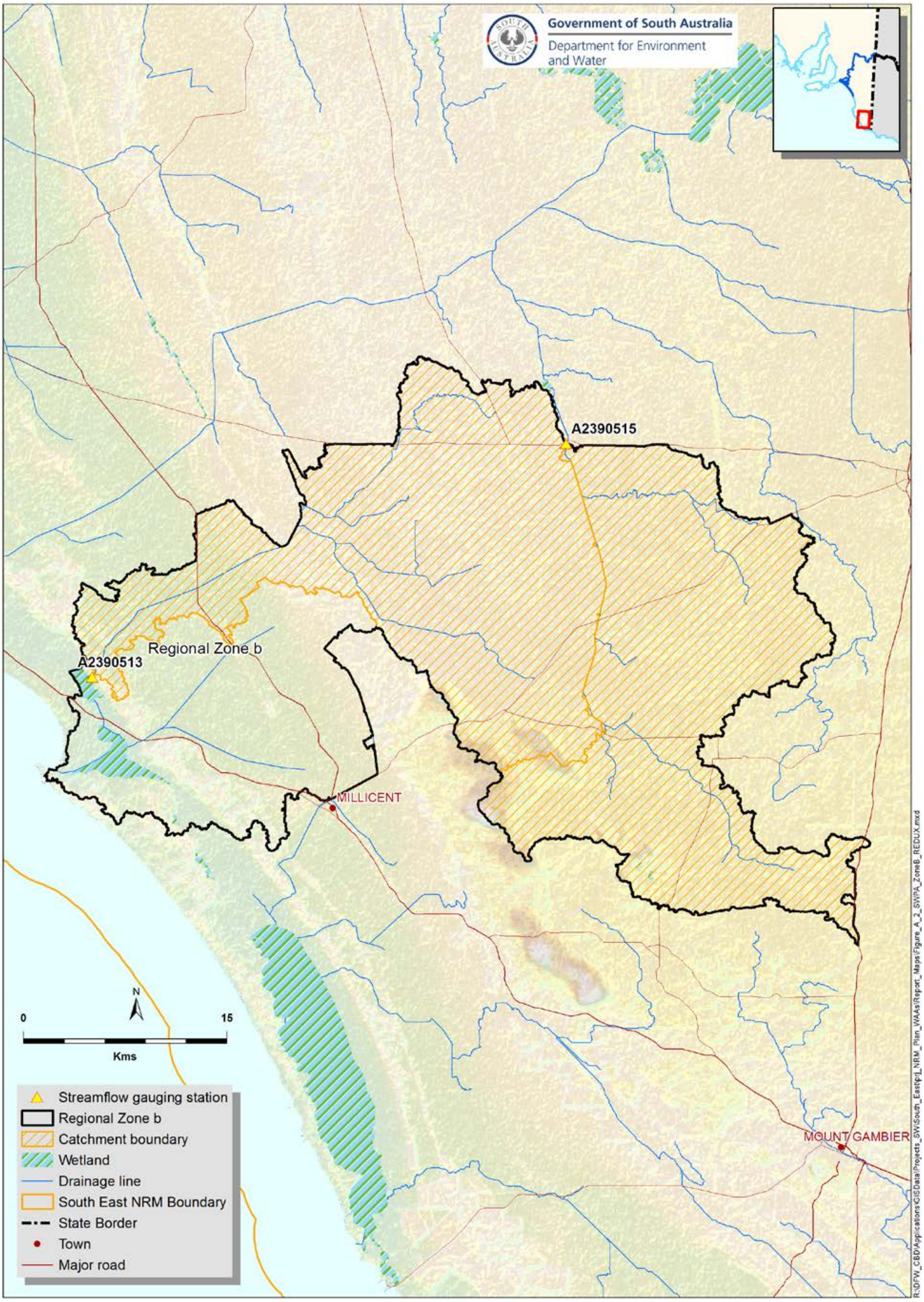

Figure A.2 Existing Regional Zone b SWPA

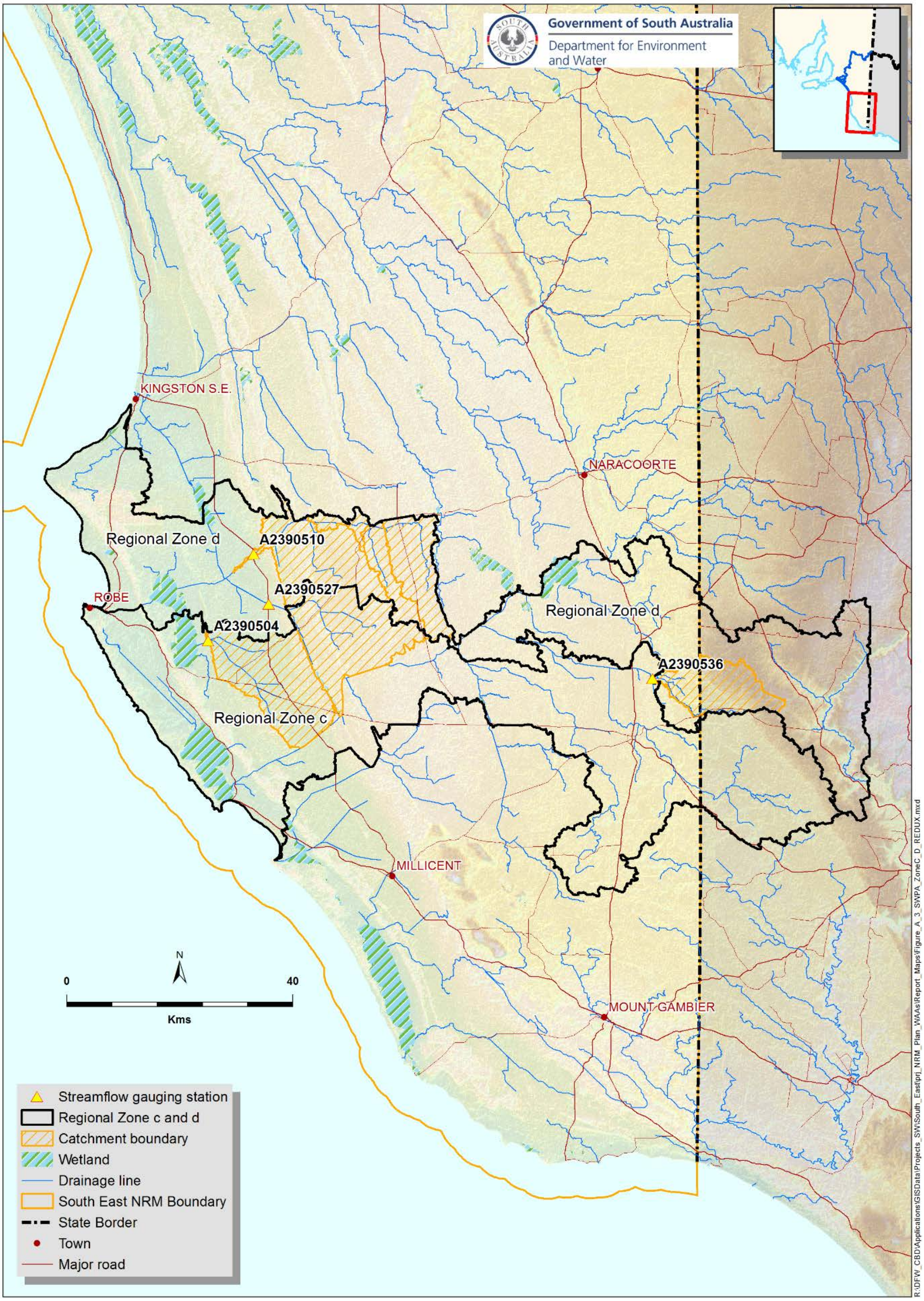

Figure A.3 Existing Regional Zone c SWPA and Regional Zone d SWPA

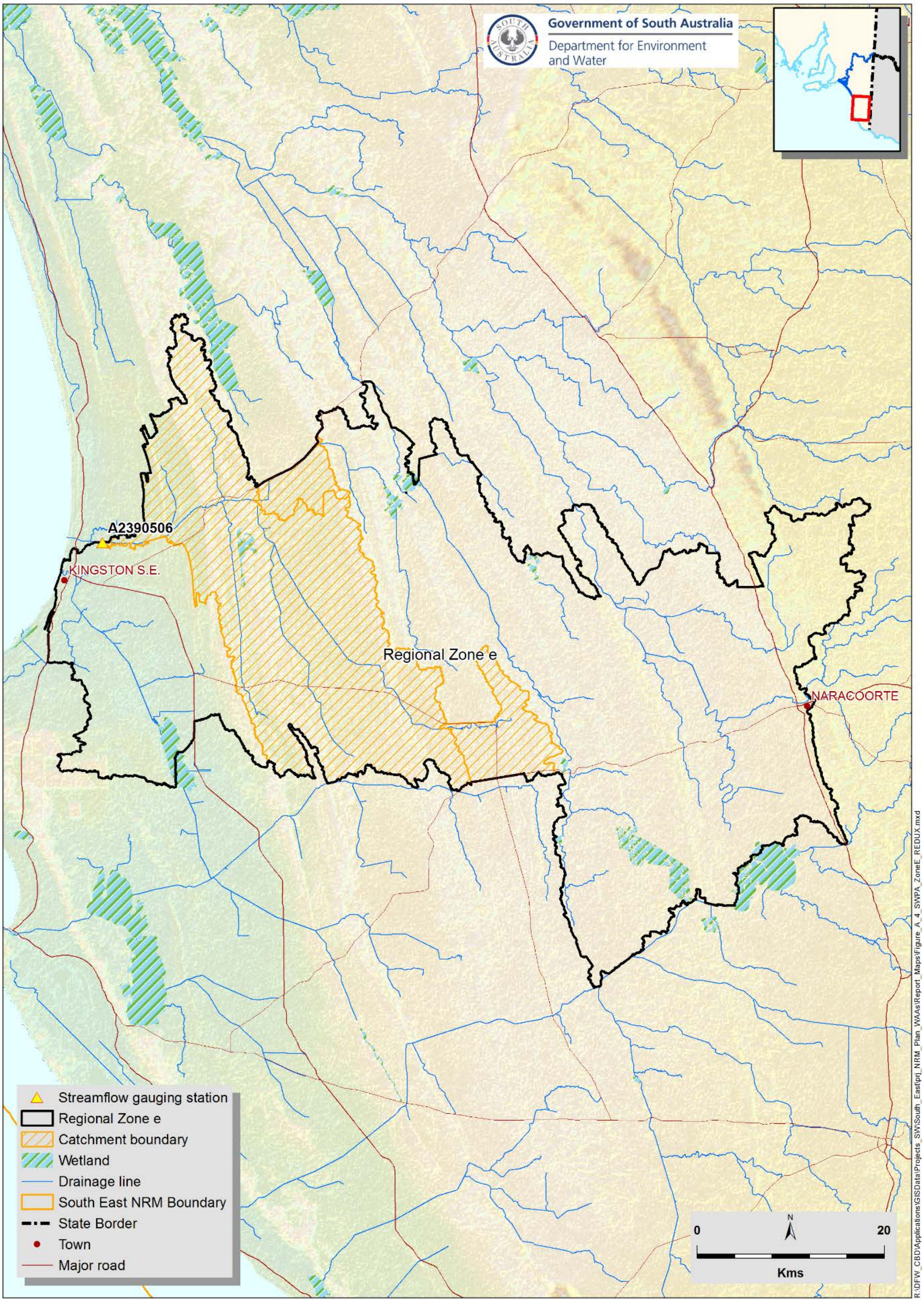

Figure A.4 Existing Regional Zone e SWPA

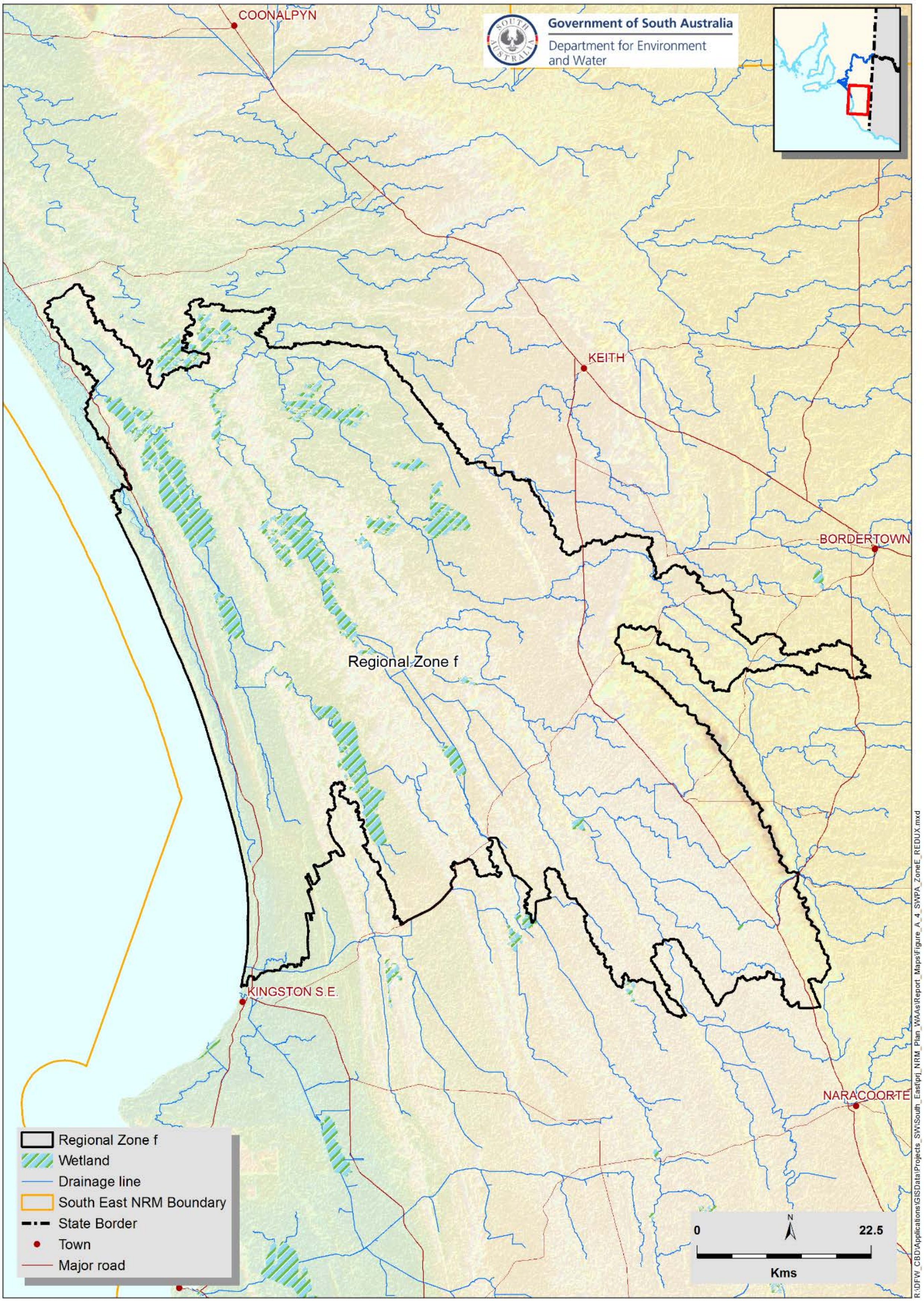

Figure A.5 Existing Regional Zone f SWPA

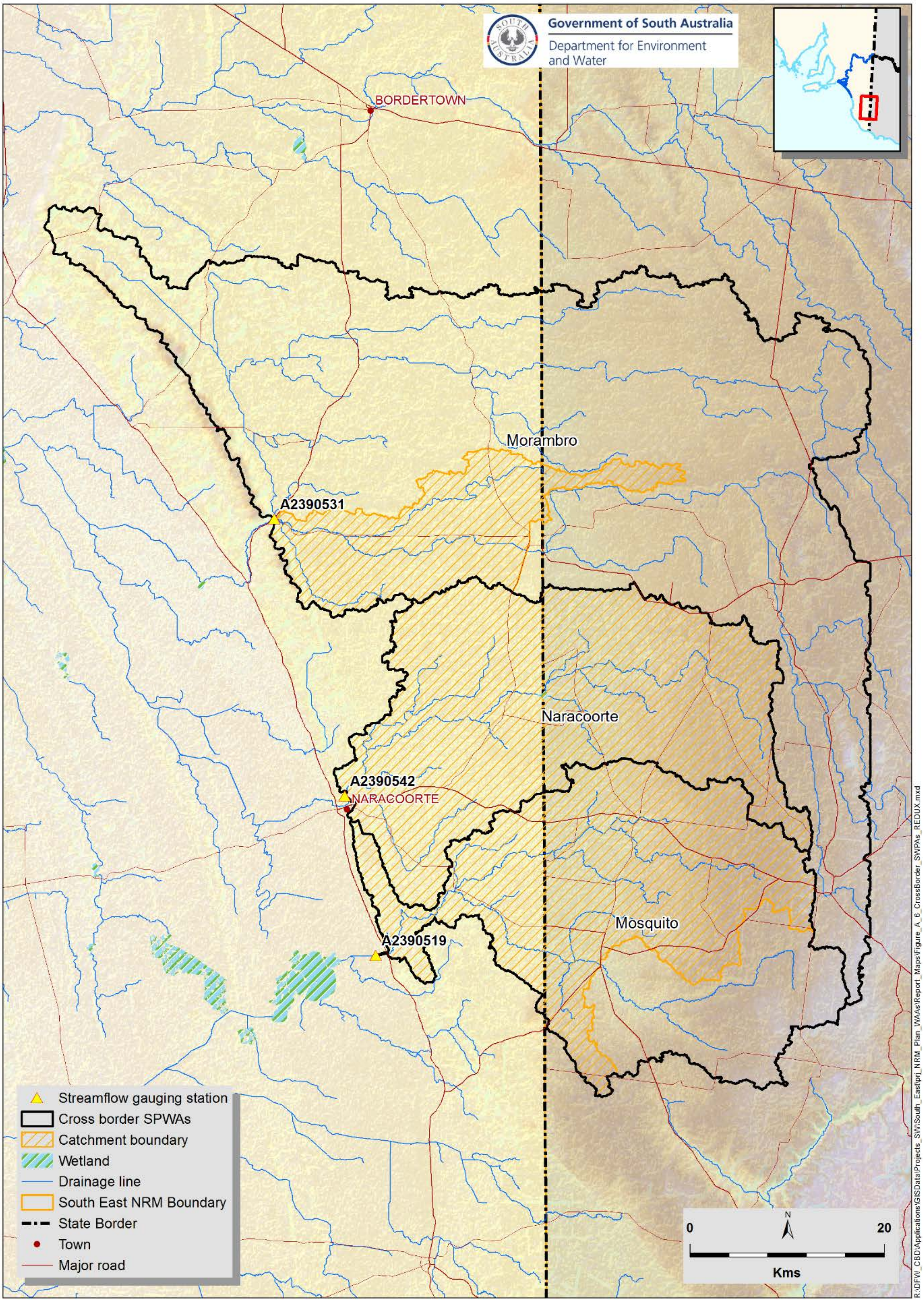

Figure A.6 Existing cross-border SWPAs

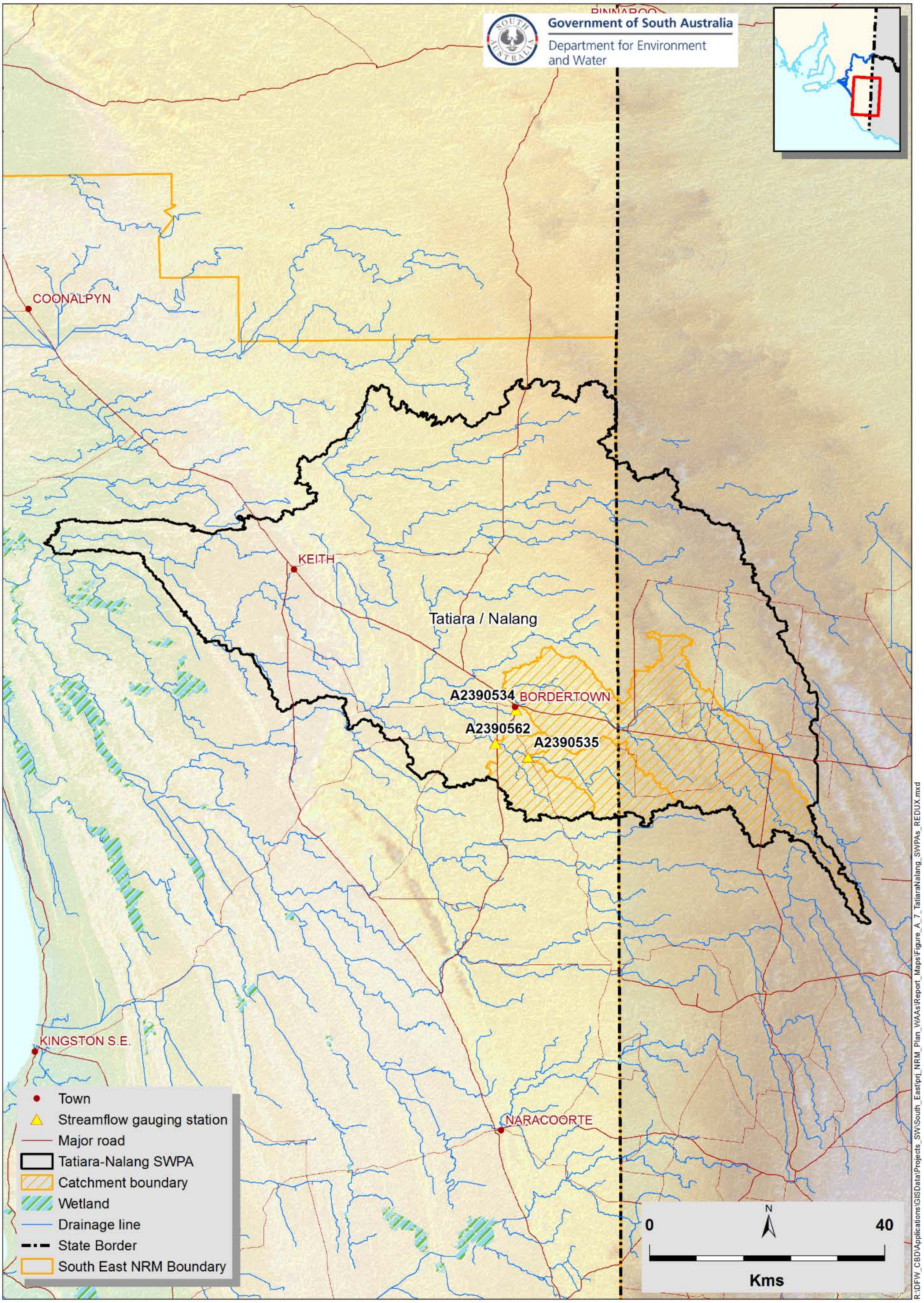

Figure A.7 Existing Tatiara–Nalang SWPA

B. Rainfall-runoff relationships for streamflow gauges in the SE Region

Figure B.1 Locations of hydrological gauges to inform rainfall-runoff relationships of proposed SWPAs

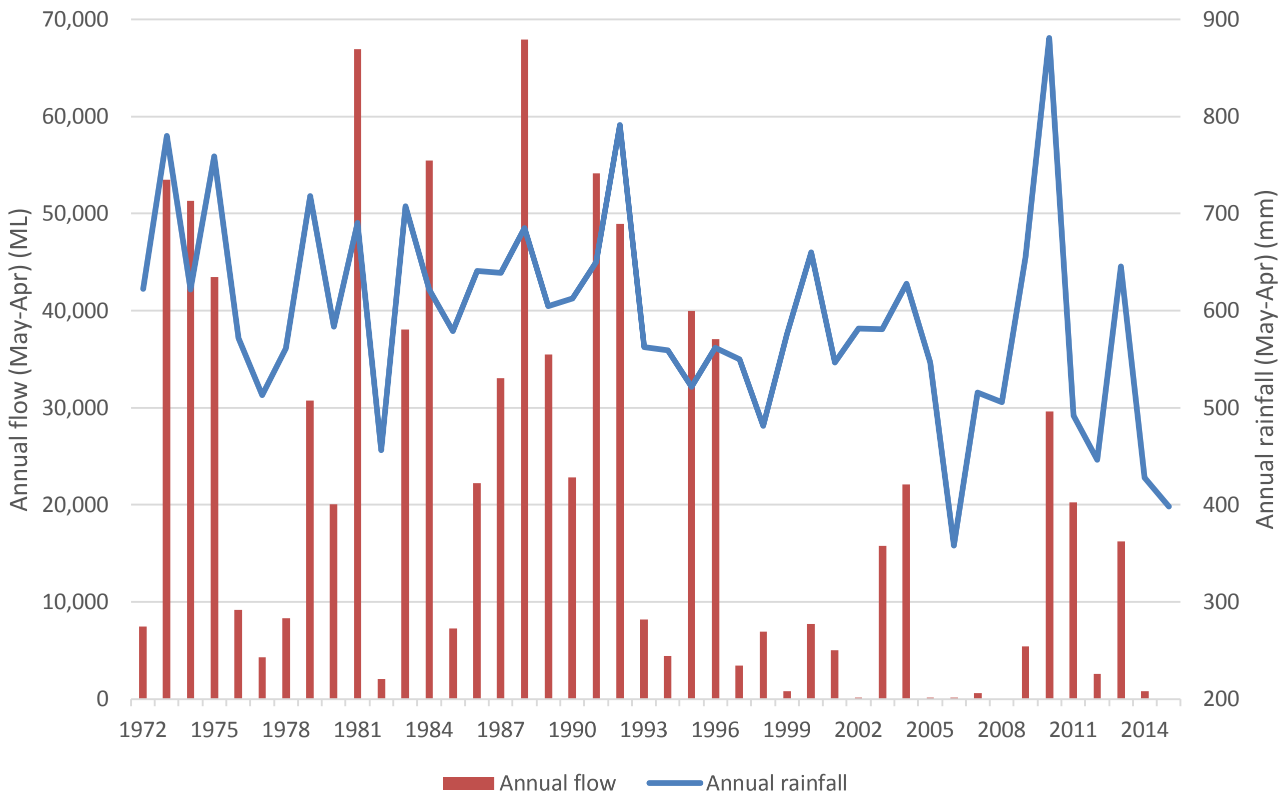

Figure B.2 Annual flows for Mosquito Creek (A2390519) alongside area-average annual rainfall

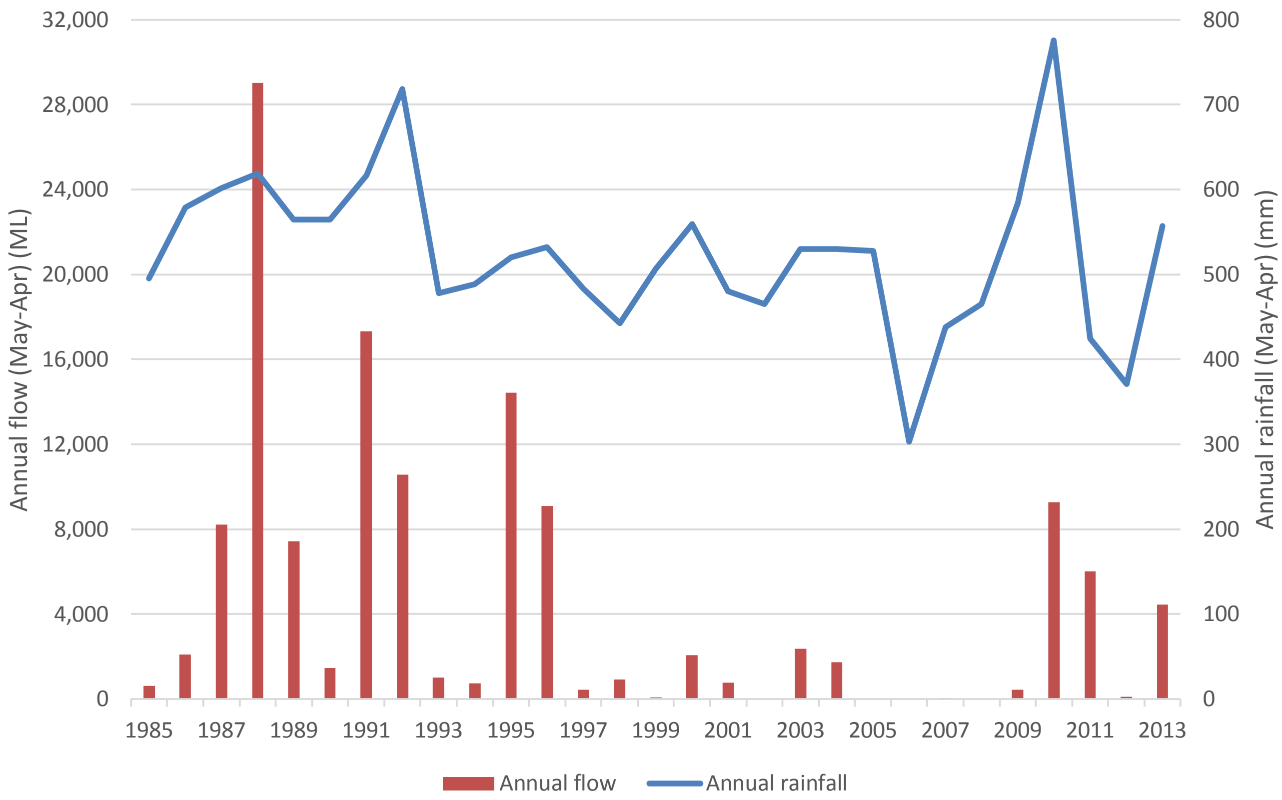

Figure B.3 Annual flows for Naracoorte Creek (A2390542) alongside area-average annual rainfall

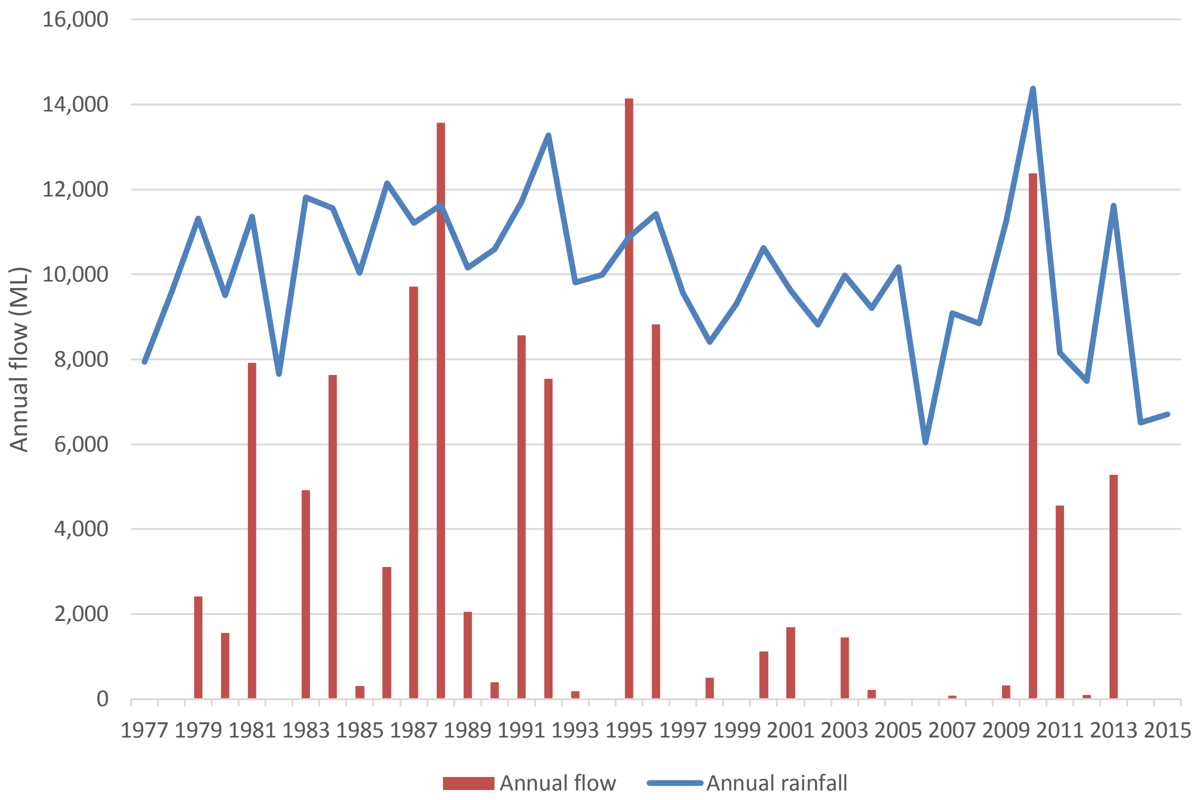

Figure B.4 Annual flows for Morambro Creek (A2390531) alongside area-average annual rainfall

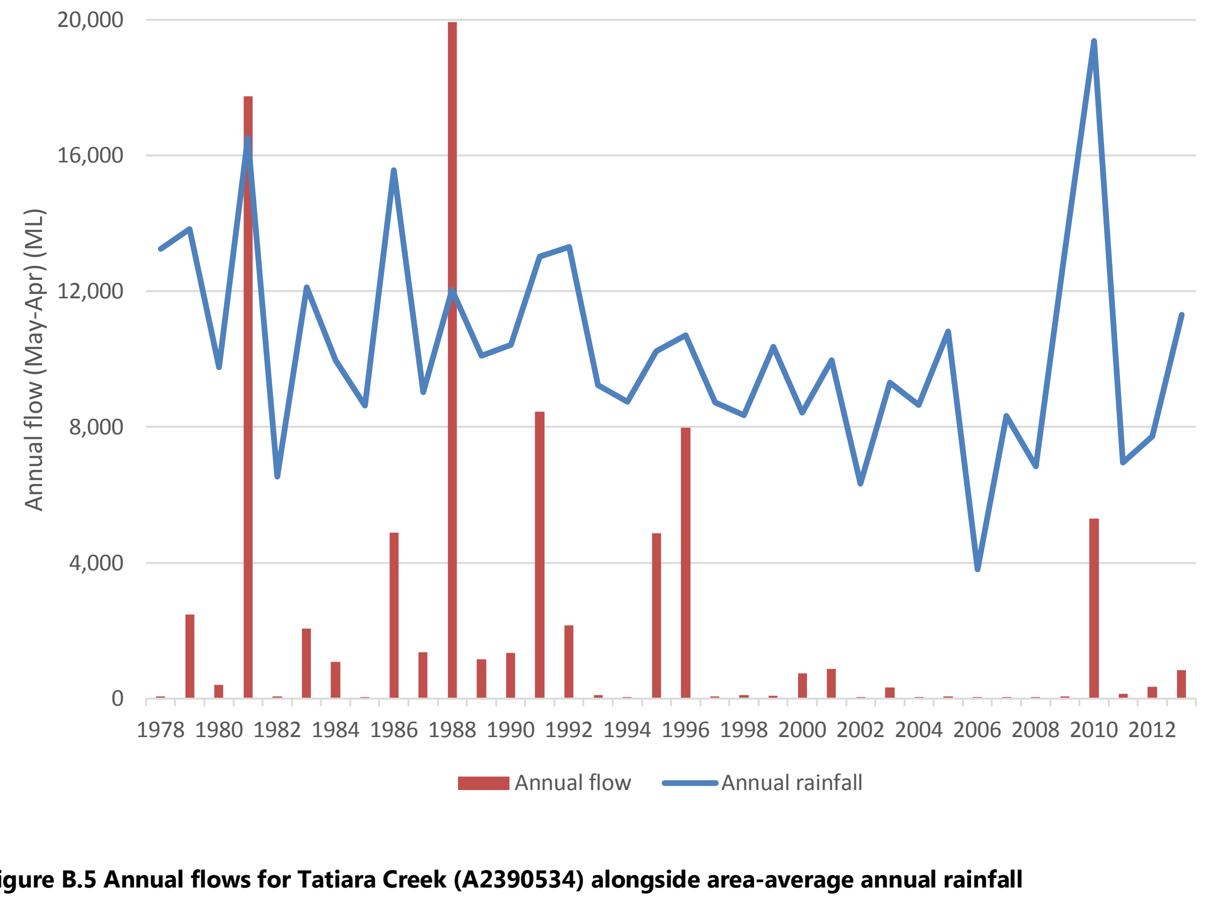

Figure B.5 Annual flows for Tatiara Creek (A2390534) alongside area-average annual rainfall

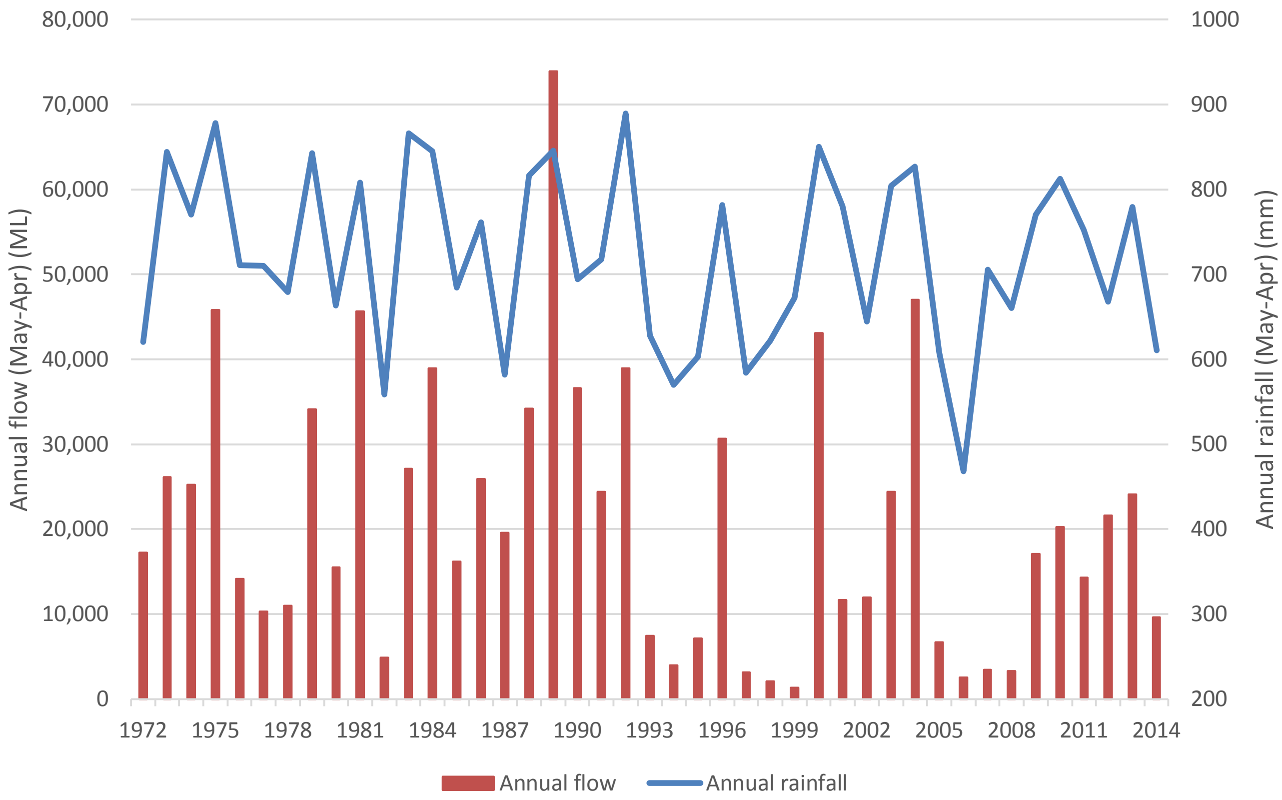

Figure B.6 Annual flows for Reedy Creek–Mt. Hope Drain (A2390513) alongside area-average rainfall

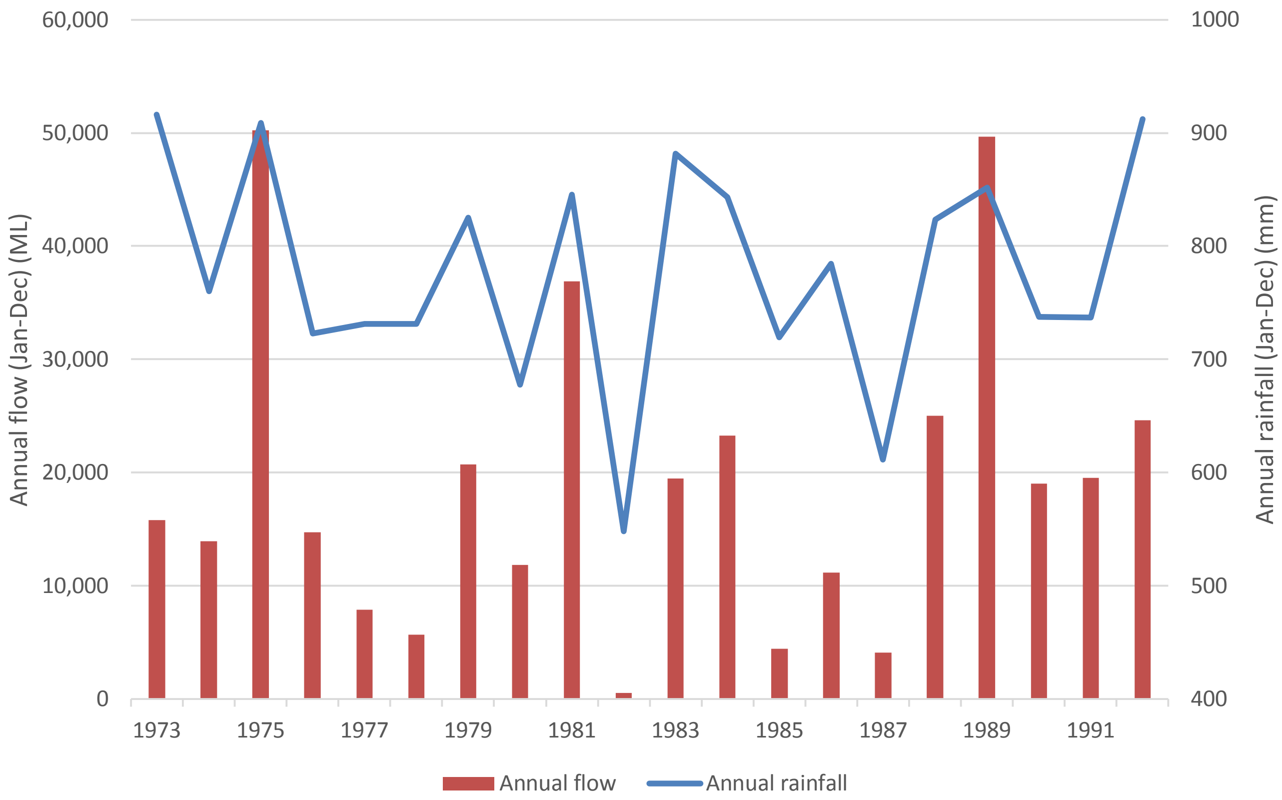

Figure B.7 Annual flows for Bakers Range South watercourse (A2390515) alongside area-average rainfall

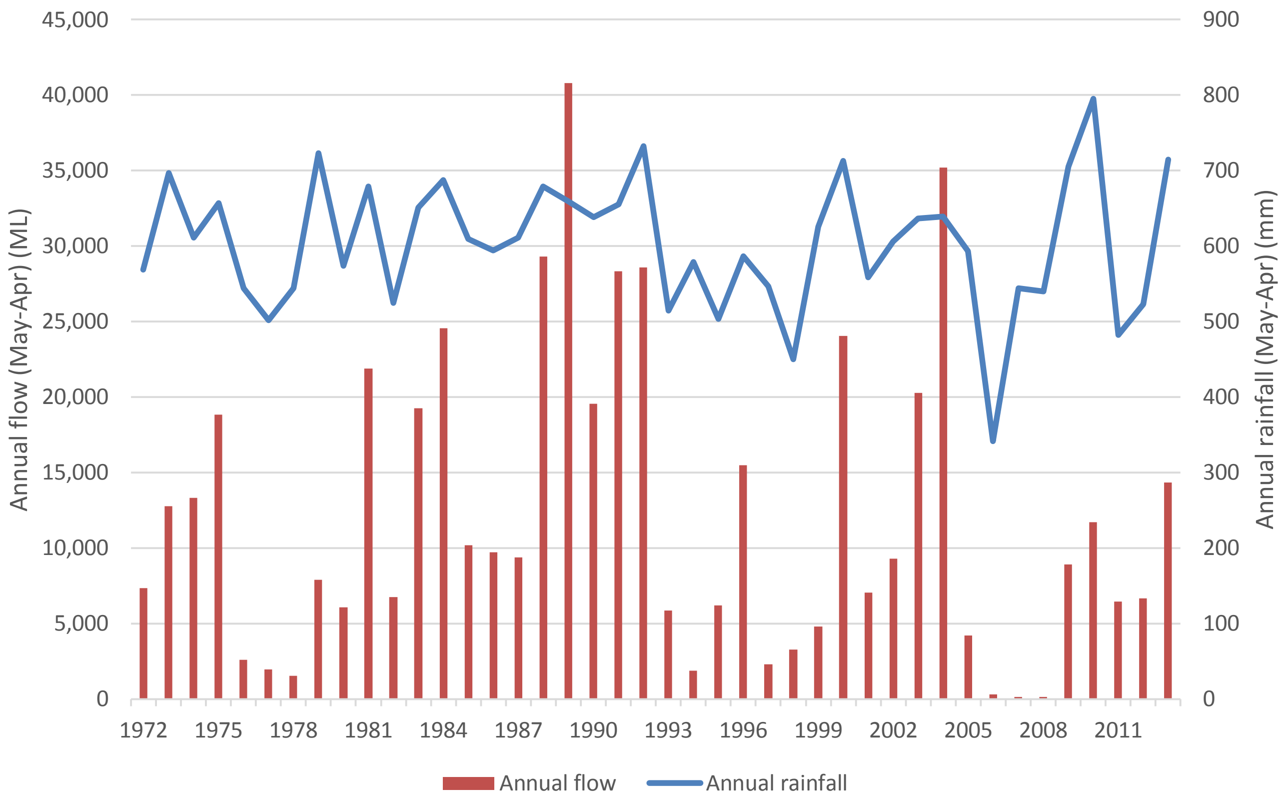

Figure B.8 Annual flows for Drain K (A2390510) alongside area-average annual rainfall

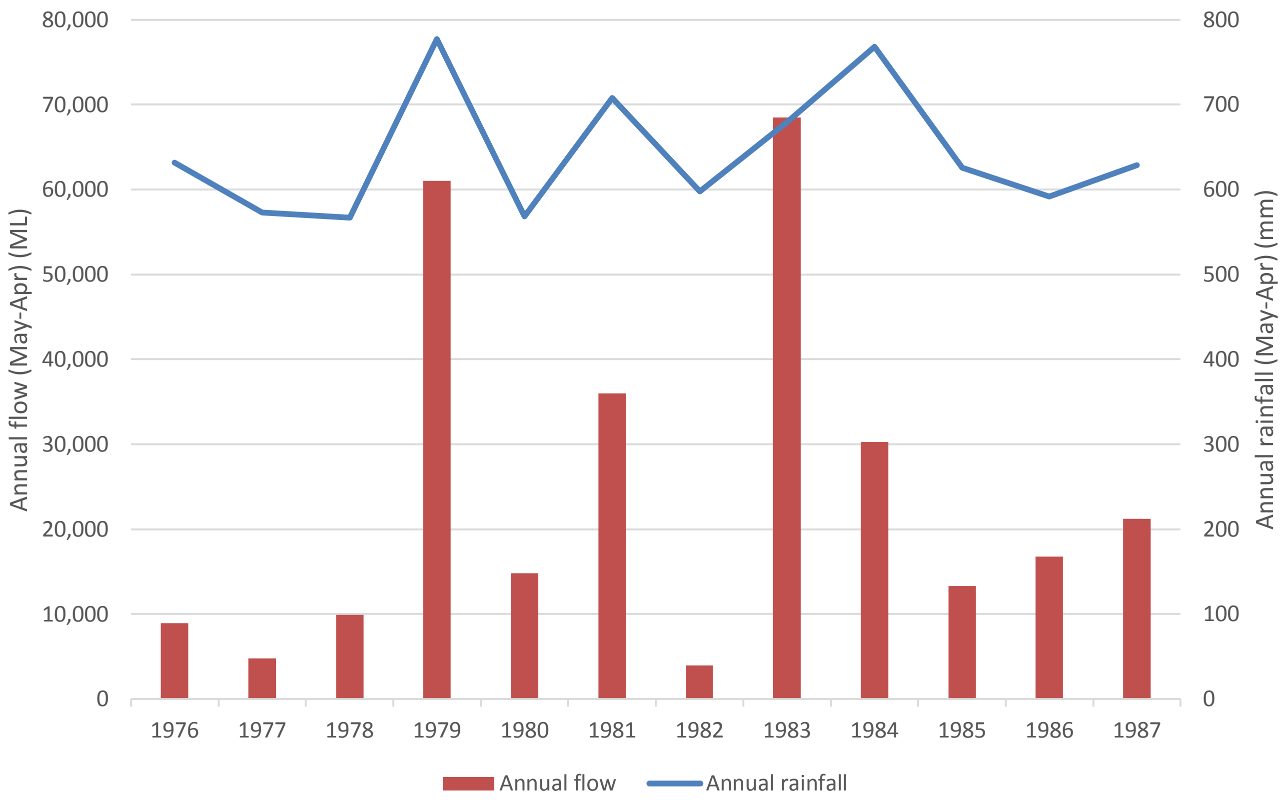

Figure B.9 Annual flows for Bray Drain (A2390504) alongside area-average annual rainfall

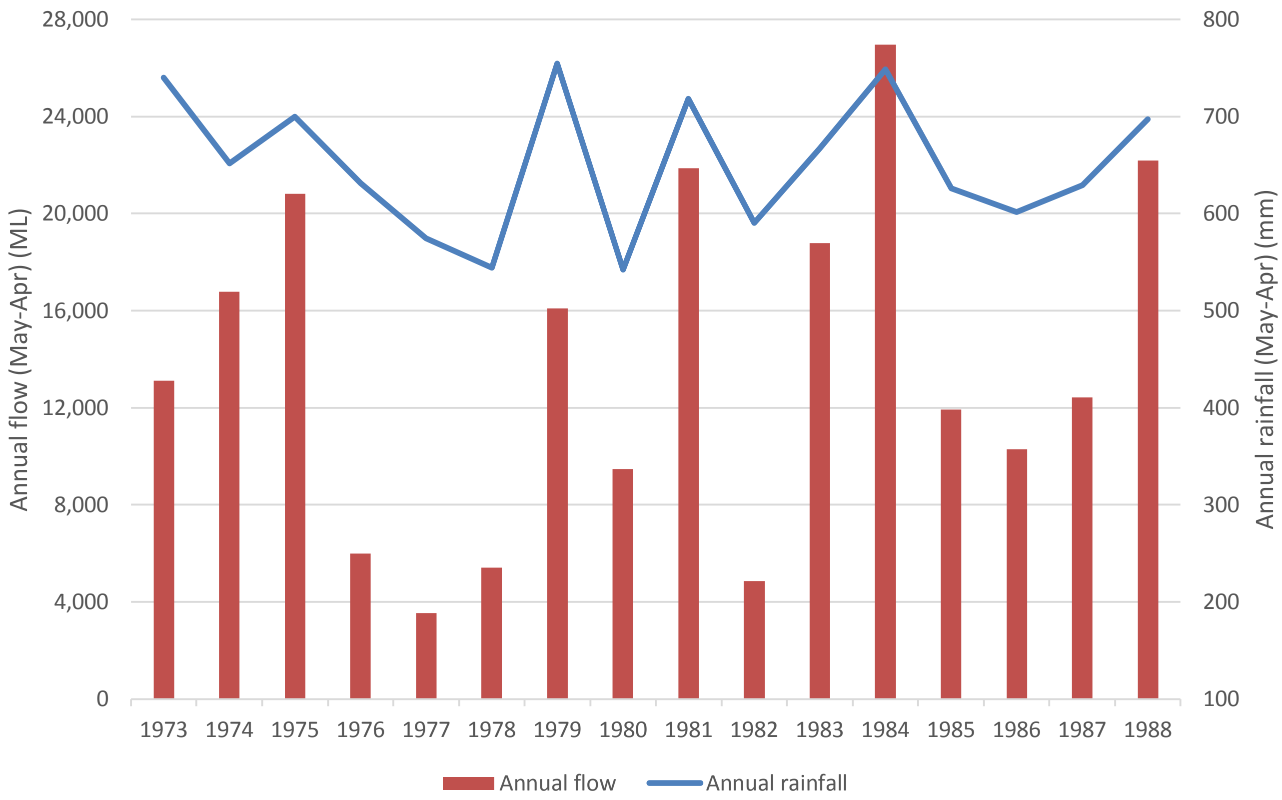

Figure B.10 Annual flows for Wilmot Drain (A2390527) alongside area-average annual rainfall

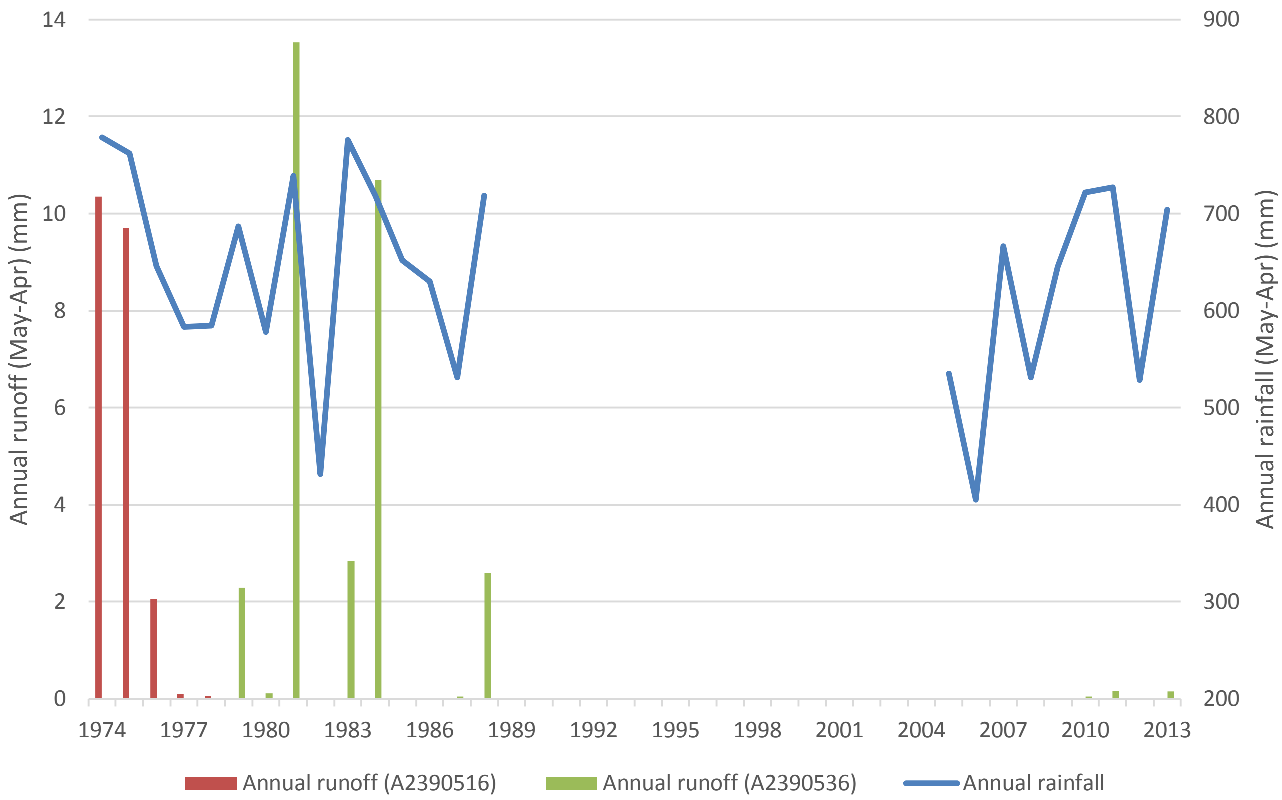

Figure B.11 Annual runoff for Drain C (A2390516 and A2390536) alongside area-average annual rainfall

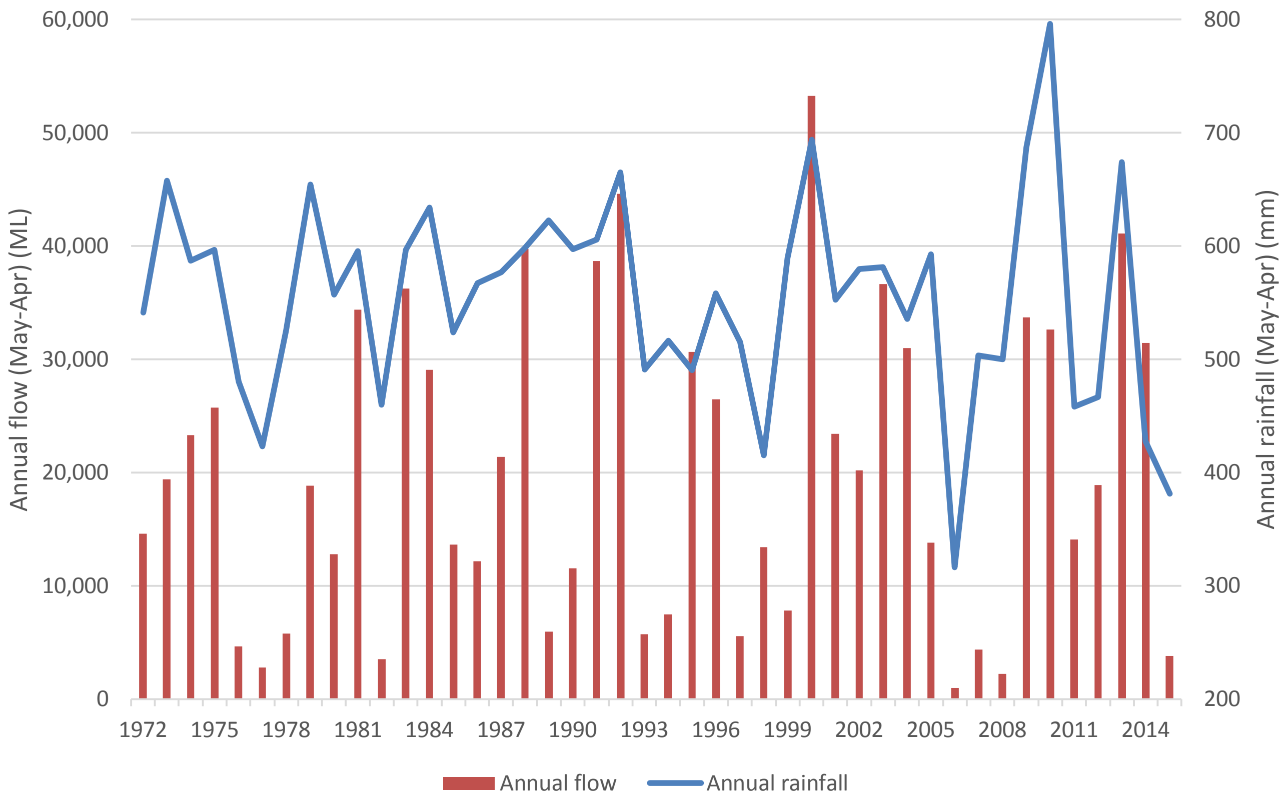

Figure B.12 Annual flows for Blackford Drain (A2390506) alongside area-average annual rainfall

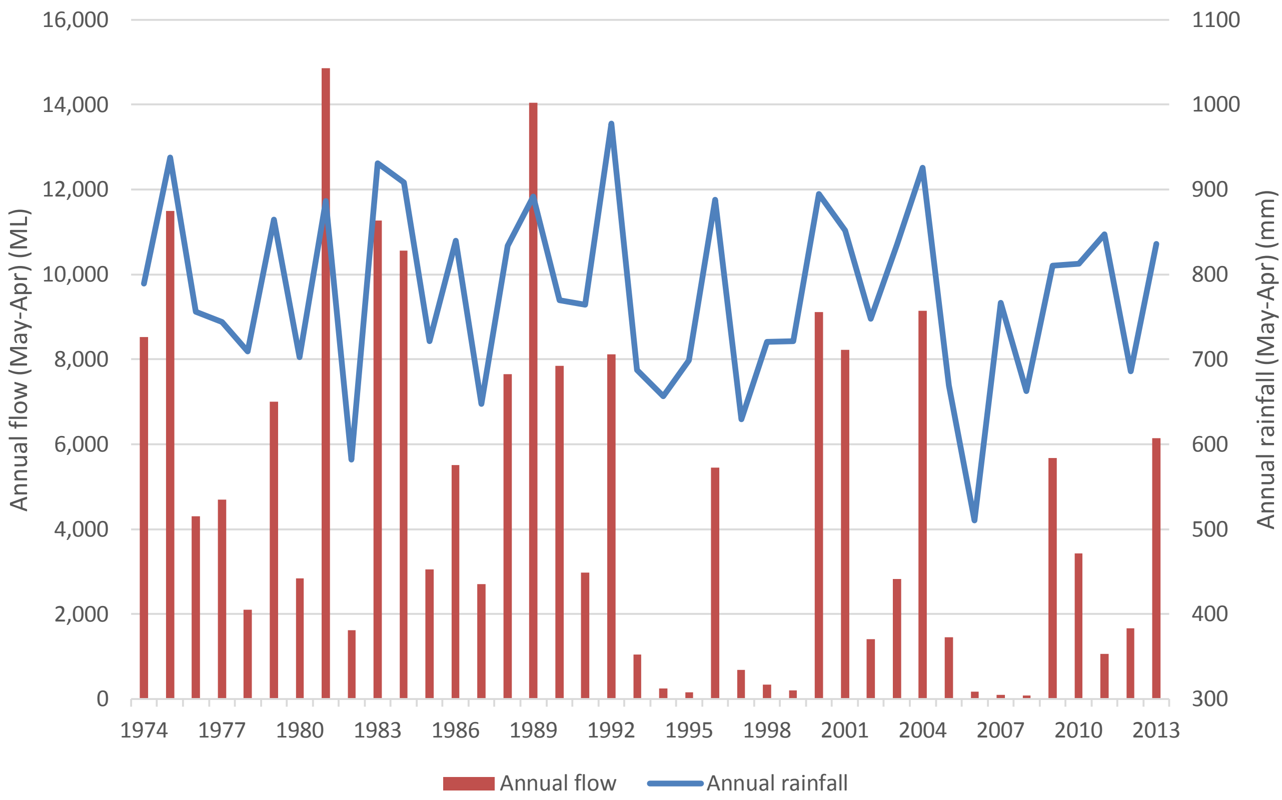

Figure B.13 Annual flows for Stony Creek (A2390523) alongside area-average annual rainfall

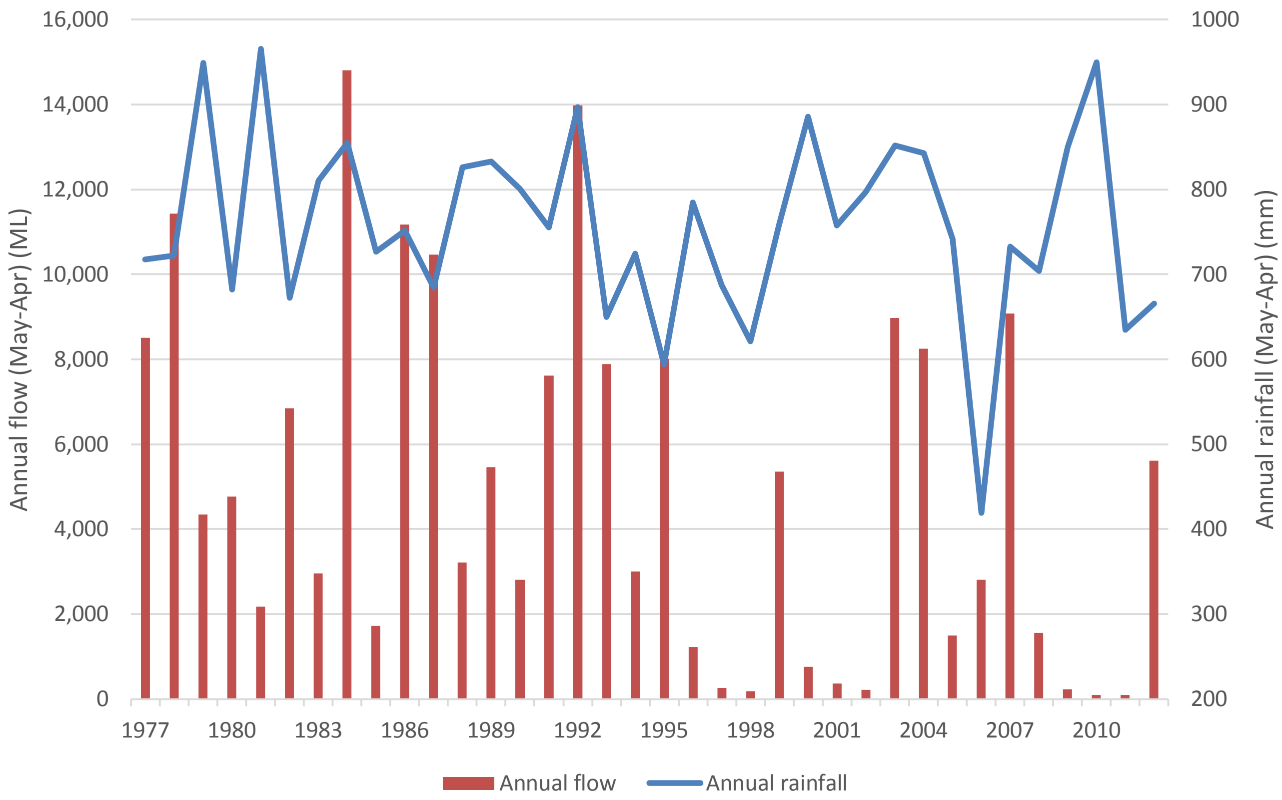

Figure B.14 Annual flows for Drain 48 (A2390533) alongside area-average annual rainfall

C. Discussion about the 25% rule

The State NRM Plan (2006) defined a standard approach in defining limits on the use (termed the 25% rule) and capture (in on-stream dams as twice the use limit, termed the 50% rule) of surface water resources to ensure equitable sharing. As stated in Appendix 2 of the State NRM Plan (2006):

> 'Outside prescribed areas, and until there is additional information, *25% of median annual adjusted* catchment yield should be used as an indicator of the sustainable limit of the catchment surface water and watercourse water use. 'Adjusted' is defined as the *annual catchment discharge with the impact of dams removed*'

The term Sustainable Use Limits (SULs) is often used to describe the total volume of surface water that can be used, as calculated through the 25% rule, with the allowable dam capacity limit (for 'on-stream' or 'catching dams' and not including 'off-stream' or 'holding' dams') being twice the SUL. It needs to be noted that the use of the term 'sustainable' is related to an equitable sharing of surface water resources between downstream users and does not necessarily include water dependent ecosystems as downstream users. As such, an alternative term Water Use Limits (WULs) is sometime used if there has been no explicit account for environmental water requirements.

Additional work has been undertaken in recent years across the Mt Lofty Ranges (MLR) to further define ecologically sustainable use. 'Adjusted catchment yield' or 'Annual catchment discharge with the impact of dams removed', is estimated using different methods based on the availability of streamflow data in the catchment and/or availability of a calibrated rainfall-runoff model for the catchment. The different methods for estimating adjusted catchment yield are as follows:

Application	Method used	Details of yield calculation
Gauged catchments/sub-catchments	Catchment rainfall-runoff modelling	A hydrological model is built to represent the catchment's rainfall-runoff generation processes, with explicit spatial and functional representation, within the model, of activities related to the capture, diversion and extraction/loss of surface water as: (i) water use and evaporation from farm dams (ii) water diverted and extracted from watercourses (iii) water used by plantation forestry within the catchment. The model is then calibrated to streamflow records from monitoring sites at the catchment outlet. The flow generated from this calibrated model represents 'catchment yield with the impact of dams (watercourse extractions and plantation forestry) **included**'. The model is then run by removing the farm dams (watercourse extractions and plantation forestry) and the resulting flow represents 'catchment yield with the impact of dams (watercourse extractions and plantation forestry) **removed**', otherwise termed as 'adjusted catchment yield'. The results of this model run can then be used to develop a relationship between annual rainfall and adjusted catchment yield ('rainfall – adjusted catchment yield curve'). It should be noted that the modelling of Wood and Way (2011) is not at the scale of modelling individual (or lumped) farm dams, and new models would need to be developed.

Application	Method used	Details of yield calculation
Ungauged catchments that are hydrologically similar to, and nearby, gauged catchments	Rainfall – Adjusted Catchment Yield curve	Adjusted catchment yield for an ungauged catchment or sub-catchment can be estimated using (i) the catchment-average mean annual rainfall for the sub-catchment/catchment, and (ii) a 'Rainfall-Adjusted catchment yield curve' developed for a hydrologically similar catchment/sub-catchment. This would require a calibrated model, however the models currently for catchments in the region are not at the scale that is required for this exercise.
Gauged/Ungauged catchments or sub-catchments that do not have a rainfall-runoff model	Incorporate (add) the estimated impacts of farm dams, watercourse extractions (diversions) and plantation forestry to yield estimates that have been derived from streamflow data.	**Farm dam impacts:** Experience has shown that the volume that can reliably be accessed from a farm dam in MLR catchments, in the long-term, is estimated to be *half (50%) of its capacity* (Fact sheet 81, DWLBC). Hence, it could be inferred that the impact of a farm dam on surface water resources is half its capacity. This estimate was made by taking into account numerous factors including, lack of inflow to dams during dry years, unharvestable spills occurring from farm dams during large flow events and wet years, evaporation and seepage. This estimate was based on an analysis of around 700 farm dams across the MLR (McMurray, 2004), which indicated that the average use from farm dams was '*around 19% of capacity and a similar figure for water lost through evaporation*'. The report also concluded that '*this was during the cooler than typical summer of the study period (summer 2001–2). More typical average figures of 25–30% for usage and evaporation, or possibly higher*'. Further detailed modelling of MLR catchments during recent years suggest that farm dam impacts varied, but on average appear to support this estimate. However, given the differences in climate and hydrogeology of catchments in the South East NRM Region, in comparison to the MLR catchments, further investigation would be required to reliably assess the impact of farm dams in the region. **Watercourse extraction/diversion**: The impact of watercourse extractions/diversions would be the actual volumes that are diverted/extracted. **Plantation forestry impacts**: Plantation forestry in the MLR and Kangaroo Island (KI) catchments has been estimated to reduce potential surface runoff by 15%. The relative impact of plantation forestry on surface runoff in the South East catchments needs to be confirmed.

The process undertaken to calculate WULs for gauged/ungauged catchments or sub-catchments that do not have a rainfall-runoff model would be as follows:

WUL (ML) = 0.25 X [Median Annual Streamflow (ML) + IWC (ML) + IFD (ML) + IPF (ML)]

Where:

IWC (ML) = average annual water extracted/diverted from watercourses

IFD (ML) = average annual impact of farm dams on streamflow

(In MLR catchments, IFD (ML) = 0.5 X Total farm dam volume (ML) within the catchment)

IPF (ML) = average annual impact of Plantation Forestry on surface water

(In MLR/KI, IPF = 0.85 X avg annual adjusted runoff (mm) X area of forestry (ha) X conversion factor)

The surface water volumes that would be available for further development (WAD) could then be calculated as:

WAD (ML) = WUL – [IFD (ML) + IWC (ML) + IPF (ML)]

As stated in DWLBC's Fact Sheet 81 (DWLBC, 2007), the 25% rule evolved from the 50% rule as defined in the State Water Plan (DWR, 2000). To ensure that all surface water was equitably shared, the 50% rule required that half the average runoff from any property should pass to downstream users, leaving a maximum of 50% to be captured for use.

Experience has shown that, due to the lack of inflow during dry years, unharvestable spills occurring in large events and wet years, as well as evaporation and seepage, only half of this volume can be reliably accessed from farm dams every year, giving rise to the 25% rule.

D. Process undertaken by NRSE to estimate farm dam volumes

Natural Resources South East recently conducted a review of farm dams for the cross-border SWPAs of Mosquito, Naracoorte, Morambro and Tatiara–Nalang. This review followed a work procedure entitled 'Digitising hydrologic features' (DEWNR, 2011), and included the following steps:

- Spatial data were extracted from the DEW corporate WaterBodies topographic dataset (using a definition query of FEATURECODE = 4812 to isolate dams).
- A fishnet grid (500 m x 500 m) was created and systematically used to identify farm dams within the South East 2013 aerial imagery layer, incorporating recent imagery from the Google EarthTM platform where necessary.
- A Digital Elevation Model (DEM) at 10m resolution, developed in 2008, was also used to assist in the identification of farm dams, with classification rendering utilised to identify surface water boundaries.
- Individual farm dams included in the DEW WaterBodies topographic dataset were then reviewed against imagery and LiDAR information, with dams constructed after 2008 only reviewed against imagery.
- New dams were digitised, and attributes assigned, with dam walls identified where possible.

Following the completion of this cross-border review of farm dams, DEWNR commenced a review of all assets (including farm dams) across the remaining areas of the Region to contribute to the 2018 revision of the Emergency Services Mapbook.

Upon completion of this analysis, the WaterBodies feature class was then intersected (using ESRI ArcGIS) with the proposed SWPAs, creating a farm dam volume attribute for each proposed SWPA. Total farm dam volumes in SWPAs were calculated using the following relationships as provided in McMurray (2004):

- For dam surface areas less than 15,000 m^2, Volume (ML) = 0.0002 x ($Area^{1.25}$)
- For dam surface areas greater than 15,000 m^2, Volume (ML) = 0.0022 x Area

Volume-area relationships from McMurray (2004) were preferred to volumetric analysis with the LiDAR-derived DEM in order to maintain consistency with new dams (constructed post-2008) not included in the DEM.

It is understood that in recent years there has been an increase in the construction of clay borrow pits across the Region, and there was some difficulty in determining whether these are used as dams. Where possible recent imagery from the Google Earth™ platform was used to determine if any water were held in these pits, and if so, these were included in the farm dam layer.