TECHNICAL REPORT

EXTENSION OF THE WATER-DEPENDENT ECOSYSTEM RISK ASSESSMENT FRAMEWORK TO THE SOUTH EAST NRM REGION

2012/10

Government of South Australia
Department for Water

EXTENSION OF THE WATER-DEPENDENT ECOSYSTEM RISK ASSESSMENT FRAMEWORK TO THE SOUTH EAST NRM REGION

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FOREWORD

South Australia's Department for Water leads the management of our most valuable resource—water.

Water is fundamental to our health, our way of life and our environment. It underpins growth in population and our economy—and these are critical to South Australia's future prosperity.

High quality science and monitoring of our State's natural water resources is central to the work that we do. This will ensure we have a better understanding of our surface and groundwater resources so that there is sustainable allocation of water between communities, industry and the environment.

Department for Water scientific and technical staff continue to expand their knowledge of our water resources through undertaking investigations, technical reviews and resource modelling.

Scott Ashby
CHIEF EXECUTIVE
DEPARTMENT FOR WATER

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SUMMARY

Improved regional water planning is the foundation of the National Water Initiative (NWI), *which states 'water planning is an important mechanism to assist governments and the community to determine water management and allocation decisions to meet productive, environmental and social objectives'*. The Water-dependent Ecosystem Risk Assessment Tool will assist future water planning in the South East, South Australia, by identifying environmental assets and assessing present and future demands of the groundwater resource.

A GIS tool was developed to provide baseline information that would identify significant water-dependent ecosystem assets and processes and incorporate spatial distribution and connectivity issues and associated development threats and risks. The Water-dependent Ecosystem Risk Assessment Tool (herein Water-RAT) was originally developed by DFW for the Adelaide Mount Lofty Ranges (AMLR) NRM region. This project has extended the application's range to the South East NRM region of South Australia.

The data incorporated into Water-RAT for the South East included GIS layers specifically generated from raw data sourced from multiple agencies including DFW, DENR, SEWCDB, Native Fish Australia (NFA), and South East Regional Information Centre (SERIC). All data were analysed and processed using ESRI ArcGIS ® Software. Procedures and data manipulation methods to create layers in Water-RAT are detailed within this document.

A risk assessment approach was adopted to identify high risk zones for potential impacts to high value groundwater-dependent ecosystems (GDEs) and ecological assets from water-affecting activities and developments. The risk assessment relies on the identification of assets, likelihood of impact and existing threats to these assets. The risk zones are not intended to be used as regulatory buffers or a policy tool and do not replace environmental protection policy developed in the South East (refer to REM 2006 and SENRMB 2009). The purpose of the risk zones was primarily to provide an alert mechanism for resource managers, decision-makers and developers of a potential risk to a high value groundwater-dependent ecosystem/asset as a result of a proposed groundwater affecting activity within a certain distance of an asset. The risk zones are therefore conservative and were developed with the use of simple analytical solutions for stream depletion.

A significant limitation of the assessment and analysis undertaken to identifying high value aquatic ecosystems was the large number of wetlands in the South East (83.5% of all mapped SA wetlands) in the 'not assessed' category. In order to address this limitation, further wetland inventory in the South East was commissioned as part of the Water-RAT project, targeting unassessed wetlands in visually good condition as identified from aerial photography. Wetlands located in shallow groundwater zones (<5m to groundwater) have been targeted as these systems were acknowledged as most at risk from the major water-affecting activities in the South East, primarily irrigation and forestry.

Recommendations to improve the application of the Water-RAT tool identified through the project included that:

- *more relevant methods for identifying meaningful risk zones are investigated for future input into the Water-RAT application*
- *the accuracy and spatial coverage of aquifer property data in the South East be addressed in future. More accurate aquifer property data specifically obtained for areas surrounding high value GDEs should be a priority.*

- *limits of acceptable change in groundwater level are identified for wetland typologies in the South East.*
- *the likelihood of the groundwater-dependency spatial layer produced by SKM (2009) be groundtruthed and updated to reflect hydrological data collected from 14 representative wetland case study sites in the South East.*
- *the forestry intensity layer presented in this report be reviewed in light of future Water Allocation Plan policy and updated if required.*
- *climate change scenarios be investigated in terms of identifying high value wetlands at risk.*
- *important surface water catchment areas for the South East be identified.*
- *the extent of groundwater catchments for significant GDEs in the South East be investigated.*
- *permanently pooling high-value habitat provided by artificial drains in the South East be identified in future.*

Several new data sets have been developed as contributing spatial layers to this project, however the ability to fully analyse water-dependent ecosystems in relation to water-affecting activities was limited by available data. Major data gaps that were considered integral to the application were addressed through the Water-RAT project, including a classification of groundwater dependency for mapped wetlands and improved coverage of wetland inventory data to identify high value assets (wetlands).

1. INTRODUCTION

As part of the NWI Project *Identify and estimate the impacts of climate change on the management of water resources through development of appropriate information sets* the Department for Water (herein DFW), formerly the Department of Water, Land and Biodiversity Conservation (DWLBC), committed to extend a spatial risk assessment tool developed for the Adelaide Mount Lofty Ranges NRM region to other NRM regions in South Australia and complete a user friendly web-based front-end and reporting system. This report documents the delivery and data processing of the Water-RAT SE, implemented by the Groundwater Resource Assessment South East (GRASE) Team (former DWLBC). The web-delivery component of this project was progressed by the Information Unit (former DWLBC).

1.1. BACKGROUND

Water-affecting activities in the South East, including the use of the region's water resources (both surface water and groundwater), land use and climate changes, have an impact on water-dependent ecosystems. Currently less than 6% of the original wetland area in the South East remains.

A GIS tool was identified as a means to provide baseline information that would identify significant water-dependent ecosystem assets and processes and incorporate spatial distribution and connectivity issues and associated development threats and risks. The water-dependent ecosystem risk assessment tool (herein Water-RAT) was developed by DFW for the AMLR NRM region. The tool was developed primarily as a risk assessment framework that integrates environmental condition and process data within a GIS platform to provide a standard approach that can integrate scientific data at varying scales and level of detail. This framework allows consequences to be evaluated prior to making decisions regarding resource allocations.

In the South East, aquatic ecosystem, water licensing and allocation, and surface water flow information have traditionally been the responsibilities of DENR, DFW and SEWCDB respectively. Information on surface water catchments, groundwater resources and conditions, wetlands, aquatic biota and water resource development were fragmented, where data have been generated and managed amongst various departments and agencies, and not always made readily available. Additionally, some integral data sets for analysing risks to water-dependent ecosystems were absent. There have been difficulties in ensuring that adequate information transfer and referrals to relevant agencies of the potential impacts of water-affecting activities on the environment are consistently addressed. Expanding the Water-RAT's application to the South East provides a mechanism to improve decision-making regarding water resource allocation, referrals processes, the effective administration of policies and improved interagency knowledge exchange. At the inception of the Water-RAT SE project the assessment and referral process in the SE was based on the experience and knowledge of the assessor rather than a quantifiable data set. The Water-RAT application significantly improves information availability across agencies in a consistent and relevant format and provides the basis for formalising agreements between agencies.

1.1.1. THE STUDY AREA

The South East NRM Region of South Australia forms the project area for the extension of Water-RAT (approximately 28 120 km^2). Mean annual rainfall varies across the region, ranging from approximately 460 mm/y at Keith to 900 mm/y at Mount Burr. The region supports a significant proportion of South Australia's agricultural productivity—notably irrigation, major industry, forestry and internationally and nationally important wetland systems. The main water supply for industry, agriculture, town water and

the environment is sourced from groundwater resources, with the relatively flat topography characteristic of the region supporting limited surface water resources. As such, the risk assessment of water-affecting activities in the South East region, unlike the AMLR RNM region, has largely focussed on groundwater usage and impacts.

Hydrogeologically, the region is characterised by an upper Tertiary Limestone Aquifer (TLA), separated from an underlying Tertiary Confined Sand Aquifer (TCSA) by a clay aquitard. Overlying the TLA throughout much of the region is a series of north–west trending Quaternary beach-dune ridge systems, separated by a series of inter-dunal corridors which form the region's surface water-driven watercourses and floodplains.

The TLA forms the major source of water resources for agricultural, industrial, urban and ecosystems use in the South East. The groundwater level in the TLA has been declining over the past fifteen years and at a rate of up to 0.8 m/year over the period between September 2003 and September 2008.

Many wetlands in the South East are recognised as having a high dependency on the regional unconfined aquifer and are at risk from increasing competition for water resources and groundwater level decline. Wetland inventories have mapped over 16 000 extant wetlands and have identified 45 ecologically significant groundwater-dependent wetland complexes including the RAMSAR listed Bool and Hacks Lagoon and internationally renowned Piccanninie Ponds (RAMSAR nomination in prep., DENR) and Ewens Ponds. The requirement for an assessment of the likelihood and seasonality of dependence of the regions wetlands has been addressed as part of the Water-RAT project (refer to SKM 2009).

An estimated 2515 km of drains have been established in the South East region since settlement, beginning in the 1800s. The drains were designed to relieve surface water inundation in the Lower South East, and control saline groundwater levels in the Upper South East, improving the agricultural productivity of the region. The drains have brought about a major landscape change across the South East, removing over 93% of the original wetland extent. An estimated 45% of the South East landscape was subject to inundation either permanently or seasonally prior to drainage. Currently less than 6% of the original wetland area remains, albeit fragmented and in an altered hydrological state (Fig. 1). Less than 10% of remaining wetland area is considered intact (Harding 2007). Consequently, protecting the hydrology and hydrogeology of remaining intact wetland ecosystems is of significant importance in sustaining the SE region's biodiversity values.

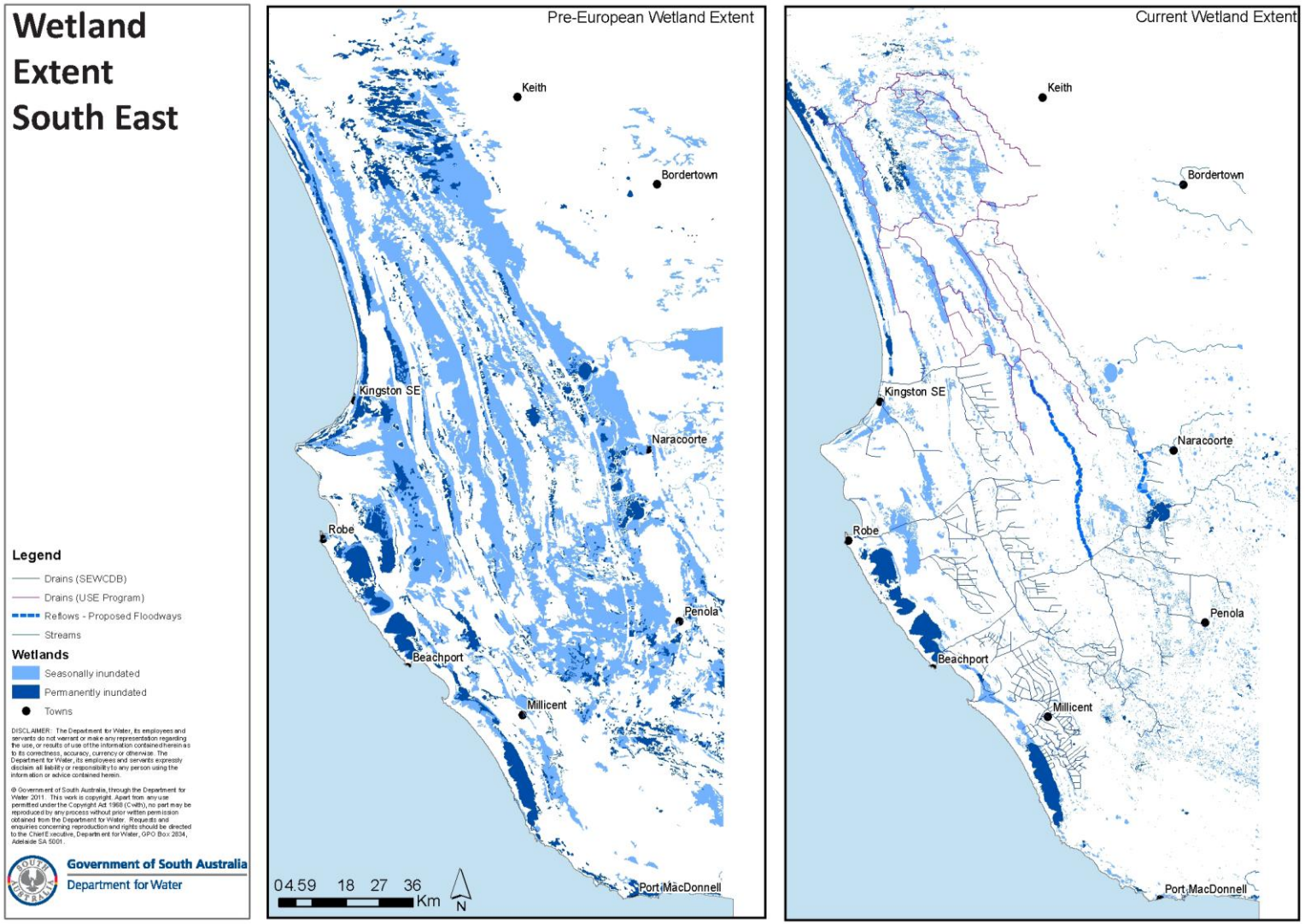


Figure 1. Wetland extent in the South East region - Pre-European and current extents

1.1.2. MANAGEMENT–POLICY APPLICATION

Water-RAT has been used to develop GIS coverages to assist planning and policy within the South East NRM region. A review of policy and legislation relevant to the development and application of these coverages was undertaken at the commencement of the project and is summarised in Appendix A. The coverages address water-affecting activities, water resource use, and ecosystem assets such as wetlands and threatened aquatic flora and fauna. These coverages will enable a preliminary assessment of the potential impact of a water-affecting activity on a site and prescribe a level of assessment required by the proponent to investigate and address any potentially negative impacts on water resources and significant ecosystems–environmental assets.

1.2. AIMS AND OBJECTIVES

The aim of the Water-RAT project for the South East is to develop a spatial risk assessment tool in the form of a GIS workspace and framework for evaluating impacts on water-dependent ecosystems and assets from water resource development to inform and improve water management decisions across the SE, using the AMLR Risk Assessment Tool as a template.

A number of key objectives that have been identified as principal outcomes of this project include:

- enhanced consideration of environmental issues in the assessment of water-affecting activities
- improved interagency knowledge and data exchange and referral mechanisms; and
- improved understanding of catchment context pressures on water-dependent ecosystems in the South East.

2. PROCEDURES AND OUTPUTS

The data incorporated into Water-RAT for the South East includes GIS layers specifically generated from raw data sourced from multiple agencies (Appendix I) including DFW, DENR, SEWCDB, NFA and the South East Regional Information Centre (SERIC). The program incorporates scientific data, modelled data and policy information at varying scales and levels of scientific defensibility. This section describes each layer available within the Water-RAT program, how the layers were generated and the interpretation and limitations of the data outputs.

All data were analysed and processed using ESRI ArcGIS ® Software.

Risk Assessment

A risk assessment approach was adopted to identify high risk zones for potential impacts to water-dependent ecological assets from water affecting activities and developments. The risk assessment relies on the identification of *assets, likelihood* of impact, and existing *threats* to these assets.

The following GIS spatial layers were developed (or sourced) to evaluate the connectivity between upstream and downstream areas and the potential threats to the ecosystem assets:

Planning/Policy Information

- Land parcels/titles (available from the Department for Transport, Energy and Infrastructure)
- SEWCDB drains (sourced from SEWCDB)
- USE drains (sourced from USEDSFMP)
- Groundwater Management Units: Groundwater Management Areas (sourced DFW); Interim Adaptive Management Zones (sourced NWI Project team, DFW)
- Topographic information: Roads; Towns.

Assets

- Wetlands (significance: Very High; High; Moderate; Low; Not Assessed)
- Threatened aquatic flora and fauna (EPBC Act 1999 matters)
- Threatened aquatic flora and fauna (NPW Act 1972 matters)
- Migratory Birds of international importance (JAMBA & CAMBA matters)
- Wetlands of international and national importance: Ramsar & DIWA listed wetlands (listed and current nominations)
- Significant surface water catchments
- Permanent pools (in-stream)
- Natural streams
- Karst Features (caves and sinkholes).

Likelihood

- Wetlands likelihood of groundwater dependency (on the TLA)
- Wetlands type (seasonality) of groundwater interaction (on the TLA).

Threats

- Irrigation groundwater extraction (spatial intensity of use)
- Forestry groundwater extraction (spatial intensity of use)
- High groundwater usage areas (spatial intensity of irrigation and forestry extraction)
- Forestry (plantation type)
- Groundwater level trend (resource condition indicator)
- Drainage.

The development of layers for the Water-RAT project is detailed in Section 2.1.

2.1. DATA ANALYSIS AND LAYER DEVELOPMENT

2.1.1. WATER-DEPENDENT ECOLOGICAL ASSETS

A Water-dependent Ecosystem (WDE) is defined for the purposes of this report as:

A surface water ecosystem or a groundwater ecosystem, and its natural components and processes, that depends on periodic or sustained inundation, waterlogging or significant inputs of water for its ecological integrity. In the South East, these can be defined as ecosystems or species associated with:

- Wetlands – both fresh and saline waterbodies that may be permanently, seasonally or temporarily inundated
- Watercourses and floodplains – streams, interdunal watercourses and associated seasonally or intermittently inundated floodplains. Some of these include permanent pools which are important for supporting aquatic species, particularly native fish, throughout summer and through periods of drought. Many of the artificial drain systems in the South East also contain permanent pools which are important refugia for species such as native fish and frogs.
- Lakes or a body of water
- Estuaries
- Karst features.

WDEs are significant features in the South East region and provide feeding and breeding habitat and drought refugia to waterbirds. Significantly, freshwater ecosystems of the Lower South East support extremely high biodiversity and provide habitat for many regionally and nationally threatened species. The value of WDEs also includes significant cultural, social and recreational values, which contributes significantly to the regions economy and amenity.

Less than 6% of wetland ecosystems remain in the South East post-drainage and development for agriculture. Consequently, protecting the hydrology and hydrogeology of remaining intact wetland ecosystems is of significant importance in the South East region in sustaining the regions biodiversity values.

Identifying high value aquatic ecosystems

The South Australian Wetland Inventory Database (SAWID) for the South East region, managed by DENR, provides detailed mapping of wetland ecosystems completed for wetland inventories in the Lower South East (Taylor 2006) and Upper South East (Harding 2007) regions. The wetlands spatial layer identifies 16 695 wetland polygons across the South East, and incorporates Microsoft Access® related tables including biological, physical and chemical attributes for inventoried wetlands.

A prioritisation framework was developed that uses data incorporated in SAWID to rank wetlands on parameters that were identified as useful surrogates for determining ecological-value. Four criteria were used to determine ecological value scores for each wetland:

1. landscape naturalness and connectivity
2. diversity and richness
3. threatened species and ecosystems
4. special features.

Each criterion is scored from a number of parameters as identified in Appendix B. Expert input from regional wetland ecologists provided the weighting of different scores to reflect their relative importance (Appendix B). The scores for each criterion were then combined to provide an overall Ecological Value score for each wetland, where high scores indicate high value (Harding 2007). Wetland scores using this method ranged from a minimum value of -2.0 to a maximum value of 56.4, with a mean value of 5.3 (Figure 2).

Ranked wetlands were grouped into four descriptive value classes using significant cut-off values: Very High, High, Moderate, and Low. A cut-off point was identified below which all other wetlands were classified as 'Not Assessed' due to insufficient data in one or all of the criteria fields which cannot be attributed to 'Low' value rather than poor survey effort. Figure 2 provides the frequency histogram for scored wetlands, showing the significant cut-off values for each category as identified by the Jenks Natural Breaks optimisation method.

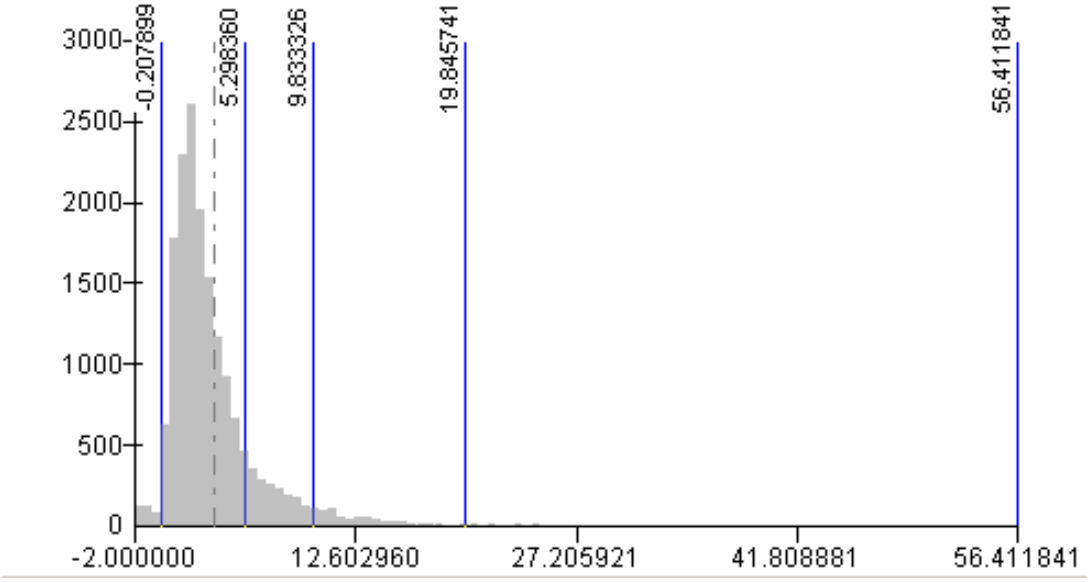


Figure 2. Frequency histogram of ecological value scores of mapped wetlands in the South East, showing significant cut-off values for ecological value categories.

A significant limitation of this assessment and analysis, for the purposes of use in the Water-RAT application, was the large number of wetlands (83.5% of all mapped SE wetlands) in the 'Not Assessed' category. The implications of this data gap include the risk that ecologically significant wetlands (high value assets) are not identified and therefore risk from development to these systems may be underestimated or overlooked. In order to address this limitation, further wetland inventory in the South East was commissioned as part of the Water-RAT project, targeting unassessed wetlands in visually good condition as identified from aerial photography. Wetlands located in shallow groundwater

zones (<5m to groundwater) have been targeted as these systems were acknowledged as most at risk from the major water-affecting activities in the South East, primarily irrigation and forestry.

The further inventory work used methods developed by Taylor (2006) and Harding (2007) and collected comprehensive inventory information for a further 150 wetlands from October 2008–June 2009 (Billows 2009). The prioritisation as specified in this report was reapplied to update the Significant Wetlands Layer used within the Water-RAT framework for the South East (Table 1 and Figure 3).

Table 1 Number of significant wetlands identified from wetland inventories in the South East

Significant Level	**Number of Wetlands** SAWID (Taylor 2006 & Harding 2007)	**Number of Wetlands** SAWID (Taylor 2006, Harding 2007, & Billows 2009)
Very High	94 (0.5%)	98 (0.6%)
High	831 (5%)	852 (5.1%)
Moderate	1521 (9%)	1547 (9.3%)
Low	345 (2%)	444 (2.6%)
Not Assessed	13904 (83.5%)	13 731 (82.26%)
Errors in mapping (not wetlands)		23 (0.14%)

Ground-truthing of the wetlands spatial layer via further inventory has also refined the spatial accuracy of this layer. Errors in wetland mapping, including mapped wetlands that are not wetlands, have been identified via ground-truthing and rectified in the wetlands spatial layer (Billows 2009).

The identification of high value wetland ecosystems is ongoing, and is updated periodically through SAWID.

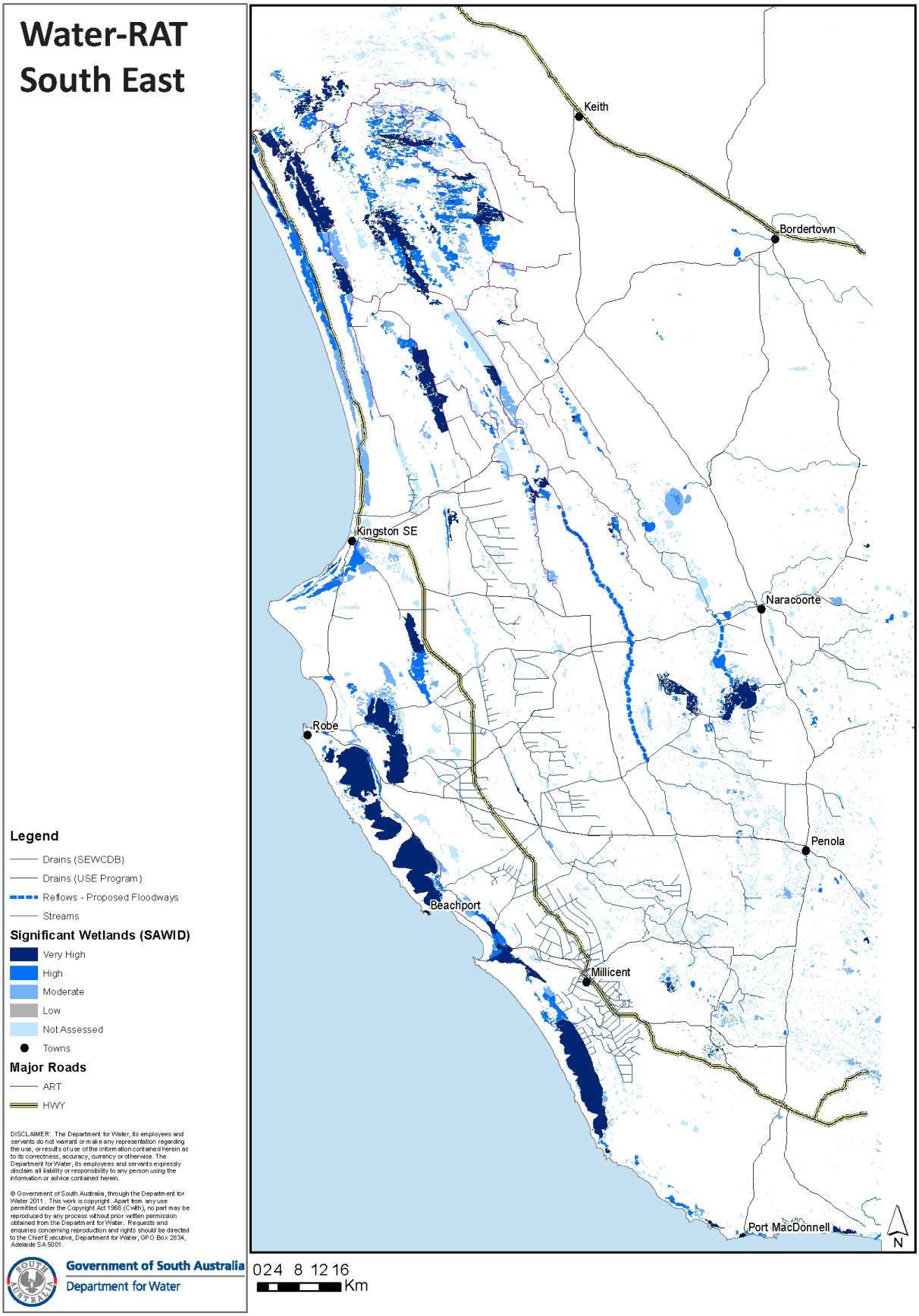


Figure 3. Water-RAT output – Significant Wetlands Spatial Layer

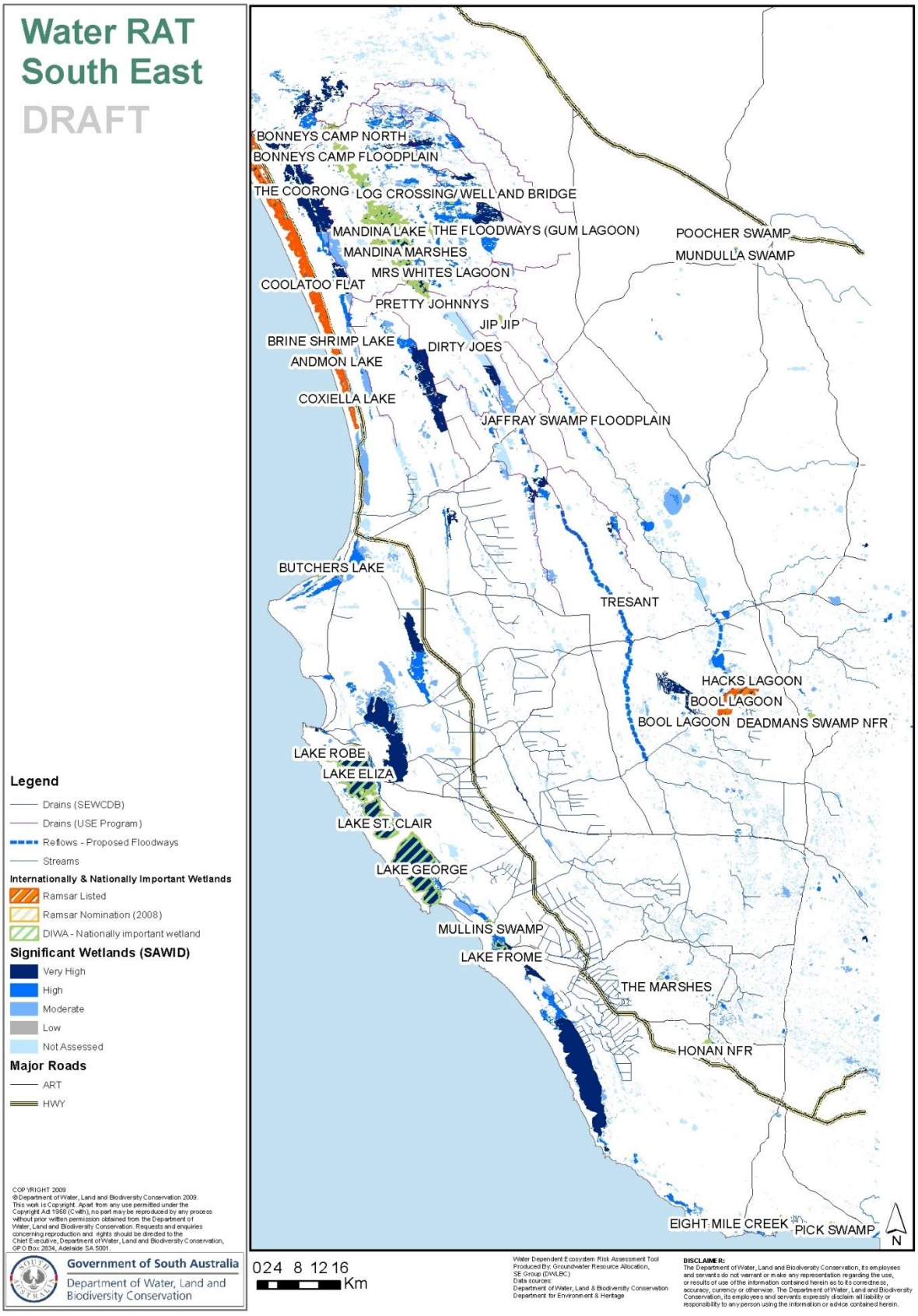


Figure 4. Water-RAT output – Internationally and Nationally recognised significant wetlands (Ramsar Convention & DIWA)

Internationally and nationally recognised wetlands

The Ramsar Convention on Wetlands (1971) is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. In the South East, two wetland complexes are recognised under the Ramsar Convention: including Bool and Hacks Lagoon and The Coorong. The Piccanninie Ponds and Pick Swamp wetland complex at the time of writing is in the process of nomination.

The Directory of Important Wetlands in Australia (DIWA) (ANCA 1996) identifies wetlands of national significance. Thirteen wetland complexes in the South East are currently listed in this directory (Fig. 4).

Aquatic flora and fauna

The EPBC Act (1999) is the main Australian Government legislation for protecting the environment and conserving biodiversity. The aim of the Act is to protect native species, identify processes that threaten all levels of biodiversity and implement plans to address these processes. The Act also enshrines obligations under the Ramsar Convention (1971). In the South East, eight fauna and five flora species that have aquatic dependencies for all or part of their life-cycle have been identified (Table 2).

Table 2. Aquatic flora and fauna species listed under the EPBC Act (1999) in the South East

COMMON NAME	SPECIES	EPBC Act
Flora		
Swamp Greenhood	*Pterostylis tenuissima*	V
Silver Daisy-bush	*Olearia pannosa* ssp. *pannosa*	V
	Senecio psilocarpus	V
Southern Pipewort	*Eriocaulon australasicum*	E
Maroon Leek-orchid	*Prasophyllum frenchii*	E
Fauna		
Yarra Pygmy Perch	*Nannoperca obscura*	V
Australian Grayling	*Prototroctes maraena*	V
Dwarf Galaxias	*Galaxiella pusilla*	V
Ewen's Pygmy Perch	*Nannoperca variegata*	V
Growling Grass Frog	*Litoria raniformis*	V
Glenelg Spiny Crayfish*	*Euastacus bispinosus*	E
Little Tern	*Sterna albifrons*	E

Source: SAWID December 2008 (DENR 2008)
(E) Endangered; (V) Vulnerable * Listed under EPBC Act in 2011

Threatened aquatic fauna and flora coverages were generated for the Water-RAT using data from SAWID (DENR 2008) and the Native Fish Inventory (Hammer 2008), including:

- EPBC Act (1999) listed aquatic flora and fauna
- Migratory birds (JAMBA / CAMBA)
- State threatened aquatic flora and fauna.

These layers are activated in Water-RAT when zoomed in beyond 1:150 000 (Fig. 5) and are displayed as buffered points with Easting and Northing information removed.

Appendices C and D list threatened flora and fauna and migratory birds with aquatic dependencies recorded in the South East.

Significant surface water catchments

Natural surface water resources in the South East include the cross-border catchments of Mosquito, Naracoorte, Morambro, Nalang and Tatiara Creeks (head-waters in Victoria). The lack of significant surface topography characteristic of the South East region resulted in poor surface water drainage. A total of 1875km of surface water drains have been established and are managed by the SEWCDB to facilitate adequate drainage of the region for flood mitigation purposes on agricultural lands. Currently there is a lack of surface water catchment mapping for the South East region, apart from more easily defined cross-border catchments.

Significant surface water catchments were identified as catchments contributing surface water flows to high-value wetland assets (Fig. 6).

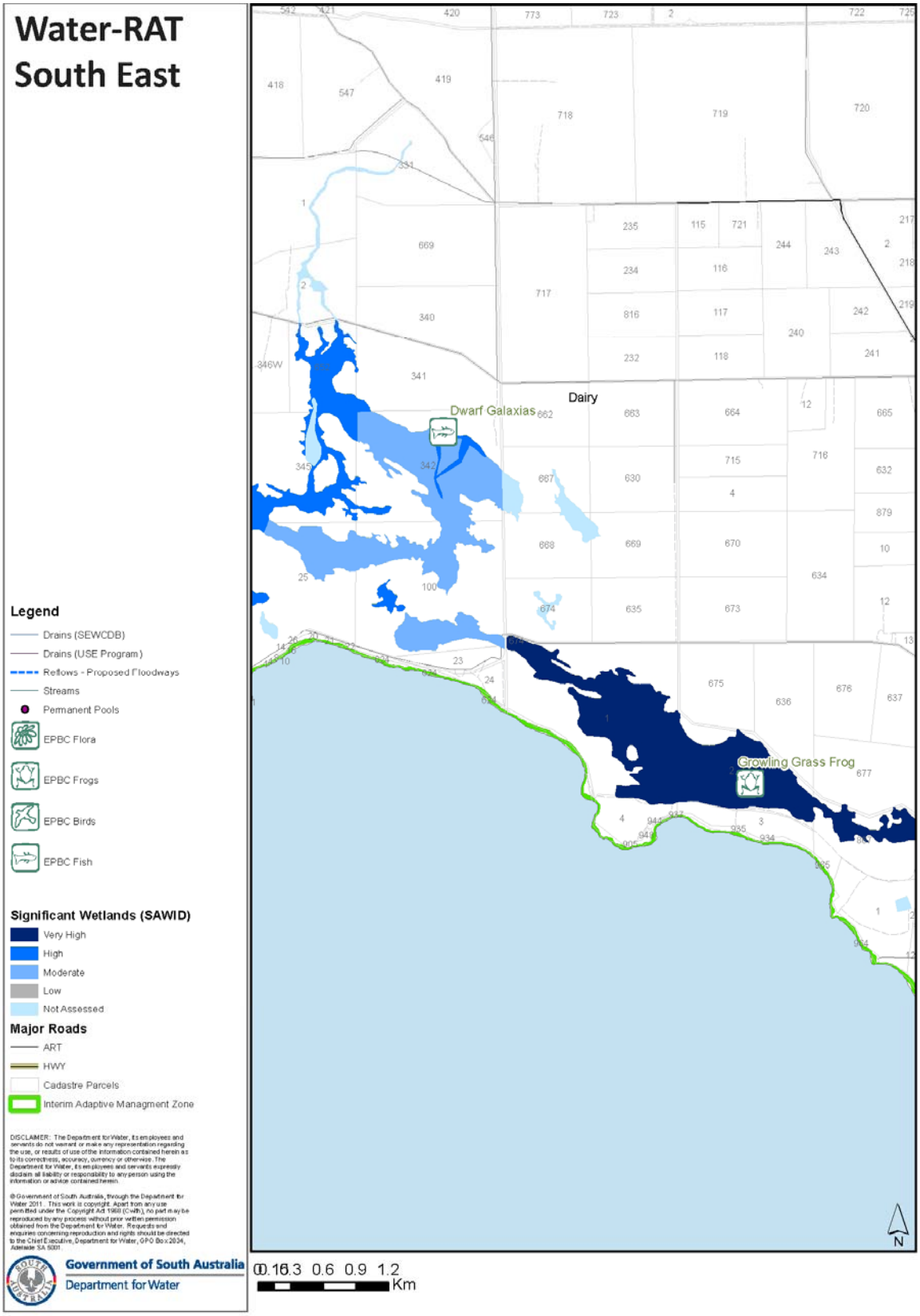


Figure 5. **Water-RAT output example– Locations of records of EPBC Act (1999) listed aquatic fauna and flora within GDEs**

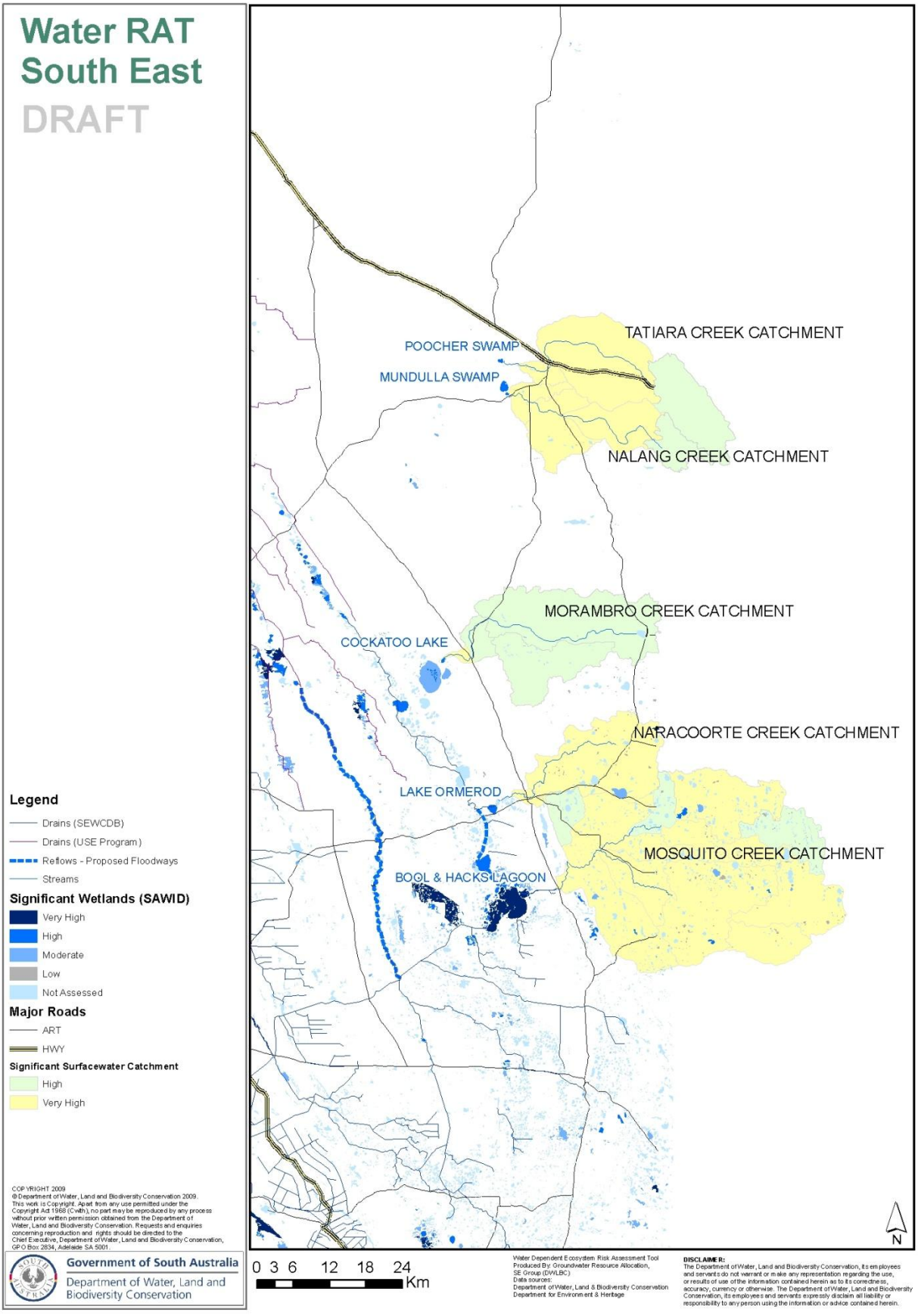


Figure 6. Water-RAT output - Significant surface water catchments

Permanent Pools

Permanent pools within seasonal and ephemeral streams and drain systems of the South East region are extremely important for maintaining core refuge areas for aquatic biota within catchments, including allowing the persistence of native fish and frog populations. Permanent pools, and their associated biological values, are currently not well identified in the South East, with the exception of Mosquito Creek. Most permanent pools that exist within streams and drains are likely to be reliant on groundwater input to sustain inundation over the drier months.

A dominant and unique feature of Mosquito Creek is its baseflow and permanent pools, which generally commence to flow in late autumn, with spring expression gradually progressing upstream (Sheldon 2007). Permanent pools in Mosquito Creek are important habitat refuges for nationally threatened species including the Southern Bell Frog (*Litoria raniformis*) and Yarra Pygmy Perch (*Nannoperca obscura*). There is strong evidence to suggest that the permanent pools within Mosquito Creek are groundwater-dependent.

Permanent pools were identified from a physical survey of the southern reaches of Mosquito Creek (Stratman 2007) and classified as either less than or greater than 15 m in total length. A total of 293 points indicating the presence of permanent pools have been defined using these methods (Figure 7).

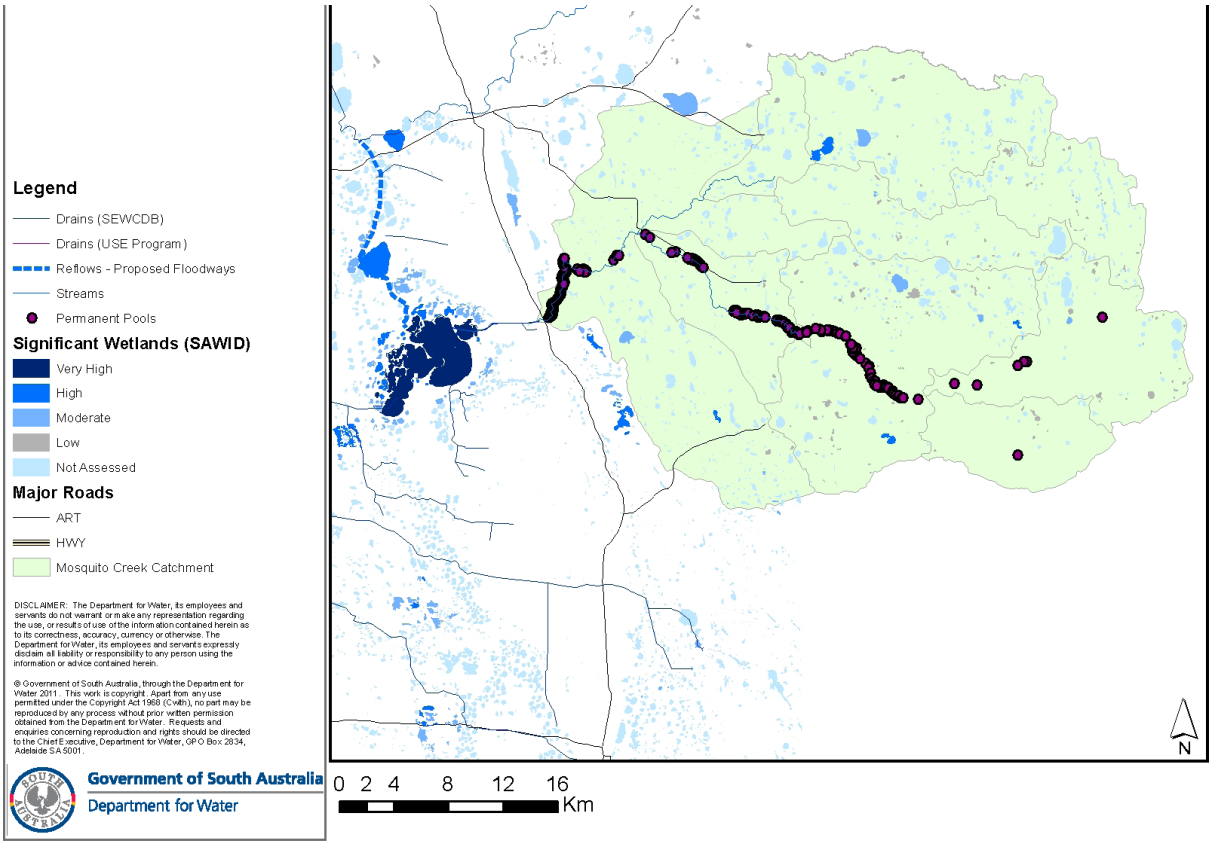


Figure 7. Locations of permanent pools in Mosquito Creek (Stratman 2007)

Karst Features

The limestone units of the Lower South East geology have numerous sinkholes, cenotes, caves and other karst features, many of which intersect the groundwater. The biotic component of these ecosystems consists largely of invertebrate fauna (mostly crustaceans), and diverse communities of micro-organisms. Some karst features, including many sinkholes and rising springs, have associated surface expressions exhibiting wetland biota.

Rising springs are karstic cavities along the coast which provide discharge points for the water table. The cavities themselves support important and well preserved habitats and also form groundwater-dependent surface habitats generally comprising a permanent lake, fringing wetland vegetation and a stream draining to the sea. Groundwater is the most important source of water in these ecosystem and small local catchments provide limited and intermittent surface runoff.

Karst features, including only those that have surface expressions such as caves, sinkholes, cenotes and rising springs, have been mapped using GPS by local private caving and diving groups. The specific feature locations are not available as public datasets, however Figure 8 identifies the areas in the South East where karst features occur, or are likely to occur. The data were derived from buffered point-information from known karst feature locations. The output dataset should only be used as a guide and more accurate location data sought if necessary.

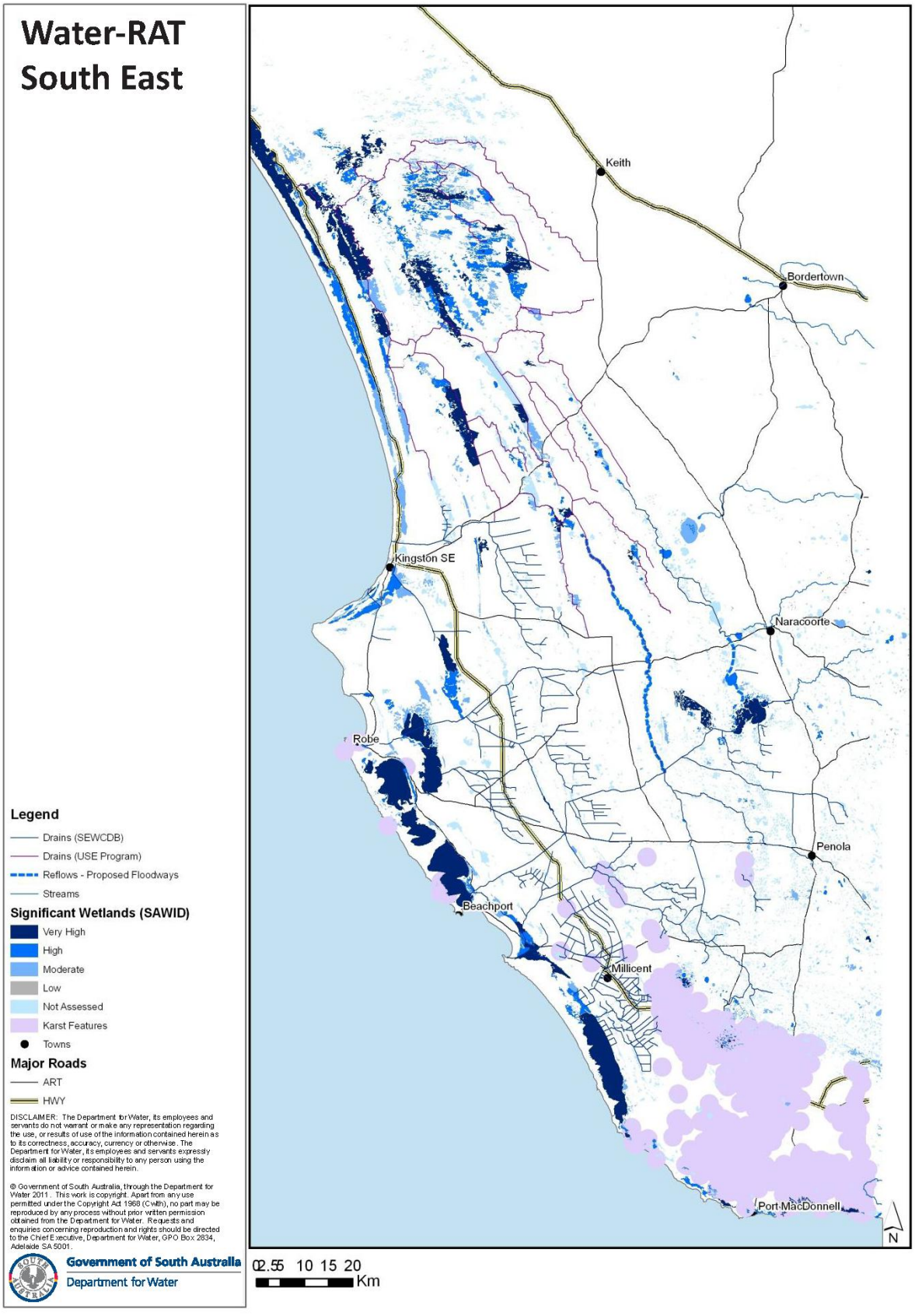


Figure 8. Area identified as likely to contain Karst Features

2.1.2. LIKELIHOOD OF GROUNDWATER DEPENDENCE

A groundwater-dependent ecosystem (GDE) is defined as an ecosystem which requires access to groundwater to meet some or all of its water requirements (SKM 2009).

Many wetlands in the South East are recognised as having a high dependency on the regional unconfined aquifer (Tertiary Limestone Aquifer–(TLA)) and are at risk from increasing competition for water resources, including expanding plantation forestry, industrial and agricultural groundwater extraction and surface and groundwater drainage.

A general lack of information on role groundwater interaction plays in supporting the region's ecological assets (primarily wetlands) was identified as a key knowledge gap. Given that these ecosystems are at high risk from current and future water resource development it was considered necessary that a data-set be developed identifying the likelihood of groundwater dependence on the TLA and the type of interaction (seasonal or permanent dependence). The methods used to develop this layer, and associated limitation of it use, are detailed by SKM (2009), commissioned as a component of the Water-RAT project. Figures 9 and 10 illustrate the output layers of this analysis that are incorporated into Water-RAT for the South East.

Groundtruthing of the classification of groundwater dependency on the TLA (SKM 2009), including the installation of surface and groundwater monitoring infrastructure at 14 representative wetland sites across the South East began in June 2009.

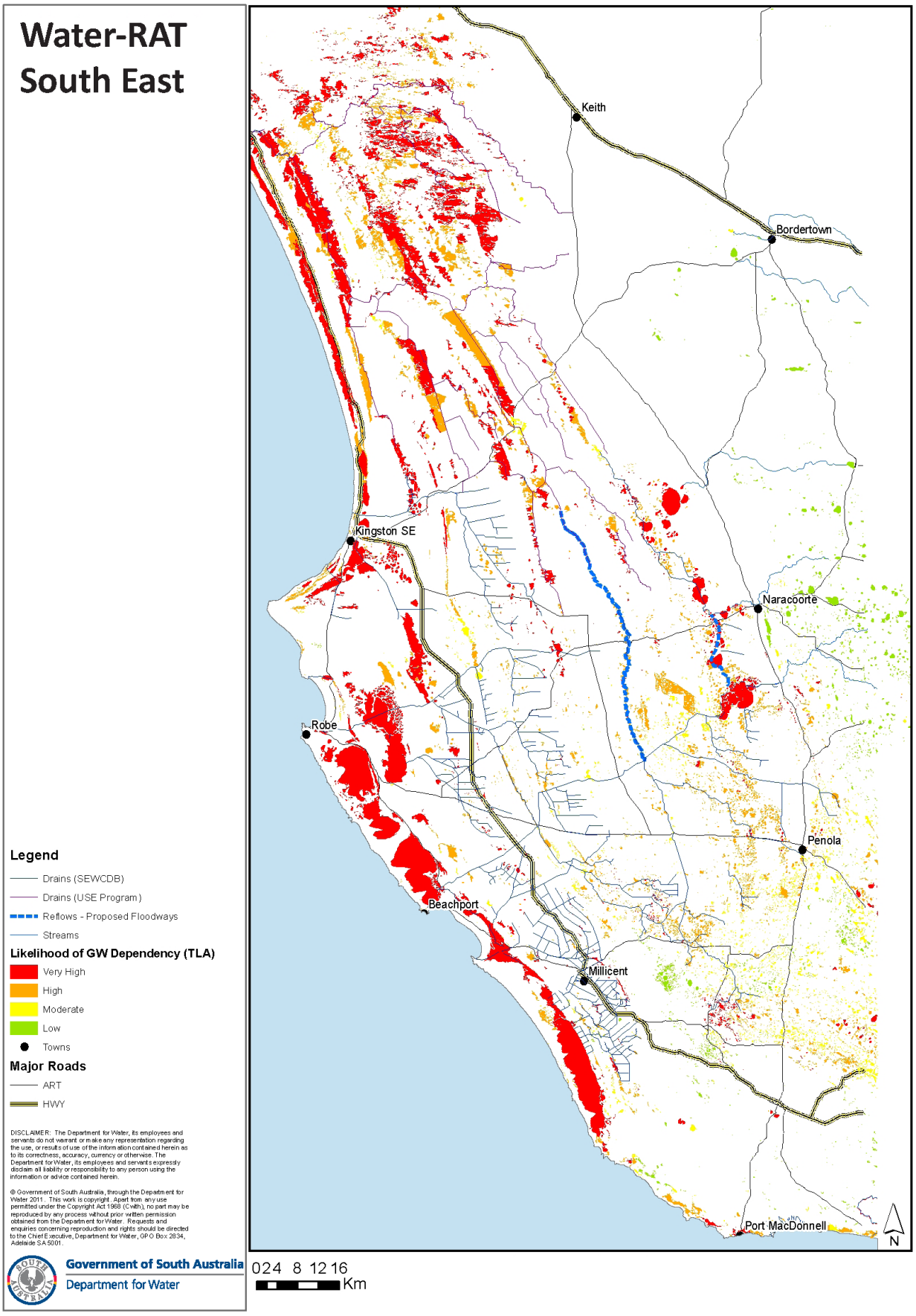


Figure 9. Water-RAT output – Likelihood of Groundwater-Dependence of Wetlands on the Tertiary Limestone Aquifer

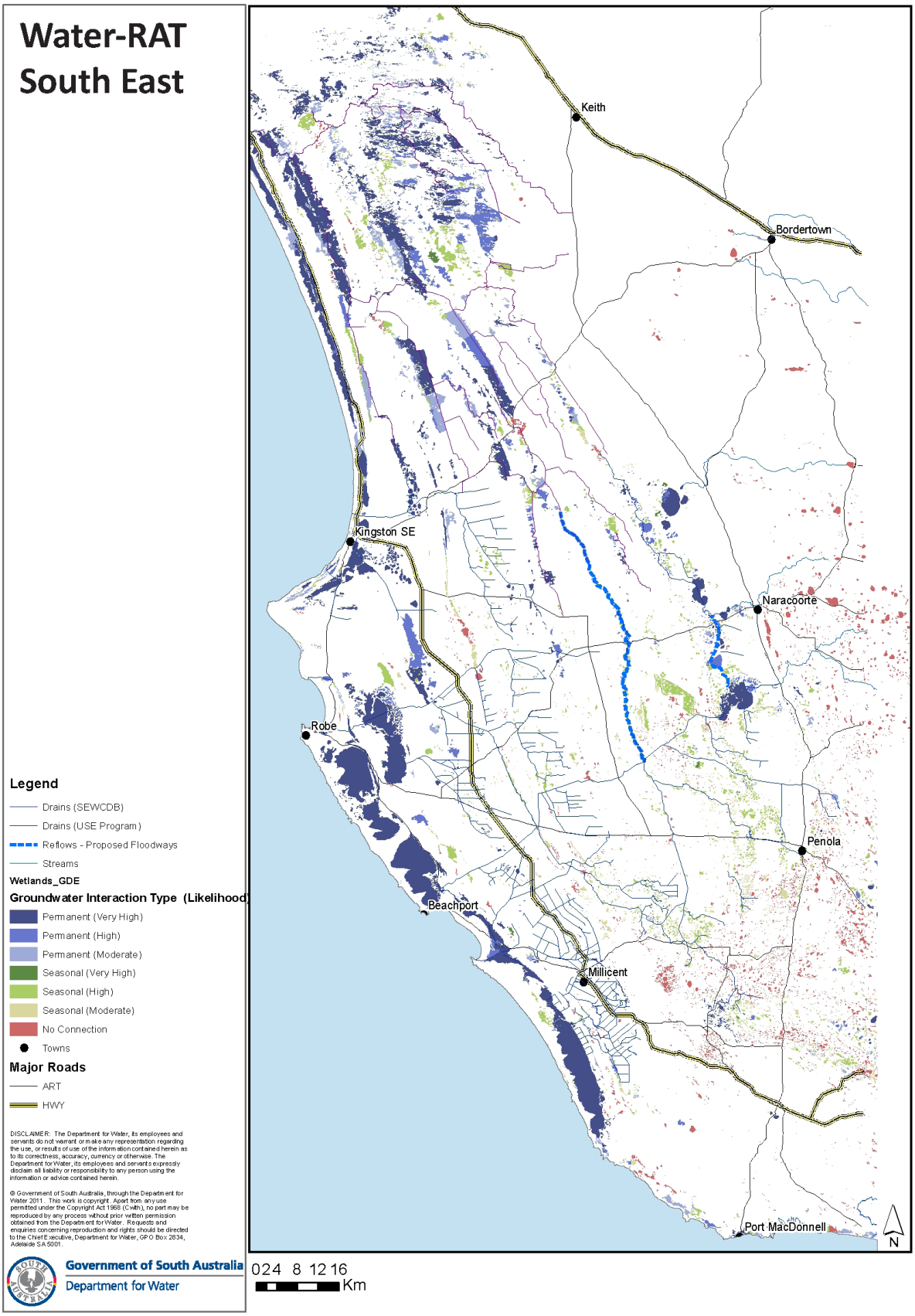


Figure 10. Water-RAT output – Wetlands Type of Groundwater Interaction with the Tertiary Limestone Aquifer

2.1.3. THREATS TO WATER-DEPENDENT ECOSYSTEMS

Groundwater level trends

Water allocation plans (WAP) for the prescribed wells areas in the South East identify a groundwater resource condition trigger, where the taking of water for a new allocation or transfer of allocation shall not cause, or be likely to cause, a mean (arithmetic) decrease in groundwater levels of greater than 0.1 metres per year (measured over the previous five years).

Groundwater-level trend was calculated using groundwater monitoring data collected for the observation well network in the South East, stored in the South Australian observation well database, SA Geodata. Mean (arithmetic) trend was calculated for a five-year period: Dec. 2003–Dec. 2008 for unconfined aquifer observation wells. Data from confined wells, and pumping and anomalous data, were filtered out of the analysis. Appendix E identifies the observation wells used in the analysis.

The trend data were interpolated using ESRI ArcGIS Geostatistical Analyst tools using the Ordinary Kriging method to create a spatial groundwater level trend layer for Water-RAT (Fig. 11).

Groundwater usage – high groundwater usage areas

A total annual groundwater usage layer was developed using Spatial Analyst Raster Calculator where the pixel values in layers produced for irrigation intensity and forestry intensity were summed. This analysis produced the High Groundwater Usage layer for the Water-RAT where areas with combined groundwater extraction (irrigation + forestry) greater than 100 ML/Km^2/year are shown (Fig. 15).

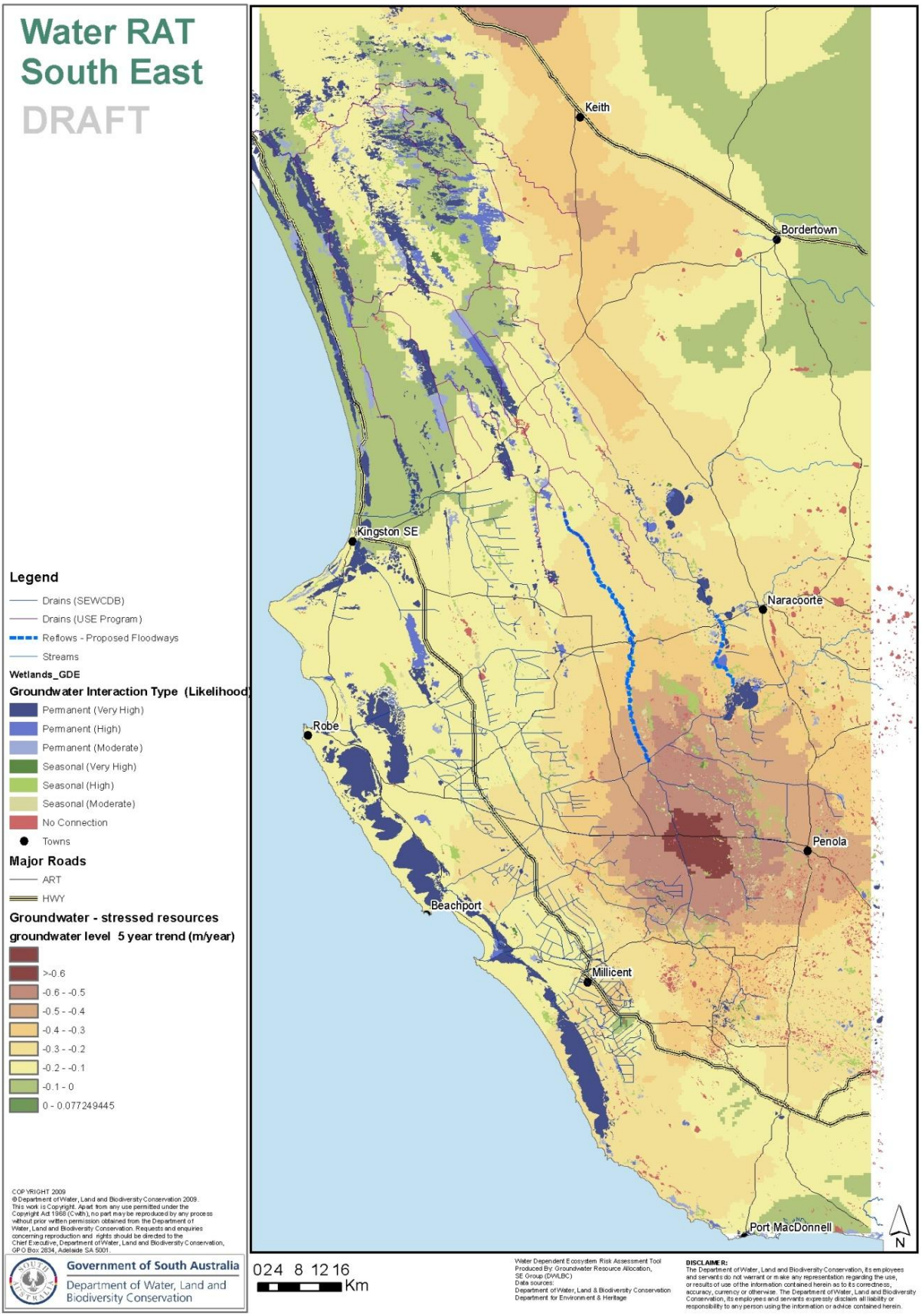


Figure 11. Water-RAT output – Groundwater level trend Dec 2003 – Dec 2008 in the unconfined aquifer (TLA)

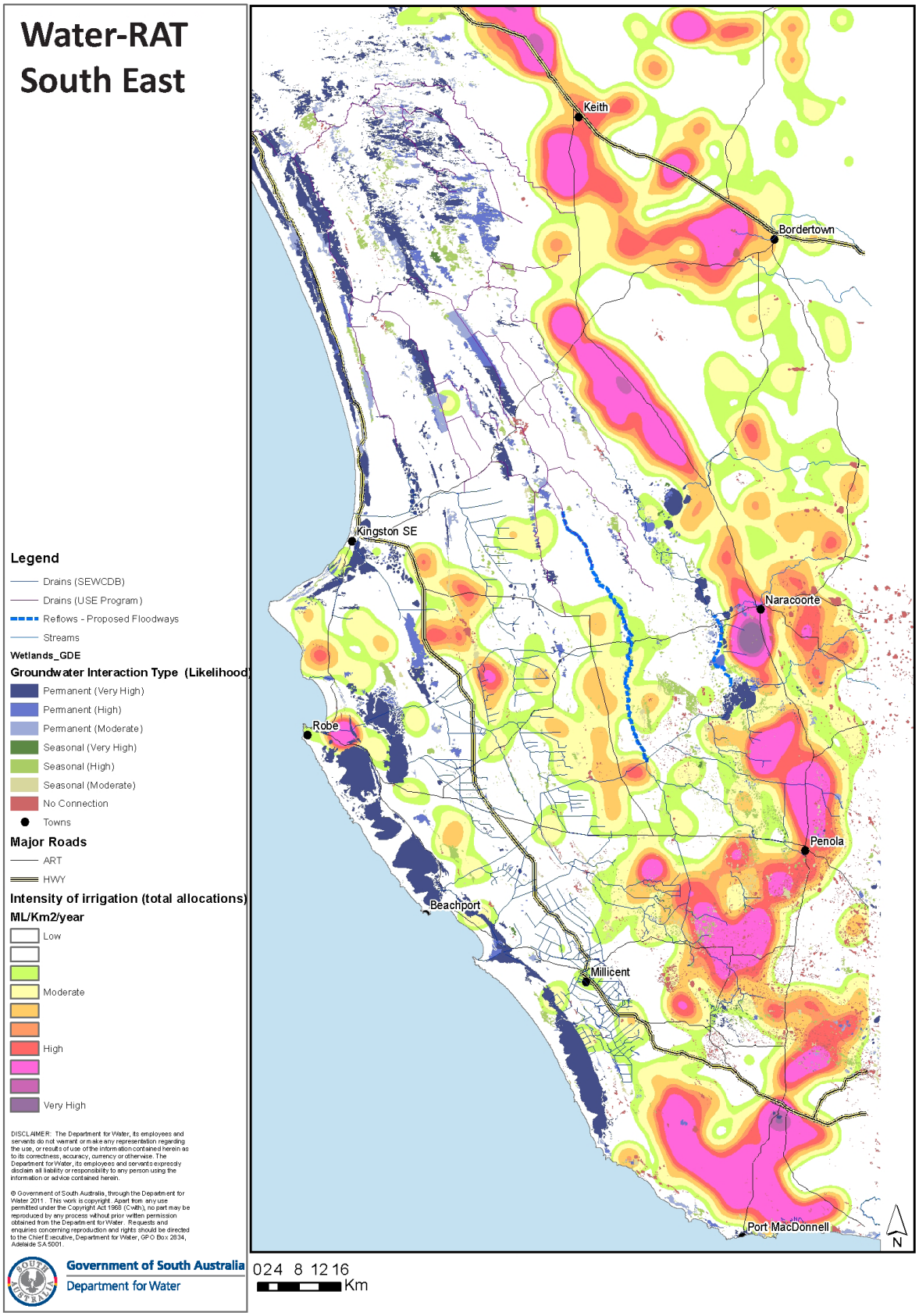


Figure 12. **Water-RAT output – Intensity of Irrigation (total allocations)**

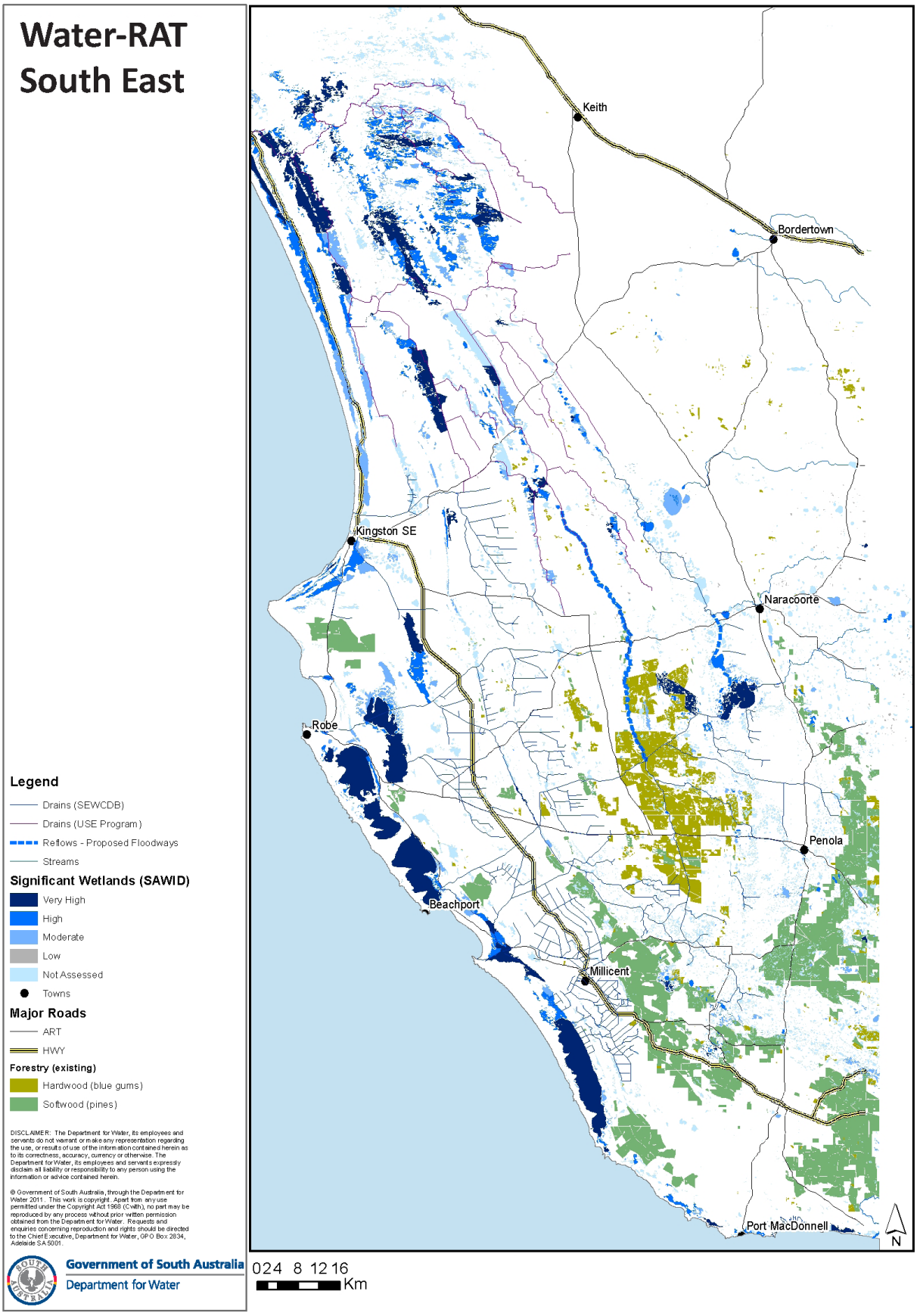


Figure 13. Water-RAT output - Extent of plantation forestry in the South East (November 2005)

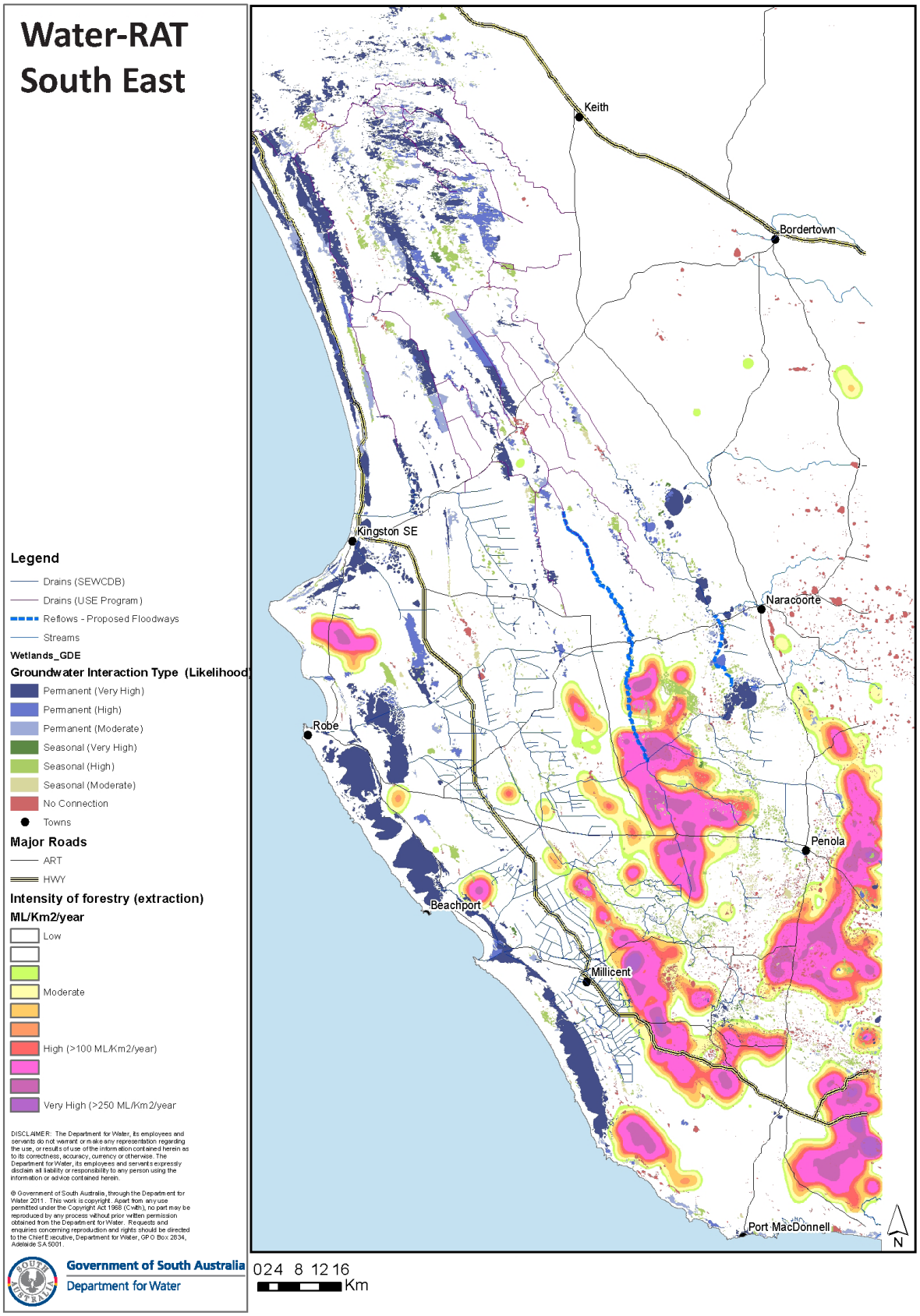


Figure 14. Water-RAT output – Intensity of forestry (estimated groundwater extraction)

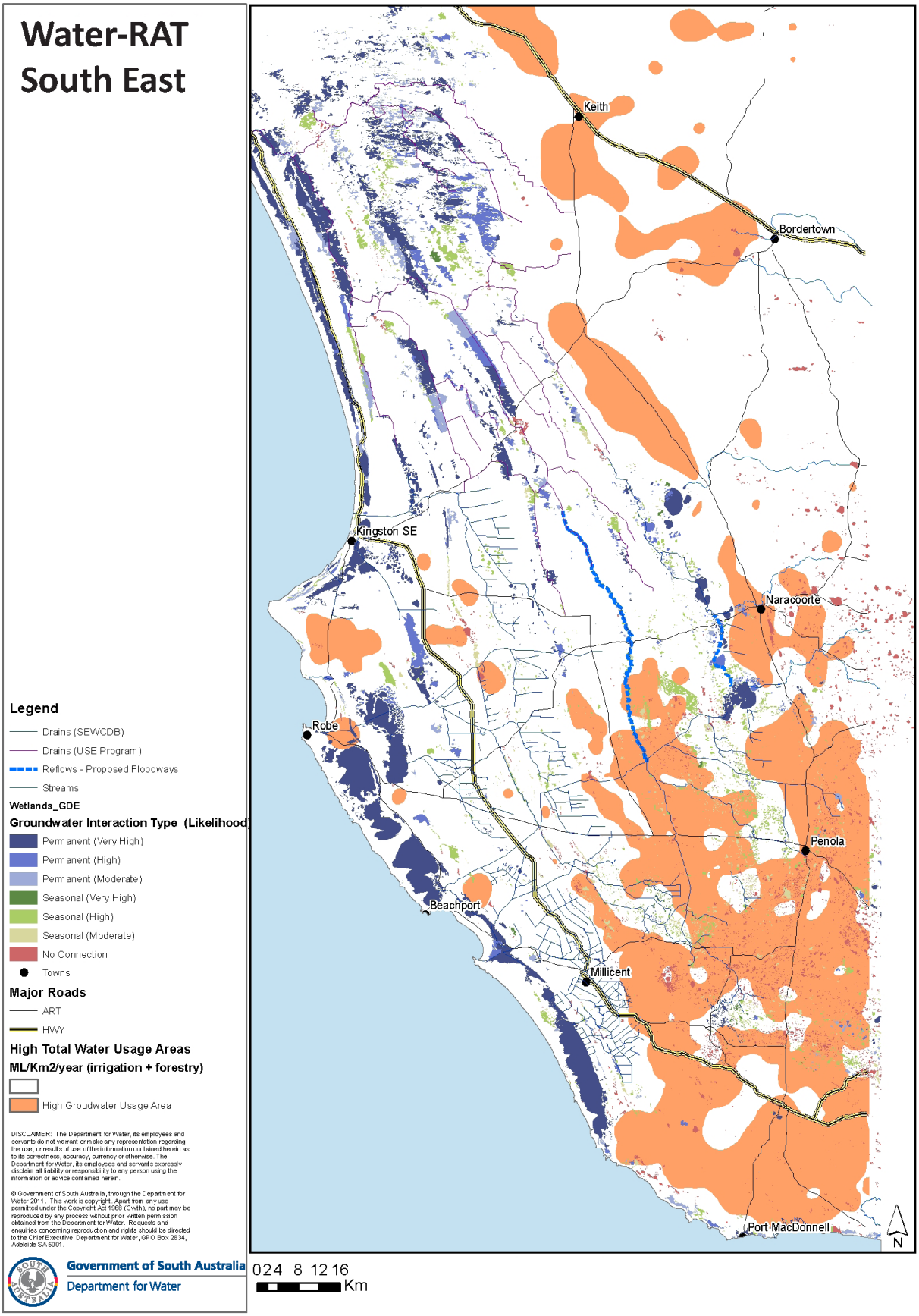


Figure 15. Water-RAT output - Total estimated groundwater usage (both irrigation and forestry)

2.1.4. GROUNDWATER DEVELOPMENT RISK ZONES

Groundwater development risk zones were applied to high value water-dependent assets (high value wetlands and permanent pools as identified in Section 2.1.1) that also have a high likelihood of groundwater dependence (as identified in Section 2.1.2) (Fig. 16). The purpose of the risk zones was primarily to provide an alert mechanism for resource managers, decision-makers and developers of a potential risk to a high value groundwater-dependent ecosystem/asset as a result of a proposed groundwater affecting activity within a certain distance of an asset. The risk zones are therefore conservative, do not constitute regulatory buffers and were developed with the use of simple analytical solutions for stream depletion.

The risk zones are not intended as a policy tool and do not replace environmental protection policy currently being developed in the South East (refer to REM 2006 and SENRMB 2009). A number of considerations are required to fully assess the potential impact of a proposed groundwater development activity, including the annual taking volume of the application and depth of extraction, the drawdown effects and the determination of sustainable limits of extraction to minimise the impacts to the environmental water requirements of GDEs.

The Glover-Balmer (1954) unique characteristic response curve for stream depletion was used to calculate risk zones from groundwater-dependent assets. The Glover-Balmer method is widely used and is particularly useful for rapid analysis in aquifers where no calibrated numerical-model has been constructed, despite a number of restrictive assumptions (Contor 2011). These assumptions and idealisations regarding aquifer conditions and geometry are inherent in the use of the Glover-Balmer (1954) analytical solution, where the waterbody is assumed to fully penetrate the aquifer, the water table is flat (i.e. the waterbody is neither gaining nor losing), and the waterbody substrate does not consist of low permeability sediments. Many other methods exist for assessing more typical or likely scenarios (Merrick 2006; Rassam & Werner (2008) provide a detailed overview of available methods), however given that the purpose of the risk zones within the Water-RAT framework is to provide an alert to a potential significant impact, and not determine regulatory buffers, the simple analytical model was applied in this instance.

The Glover-Balmer method required identification of a single value for transmissivity (T) and storage coefficient (S). Transmissivity (m^2/d) values were obtained from previous records and reports from aquifer tests throughout the South East (Appendixes F and G) and a mean (geometric) transmissivity value for each Interim Adaptive Management Zone in the South East was calculated (Appendixes F and G). A storage coefficient of 0.1 was assumed.

The high risk zones calculated using the Glover-Balmer stream depletion analytical method are on average 762 m greater than the buffers prepared by REM (2006) and 30 m greater than those revised for the 10 mm drawdown scenario using Hotspots model in a review of the buffer policy (Merrick 2006) at the 5% impact zone (Appendix H). It is therefore considered that the risk zones displayed are sufficiently conservative and meaningful, without being unrealistic, to be used as an alert to a potential significant impact within the scope of the risk assessment tool. Merrick (2006) predicts that the current environment protection zones calculated from an approximation of the Theis Equation (REM 2006) are generally too close, by about 30% on average, for 100 mm drawdown impact.

Acceptable limits of change have not been determined for groundwater-dependent ecosystems in the South East and would likely vary depending on wetland typology and degree of groundwater-dependency of the ecosystem.

Table 3. Groundwater development risk zones (Glover-Balmer Analytical solution of buffer zones)

IAMZ	Transmissivity T (m^2/d)	Zone 10% impact (m)	Zone 5% impact (m)	Zone 1% impact (m)
Dairy	469	1083	1531	3424
Mt Gambier	375	968	1369	3062
Lk Bonney	341	923	1306	2920
Glencoe	218	738	1044	2335
The Pines	350	935	1323	2958
Coonawarra	2382	2440	3451	7717
Lucindale	759	1377	1948	4356
Robe	462	1075	1520	3399
Kingston	911	1509	2134	4772
Padthaway	9985	4996	7066	15800
Naracoorte Ranges	1373	1853	2620	5859
USE	3200	2828	4000	8944
Tintinara/Coonalpyn	1500	1936	2739	8944
Stirling	2441	2470	3494	7812

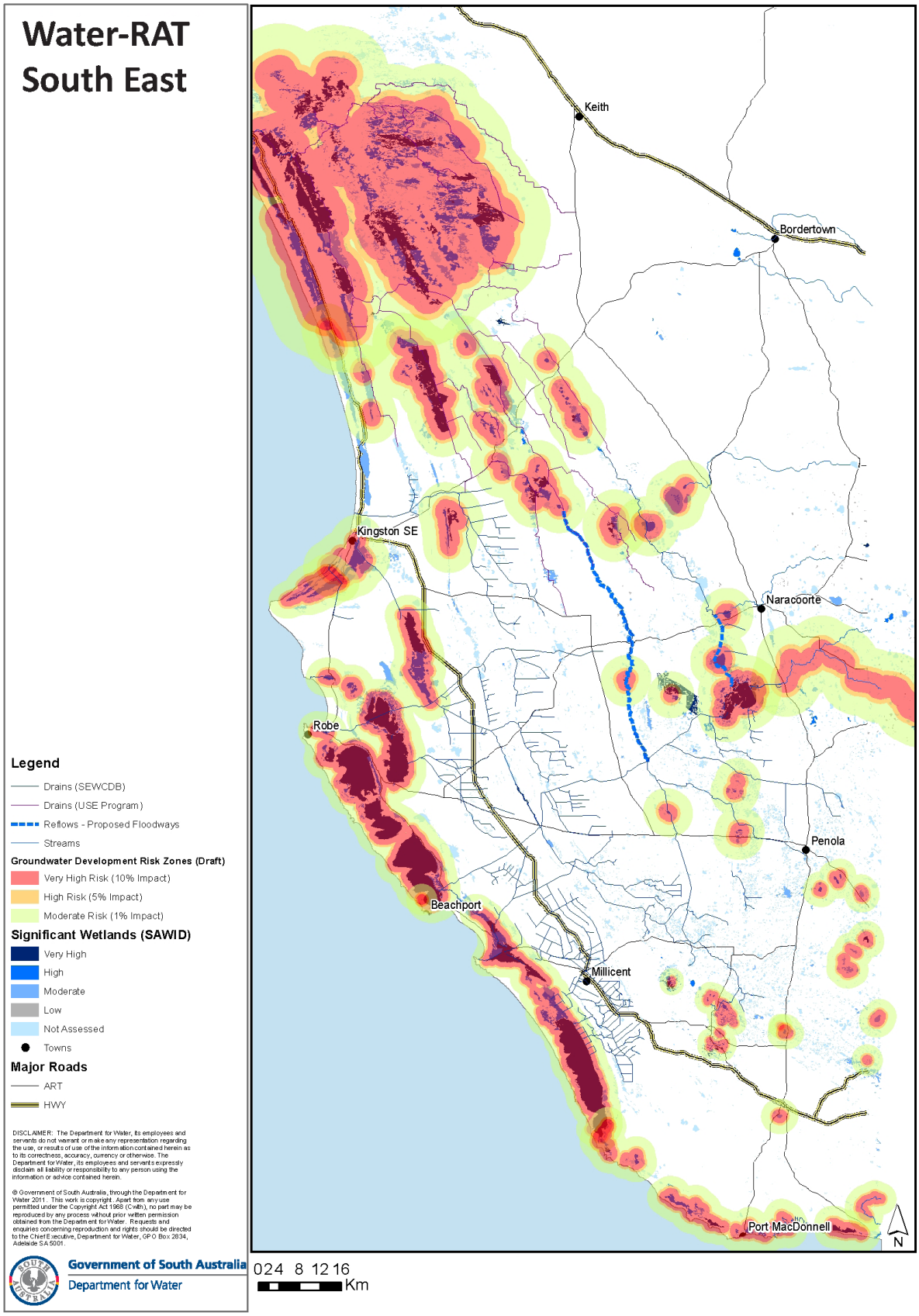


Figure 16. Water-RAT output - Groundwater development high risk zones for potential impact to high significance groundwater-dependent ecosystems

3. CONCLUSIONS AND RECOMMENDATIONS

The Water-RAT project has provided a method for improved delivery of water resources information for the South East, focussing on the identification of water-dependent ecological assets in the landscape, their interaction with surface and groundwater resources and the level of existing threats.

Several new data sets have been developed as contributing layers to this project, however the ability to fully analyse water-dependent ecosystems in relation to water-affecting activities was limited by available data. Major data gaps that were considered integral to the application were addressed through the Water-RAT project, including a classification of groundwater dependency for mapped wetlands and improved coverage of wetland inventory data to identify high value assets (wetlands). A number of data gaps unable to be filled via this project, and limitations of the project scale were identified. A summary of some of the major limitations and further recommendations to improve the application of Water-RAT identified through the project is provided below.

It should be noted the outputs of this report represent a snapshot in time dependent on the currency of a number of data-sets. Updating of underpinning data and spatial layers in the future is likely to result in different outputs from those presented in this report.

3.1. DATA AND PROCESSING

Groundwater-dependent ecosystem development risk buffer zones

The approach adopted for the identification of high risk zones for the Water-RAT project used a simple analytical model with many assumptions that may not realistically fit the hydrogeological characteristics of the South East. Although this approach is considered sufficient for the scope and purpose of this phase of the Water-RAT project, it is acknowledged that more realistic simulations could be achieved using other available methods (e.g. Hotspots model (Merrick & Merrick 2007)). This level of accuracy required more resources than that which was available as part of the Water-RAT project.

The accuracy and spatial coverage of aquifer properties for assessing likely impacts due to groundwater resource development are integral to the outcome of any analysis procedure, regardless of method. Aquifer transmissivity data was sourced from many aquifer-test reports in the South East (from early 1970s onwards). Due to the poor spatial density of this data, a geometric mean transmissivity value was calculated for each groundwater management zone. The larger Interim Adaptive Management Zones (unpublished DFW internal use) were used rather than the existing Groundwater Management Areas (GMA) due to the poor spatial coverage of transmissivity data. As demonstrated in Appendixes F and G, these data varied considerably within each region. Ideally, the nearest actual transmissivity record should be used to calculate individual buffers for each wetland on a site-by-site basis.

- *It is recommended that more relevant methods for identifying meaningful risk zones be investigated for future input into the Water-RAT application and GDE protection policy in the South East.*
- *It is recommended that the accuracy and spatial coverage of aquifer property data in the South East be addressed in future. More accurate aquifer property data specifically obtained for areas surrounding high value GDEs should be a priority.*

There is a need to define the magnitude of acceptable drawdown impact for groundwater-dependent ecosystems in the South East. An acceptable drawdown may not necessarily be uniform across all different types of GDEs in the region. For example, a shallow seasonal groundwater-dependent marsh

could be significantly impacted by a 100 mm drawdown, whereas a deep coastal lagoon may be less so. It has therefore been recognised that typologies for South East wetlands (as prepared by Scholz & Fee 2008) should address limits of acceptable change in both groundwater and surface water input when defining Environmental Water Requirements. Additionally, different wetland typologies have differing sensitivities to threatening processes. As this level of information is not yet available for wetlands in the South East, each wetland is treated as having the same level of susceptibility to a threatening process. However, the likelihood of groundwater dependency analysis prepared as part of this project (SKM 2009) has significantly increased the ability to identify and predict specific risks to GDEs.

- *It is recommended that limits of acceptable change in groundwater level be identified for wetland typologies in the South East.*

Climate change

Projected climate change scenarios should be incorporated into the Water-RAT framework to assist in identifying the likely implications of climate change to important water-dependent ecosystems in the South East. The development of GDE-likelihood mapping and analysis of further likely declining groundwater trends, as a result of reduced recharge, has the potential to identify high value assets at risk as a result of climate change.

- *It is recommended that climate change scenarios be investigated in terms of identifying high value wetlands at risk.*

Surface water and Groundwater Catchments

The identification of significant surface water catchments for high value wetlands could only be achieved for mapped catchments—the cross-border catchments of Mosquito, Naracoorte, Morambro, Nalang and Tatiara Creeks. The lack of distinct topography in addition to the extensive drainage networks throughout the South East impedes easy identification of distinct surface water catchments throughout much of the region. However, the identification of important surface water catchments is integral to managing catchment scale water development issues and should be pursued in the future.

Additionally, the development of groundwater catchment zones for high value groundwater-dependent ecosystems could be developed with use of modelled groundwater level surfaces (SKM 2009). In addition to the high risk zone approach, the identification of groundwater catchment zones for high value GDEs would provide a more comprehensive evaluation of limits of sustainable groundwater development in groundwater capture zones for GDEs.

- *It is recommended that important surface water catchment areas for the South East be identified.*
- *It is recommended that the extent of groundwater catchment zones for significant GDEs be investigated.*

Groundwater Dependency

The likelihood of groundwater-dependency analysis prepared as part of this project (SKM 2009) has significantly increased the ability to identify and predict specific risks to GDEs in the South East however there is a need for groundtruthing of SKM data. The installation of surface water and groundwater monitoring infrastructure at 14 representative wetland cast study sites across the South East began in June 2009 in an effort to groundtruth the spatial layers produced by SKM (2009). To date the data collected from the 14 case study sites has not been used to update the spatial layer for groundwater dependency used in the Water-RAT.

- *It is recommended that the likelihood of groundwater dependency spatial layer produced by SKM (2009) be groundtruthed and updated to reflect hydrological data collected from 14 representative wetland case study sites.*

Forestry

Direct extraction values for forest plantations were sourced from Latcham *et al.* (2007) for the purposes of the risk assessment tool. As further research becomes available and policy is developed (SENRMB, in prep 2009) it is expected that extraction values and plantation areas may change.

- *It is recommended that the forestry intensity layer be reviewed in light of future water allocation plan policy and updated if required.*

Permanent Pools

Permanent pools have been mapped in Mosquito Creek (Stratman 2007) to identify significant threatened fauna refuges. Whilst Mosquito Creek is unique in the South East, where base-flow is thought to be a significant contributing factor (Sheldon 2007), there has been no similar investigation of other creeks in the region. However it is considered unlikely that permanent pools exist in other natural cross-border creeks, given the depth to groundwater suggesting that these creeks are surface water driven. The extensive networks of drains constructed throughout the South East collect surface water runoff and many have a significant groundwater input. The environmental value of artificial permanent pools in the drainage network has not been assessed, nor mapped.

- *It is recommended that permanently pooling high value habitat provided by artificial drains in the South East be identified*

APPENDIXES

A. KEY POLICY AND LEGISLATION INSTRUMENTS RELEVANT TO WATER-DEPENDENT ECOSYSTEMS IN THE SOUTH EAST

Water Allocation Plans (Groundwater and Surface water) 2001

NRM Act Chapter 4 Part 2 Division 2:

4a i) Must include: an assessment of the quantity and quality of water needed by the ecosystems that depend on the water resource and at the times at which, or the periods during which, those ecosystems will need that water; and

ii) An assessment as to whether the taking or use of water from the resource will have a detrimental effect on the quantity or quality of water that is available from any other water resource.

4b i) provide for the allocation and use of water so that an equitable balance is achieved between environmental, social and economic needs for the water; and ii) the rate of water use is sustainable.

SECWMB Plan 2003–08

Goal: To identify, protect and enhance ecosystems and their associated biodiversity that depend on water.

Strategy: Manage ecosystems and biodiversity

Actions:

- Enhance development planning for water quality and ecosystem protection
- Identify major WDE's and identify threats
- Develop management plans for key WDE's
- Investigate and refine EWR's for key WDE's.

***Catchment wide provisions – Principles*:**

- Activities should not adversely affect WDE's
- Activities should not adversely affect the capacity for the migration of native aquatic biota or their EWR's
- Activities should not adversely affect the quality, quantity, duration or in any other way the supply of water to WDE's
- Activities should occur in a manner that protects the ecological values of ecosystems and natural features of lakes, wetlands watercourses or floodplains
- Drains should be designed and constructed to enable the preservation and enhancement of ecological functions of ecosystems reliant on groundwater and surface water
- Culvert and bridge design and construction shall include provisions to ensure fixed sill-levels do not adversely impede the flow of water in a watercourse, across a floodplain or a lake/wetland
- The placement of a road that spans a watercourse, floodplain, lake, wetland or an area subject to inundation, should not adversely affect the provision of EWR's of those areas.

Surface water Policy Areas – Principles:

- Dams to be located off-stream
- Capacity of dams in surface water policy areas shall not exceed volume – policy area (ha) x max dam capacity factor (0.05-0.07 ML/ha) (see policy area runoff and allotment runoff estimates)
- Dams on divided allotments should not exceed 30% median runoff of original allotment
- Infrastructure to enable diversion of water from a watercourse or floodplain shall be constructed to allow no more than 50% of the available flow to be diverted at any time
- Water storage or diversion should not cause unacceptable groundwater mounding or cause adverse impacts to neighbours
- Dams should not be located in ecologically sensitive areas or areas prone to erosion
- Drainage wells should not be constructed in wetlands as mapped in SAWID, or banks of a watercourse
- Construction and siting of wells for drainage purposes should not compromise surface water flow to WDE's
- Specific policy area principles apply.

State NRM Plan 2006

Goals:

- Adopt policy guidelines for managing rivers and wetlands
- Ensure planning policy addresses the importance and value of WDE's, particularly watercourses, floodplains and wetlands (Ramsar and DIWA) and prevent development that would impact upon ecosystem function or habitat value
- Develop a robust water accounting system to provide certainty to consumptive users and for the environment
- Review the legislative and institutional arrangements that directly relate to NRM to ensure efficient coordination and that arrangements support effective and sustainable landscape/ecosystem management
- Encourage and remove impediments to cooperation between institutions with responsibilities that effect NRM
- Encourage cooperation between land use, industry and NRM policy bodies.

Strategy: Use the state NRM Plan as a guide to provide comment on development applications.

Resource condition targets:

- By 2011 all ecosystems dependent on prescribed water resources have improved ecosystem health
- By 2020 all aquatic ecosystems have improved ecosystem health.

Water Allocation and Management Guidelines (*State Water Plan 2000*)

Surface Water:

- Outside prescribed areas until there is additional info, 25% median annual adjusted catchment yield should be used as an indicator of the sustainable limit of the catchment surface water and watercourse water use
- Pumping or diversions from a watercourse must not result in the water in refuge pools falling below critical ecological levels
- Off-stream dams are preferable.

Groundwater:

- In calculating sustainable yields, a precautionary approach must be taken with sustainable yield being lower where there is limited knowledge, large existing use, higher risks, and less reliable recharge
- Management controls in WAP's on stock and domestic use of water from groundwater basins should be applied where required to achieve sustainable use. Current and likely future S&D requirements must be included in assessments of resource use.

Water for the environment:

- Water allocations and management decisions must take a precautionary approach by first ensuring environmental benefit outcomes, including natural ecological processes and biodiversity of WDE's are maintained. It follows that further allocation of water for new consumptive uses and any other new water resource developments, must ensure ecological values are protected
- In systems where there are existing consumptive users, environmental water provisions must be as close as possible to the required EWR's while recognising rights of existing users
- Where environmental water provisions cannot meet EWR's arrangements should be established that will allow for the requirements to be met in the minimum time practicable (considering socio-economic needs)
- The provision of water for the environment is recognised under the NRM Act. Environmental water provisions will be legally described and protected through WAP's (through operational/extraction constraints described in WAP's and effected through conditions on permits and licences to take water
- All water uses must be managed so as to achieve defined environmental outcomes
- Environmental water provisions should be linked to environmental objectives.

Principles for riparian and floodplain management:

- Protection of refuge areas and maintenance of connections along watercourses must be given priority due to the highly variable flow patterns
- Interactions between surface water and groundwater must be maintained so as to sustain ecological function and dependent biodiversity that rely on this hydrological connectivity.

Principles for wetland management:

- The management of natural wetlands should aim to provide adequate water in an ecologically appropriate regime and appropriate quality so as to maintain wetland function and ecological value

- There should be recognition of wetland values and their management and protection in all relevant statutory and non-statutory planning processes
- Wetlands of recognised conservation significance should be given special protection and management so as to maintain their ecological values.

NRM Act 2004

Promotes sustainable and integrated management of SA's natural resources and make provision for their protection.

Chapter 2 Part 1 – Objectives:

1c) provides for the protection and management of catchments and the sustainable use of land and water resources

2c) avoid, remedy or mitigate any adverse effects of activities on natural resources

3a) decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equity considerations

3b) if there are threats of serious or irreversible damage to natural resources, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

3c) decision-making processes should be guided by the need to evaluate carefully the risks of any situation or proposal that may adversely affect the environment and to avoid wherever practicable causing any serious or irreversible damage to the environment.

Chapter 7 Part 2 Division 1 126 – Relevant authorities:

DFW – activities under 127 3 a–c

NRMB – activities under 127 3 d

127 3 e–f – either of above

Permit required to:

3a) drill, plug, backfill or seal a well

b) Repair, replace or alter the casing, lining or screen of a well

c) Drain or discharge water directly/indirectly into a well

d) Erect, construct, enlarge, modify, remove a dam, wall or other structure that will collect/divert water flowing in a watercourse.

5b) erect, construct or place any building or structure in a watercourse or lake or on a floodplain

c) drain/discharge water directly into watercourse/lake

d) deposit or place object/solid material in watercourse/lake (or on floodplain f)

e) obstruct a watercourse or lake in any manner

g) destroy vegetation growing in a watercourse or lake or growing on the floodplain

h) excavating rock, sand, soil from watercourse, lake, floodplain, banks.

No permit required:

- Erect, construct, enlarge contour banks to divert surface water to prevent soil erosion

The Minister is able to issues a notice to a land holder in an non-prescribed water resource area if water taking exceeds a rate considered to adversely affect other users or is likely to cause damage to ecosystems that depend on water from the water resource (Chapter 7 Part 2 Division 2 132). When determining demands on available water the need for water of the ecosystems that depend on water from the water resource concerned must be taken into account.

- Permits: Decision of authority must not be inconsistent with the SA NRM Plan
- Authority must take into account Regional NRM Plan provisions.

Allocation of water (Chapter 7 Part 3 Division 2 151):

- Before allocating water the Minister may direct that an assessment of the effect of allocating water be made by an expert (DFW)
- Water is to be allocated consistent with WAP's and conditions attached to licenses must not seriously vary with the WAP.
- Chapter 7 Part 6 170 – effect of water use on ecosystems. Needs of ecosystems that are dependent on water resources must be considered in decisions regarding availability of water.

No Species Loss 2007-2017

Goals

- To build capacity to collect and share info to inform biodiversity management
- To provide a contemporary legislative framework for the protection and conservation of SA's biodiversity
- To ensure the planning and development assessment system facilitates sustainable development that minimises the impacts of development on biodiversity.

Targets

- The survey, definition of EWR's and assessment of SA's DIWA wetlands are completed by 2013
- Systems providing relevant and timely information on areas of ecological significance to inform the development planning

system are improved

- SA legislation that rationalises policy, reduces admin and compliance costs to business and improves protection of biodiversity is developed by 2010
- Planning policy and development assessment processes are informed by ecological investigation and impact assessment specific to the affected area and its biodiversity and administered in a manner that identified and protects areas of biological significance.

DENR Corporate Plan 2007-2010

Objectives – Sustainable Growth

- Provide innovative advice and solutions that seek to achieve the best environmental results from the State's major developments
- Influence government policy to secure better environmental results from development, particularly in coastal and other vulnerable areas.

Objectives – Better decisions and partnerships

- Ensure our investments in science, knowledge and information systems support our strategic and operational decision-making
- Strengthen our policy capacity and performance.

Clarify and reinforce mutual roles and responsibilities with other Government Organisations (DFW, SENRMB, EPA)

Native Vegetation Act 1991

See Schedule 1 – principles of vegetation clearance.

Vegetation should not be cleared if it:

- comprises high level of plant diversity
- comprises threatened species, community
- comprises significant habitat
- comprises a wetland or is associated with a wetland environment
- contributes to significant amenity
- contributes to erosion/salinity
- causes deterioration in water quality (surface water or groundwater)
- exacerbates intensity of flooding.

Tackling Climate Change 2007-2020

- Incorporate climate change in the sustainable management of water resources and water supply
- Increase the capacity of ecosystems to adapt to climate change.

Principle: NRM and water allocation stay within sustainable limits to ensure that the state's natural resources and ecosystems have optimum resilience and capacity to adapt to climate variability and change.

Strategies: Ensure WAP's reflect climate change projections and provide a framework to adjust water allocations if necessary.

B. PARAMETERS USED TO CALCULATE ECOLOGICAL VALUE OF WETLAND USING SAWID

Criteria	Parameter	Description	Score Range	MaxScore
Landscape naturalness and connectivity	Wetland connectivity	Indication of connectivity to other wetland bodies determined from total wetland area located within a 2 km radius of each wetland body. Expressed as a percentage of buffer area. (calculated by GIS query using wetland mapping). Wetlands hydrologically disconnected (artificially) are given a negative value.	**Max Score = 10** Percent values / 10	**20**
	Remnant vegetation connectivity	Indication of connectivity to remnant native vegetation determined from total remnant area located within a 2 km radius of each wetland body. Expressed as a percentage of buffer area. (calculated by GIS query using native vegetation mapping)	**Max Score = 10** Percent values / 10	
Diversity and richness	Native species richness	Total number of indigenous flora and fauna species that have been recorded for each wetland gives an indication of the biological diversity of the wetland. This is highly dependent on the sampling effort applied to each wetland site, and may therefore be skewed towards those wetlands that have been well surveyed in the past.	0 to 5 (ranges determined by Jenks natural breaks)	**15**
	Water-dependent fauna species diversity	The diversity (total number) of water-dependent fauna recorded (defined as a species reliant on surface water for a significant portion of their lifecycle – including waterbirds, waders, frogs, fish, and selected mammals and reptiles).	0 to 5 (ranges determined by Jenks natural breaks)	
	Diversity of habitat types (landscape components)	The total number of landscape components (diversity of habitat types) present. Landscape components include a description of the different wetland habitats identified in the Upper South East. A wetland can include 1 or more landscape components (e.g. aquatic herbland with fringing *Melaleuca halmaturorum* shrubland).	0 to 5 (ranges determined by Jenks natural breaks)	
Threatened species and ecosystems	Threatened flora and fauna	Recorded presence of threatened flora and fauna species listed in State schedules (NPW Act) and treaties (JAMBA, CAMBA), excluding those also listed under EPBC. Each individual threatened flora and fauna species is given a score relating to the level of its conservation status. Therefore a species that is listed as Endangered will score higher than one that is listed as Vulnerable.	**Max Score = 10** 0 to 1.5 (for each species, cumulative, with maximum score cut-off)	

	EPBC flora and fauna	Recorded presence of flora and fauna listed as Nationally threatened under the EPBC Act (1999). Each individual threatened flora and fauna species is given a score relating to the level of its conservation status. Therefore a species that is listed as Endangered will score higher than one that is listed as Vulnerable.	Max Score = 20 0 to 5 (for each species, cumulative)	**35**
	Threatened vegetation associations	The occurrence of defined threatened vegetation associations intersecting wetland boundaries is scored as presence/absence	0 to 5 (assigned)	
Special features	Known Breeding activity for water-dependent fauna	The total number of water-dependent fauna with recorded breeding activity. This encompasses highly significant breeding colonies into the value assessment.	0 to 5 (ranges)	**5**
			Total possible score	**75**

Modified from Harding (2007)

C. THREATENED AQUATIC FLORA – SOUTH EAST

COMMON NAME	SPECIES	NPW Act	EPBC Act
Swamp Daisy	Allittia cardiocarpa	R	
Wet-heath Daisy	Allittia uliginosa	R	
Pointed Swamp Wallaby-grass	Amphibromus archeri	R	
Long-nosed Swamp Wallaby-grass	Amphibromus macrorhinus	R	
Dark Swamp Wallaby-grass	Amphibromus recurvatus	R	
	Asperula wimmerensis	E	
	Atriplex australasica	R	
Tassel Cord-rush	Baloskion tetraphyllum ssp. tetraphyllum	V	
Pale Twig-rush	Baumea acuta	R	
Slender Twig-rush	Baumea gunnii	R	
Lax Twig-rush	Baumea laxa	R	
Hard Water-fern	Blechnum wattsii	R	
Swamp Boronia	Boronia parviflora	R	
Swamp Daisy	Brachyscome basaltica var. gracilis	R	
Matted Water Starwort	Callitriche sonderi	R	
Spade-leaf Bitter-cress	Cardamine gunnii	V	
Slender Bitter-cress	Cardamine tenuifolia	R	
Mountain Sedge	Carex gunniana	R	
Bristle-rush	Chorizandra australis	E	
Leafy Twig-rush	Cladium procerum	R	
Swamp Buttons	Craspedia paludicola	V	
Purple Crassula	Crassula peduncularis	R	
	Cyperus lhotskyanus	R	
Leafy Flat-sedge	Cyperus lucidus	E	
Waterwort	Elatine gratioloides	R	
Tuber Spike-rush	Eleocharis atricha	V	
Barren Cane-grass	Eragrostis infecunda	R	
Southern Pipewort	Eriocaulon australasicum	E	E
Prostrate Blue Devil	Eryngium vesiculosum	R	
Purple Eyebright	Euphrasia collina ssp. collina	V	
Tall Saw-sedge	Gahnia clarkei	R	
Thatch Saw-sedge	Gahnia radula	R	
Coral Fern	Gleichenia microphylla	R	
Creeping Raspwort	Gonocarpus micranthus ssp. micranthus	R	
Spreading Goodenia	Goodenia heteromera	R	
Glandular Brooklime	Gratiola pubescens	R	
Button Grass	Gymnoschoenus sphaerocephalus	E	
Small Nut-heads	Haegiela tatei	R	
Swamp Raspwort	Haloragis brownii	R	
Eichler's Raspwort	Haloragis eichleri	R	
	Halosarcia lepidosperma	R	
Matted St John's Wort	Hypericum japonicum	R	
Ruddy Ground-fern	Hypolepis rugosula	R	
Plain Quillwort	Isoetes drummondii ssp. drummondii	R	
Nutty Club-rush	Isolepis producta	V	
Swamp Isotome	Isotoma fluviatilis ssp. australis	R	
	Juncus amabilis	V	

Wiry Rush	Juncus homalocaulis	V	
Tall Rush	Juncus procerus	R	
Narrow-leaf Blown-grass	Lachnagrostis punicea var. filifolia	R	
Tall Blown-grass	Lachnagrostis robusta	R	
Stiff Raper-sedge	Lepidosperma neesii	V	
Creeping Cotula	Leptinella reptans	R	
Lanky Buttons	Leptorhynchos elongatus	R	
Wiry Buttons	Leptorhynchos tenuifolius	R	
Dwarf Nertera	Leptostigma reptans	R	
Poison Lobelia	Lobelia pratioides	R	
Wattle Mat-rush	Lomandra filiformis ssp. coriacea	R	
Swamp Mazus	Mazus pumilio	V	
Swamp Honey-myrtle	Melaleuca squamea	R	
Bottlebrush Tea-tree	Melaleuca squarrosa	R	
Slender Mint	Mentha diemenica	R	
Native Pennyroyal	Mentha satureioides	R	
Swamp Onion-orchid	Microtis orbicularis	R	
White Purslane	Montia australasica	R	
Broad Milfoil	Myriophyllum amphibium	R	
Upright Milfoil	Myriophyllum crispatum	V	
Tiny Milfoil	Myriophyllum integrifolium	R	
Varied Milfoil	Myriophyllum variifolium	R	
Swamp Daisy-bush	Olearia glandulosa	V	
Silver Daisy-bush	Olearia pannosa ssp. pannosa	V	V
Swamp Lily	Ottelia ovalifolia ssp. ovalifolia	R	
Scaly Haeckeria	Ozothamnus pholidotus	V	
Tiny Mitrewort	Phyllangium distylis	R	
Pigmy Clubmoss	Phylloglossum drummondii	R	
Squat Picris	Picris squarrosa	R	
Austral Pillwort	Pilularia novae-hollandiae	R	
Fine-leaf Tussock-grass	Poa meionectes	V	
Velvet Tussock-grass	Poa rodwayi	R	
Glenelg Pomaderris	Pomaderris halmaturina ssp. continentis	V	
Thin Pondweed	Potamogeton australiensis	V	
Blunt Pondweed	Potamogeton ochreatus	R	
Maroon Leek-orchid	Prasophyllum frenchii (NC)	E	E
Poison Pratia	Pratia concolor	R	
Tender Brake	Pteris tremula	R	
Swamp Greenhood	Pterostylis tenuissima	V	V
Drumsticks	Pycnosorus globosus	V	
River Buttercup	Ranunculus inundatus	R	
Large River Buttercup	Ranunculus papulentus	V	
Slender Buttercup	Ranunculus robertsonii	R	
Tiny Bog-rush	Schoenus discifer	R	
	Schoenus laevigatus	R	
Medusa Bog-rush	Schoenus latelaminatus	V	
Slender Bog-rush	Schoenus lepidosperma ssp. lepidosperma	R	
Gimlet Bog-rush	Schoenus sculptus	R	
Grassy Bog-rush	Schoenus tesquorum	R	
	Senecio psilocarpus	V	V
Pink Swamp-heath	Sprengelia incarnata	R	
Starwort	Stellaria caespitosa (NC)	V	
Rayless Starwort	Stellaria multiflora	R	
Beauglehole's Trigger-plant	Stylidium beaugleholei	R	

	Stylidium ecorne	R	
Broughton Pea	Swainsona procumbens	V	
Alcock's Water-ribbons	Triglochin alcockiae	R	
Yellow Bladderwort	Utricularia australis	R	
Beauglehole's Bladderwort	Utricularia beaugleholei	V	
Slender Speedwell	Veronica gracilis	V	
Beauglehole's Marsh-flower	Villarsia umbricola var. beaugleholei	V	
Native Broom	Viminaria juncea	R	
Lagoon Nancy	Wurmbea dioica ssp. lacunaria	E	
Tall Yellow-eye	Xyris operculata	R	
Pink Zieria	Zieria veronicea (NC)	R	
Manila Grass	Zoysia macrantha ssp. walshii	R	

Source: SAWID South East (December 2008) (DENR 2008)
(E) Endangered; (V) Vulnerable; (R) Rare

D. THREATENED AQUATIC FAUNA – SOUTH EAST

COMMON NAME	SPECIES	NPW Act	EPBC Act	Treaty
AVES				
Common Sandpiper	Actitis hypoleucos			JC
Australasian Shoveler	Anas rhynchotis	R		
Magpie Goose	Anseranas semipalmata	E		
Great Egret, (White Egret)	Ardea alba			JC
Intermediate Egret	Ardea intermedia	R		
Ruddy Turnstone	Arenaria interpres			JC
Musk Duck	Biziura lobata	R		
Australasian Bittern	Botaurus poiciloptilus	V		
Sharp-tailed Sandpiper	Calidris acuminata			JC
Sanderling	Calidris alba			JC
Red Knot	Calidris canutus			JC
Curlew Sandpiper	Calidris ferruginea			JC
Pectoral Sandpiper	Calidris melanotos			J
Red-necked Stint	Calidris ruficollis			JC
Long-toed Stint	Calidris subminuta	TR		JC
Great Knot	Calidris tenuirostris	TR		JC
Cape Barren Goose	Cereopsis novaehollandiae	R		
Greater Sand Plover	Charadrius leschenaultii	TR		JC
Lesser Sand Plover	Charadrius mongolus	TR		JC
Golden-headed Cisticola	Cisticola exilis	R		
Yellow-nosed Albatross	Diomedea chlororhynchos	V		
Grey-headed Albatross	Diomedea chrysostoma	V	VU	
Wandering Albatross	Diomedea exulans	V	VU	
Black-browed Albatross	Diomedea melanophris	V		
Eastern Reef Egret	Egretta sacra	R		C
Rockhopper Penguin	Eudyptes chrysocome	O		
Latham's Snipe	Gallinago hardwickii	V		JC
Oriental Pratincole	Glareola maldivarum	O		
Brolga	Grus rubicunda	V		
White-bellied Sea-Eagle	Haliaeetus leucogaster	V		C
Blue Petrel	Halobaena caerulea	V		
Little Bittern	Ixobrychus minutus	R		
Broad-billed Sandpiper	Limicola falcinellus	O		JC
Bar-tailed Godwit	Limosa lapponica	TR		JC
Black-tailed Godwit	Limosa limosa	TR		JC
Eastern Curlew	Numenius madagascariensis	V		JC
Whimbrel	Numenius phaeopus	TR		JC
Blue-billed Duck	Oxyura australis	R		
Ruff	Philomachus pugnax	TR		JC
Glossy Ibis	Plegadis falcinellus	R		C
Grey Plover	Pluvialis squatarola	TR		JC

Great Crested Grebe	Podiceps cristatus	R		
Baillon's Crake	Porzana pusilla	R		
Grey Petrel	Procellaria cinerea	O		
Short-tailed Shearwater	Puffinus tenuirostris	TR		J
Lewin's Rail	Rallus pectoralis	V		
Painted Snipe	Rostratula benghalensis	R		C
Little Tern	Sterna albifrons	V	EN	JC
Crested Tern	Sterna bergii	TR		J
Caspian Tern	Sterna caspia	TR		C
Fairy Tern	Sterna nereis	V		
Freckled Duck	Stictonetta naevosa	V		
Southern Emu-wren	Stipiturus malachurus	R		
Southern Emu-wren	Stipiturus malachurus malachurus	R		
Antarctic Petrel	Thalassoica antarctica	O		
Hooded Plover	Thinornis rubricollis	V		
Wood Sandpiper	Tringa glareola	TR		JC
Common Greenshank	Tringa nebularia	TR		JC
Marsh Sandpiper	Tringa stagnatilis	TR		JC
Common Redshank	Tringa totanus	O		C
Terek Sandpiper	Xenus cinereus	TR		JC
AMPHIBIA				
Smooth Frog	Geocrinia laevis	R		
Growling Grass Frog	Litoria raniformis	V	VU	
REPTILIA				
Swamp Skink	Egernia coventryi	E		
MAMMALIA				
Swamp Antechinus	Antechinus minimus	E		
Swamp Wallaby	Wallabia bicolor	V		
Source: SAWID South East (December 2008) (DENR 2008) (E) Endangered; (V) Vulnerable; (R) Rare				

FISH		2007 Action Plan#	EPBC Act	SA Fisheries Act
Short-finned Eel	Anguilla australis	R		
River Blackfish	Gadopsis marmoratus	E**		P
Climbing Galaxias	Galaxias brevipinnis	R		
Mountain Galaxias	Galaxias olidus	V		
Spotted Galaxias	Galaxias truttaceus	E		
Dwarf Galaxias	Galaxiella pusilla	V	VU	
Pouched Lamprey	Geotria australis	V*		
Shorthead Lamprey	Mordacia mordax	V*		
Southern Pygmy Perch	Nannoperca australis	E		P
Yarra Pygmy Perch	Nannoperca obscura	E	VU	P
Ewen's Pygmy Perch	Nannoperca variegata	V**	VU	P

Australian Mudfish	Neochanna cleaveri	E		
Australian Grayling	Prototroctes maraena	E	VU	
Congolli	Pseudaphritis urvillii	R***		

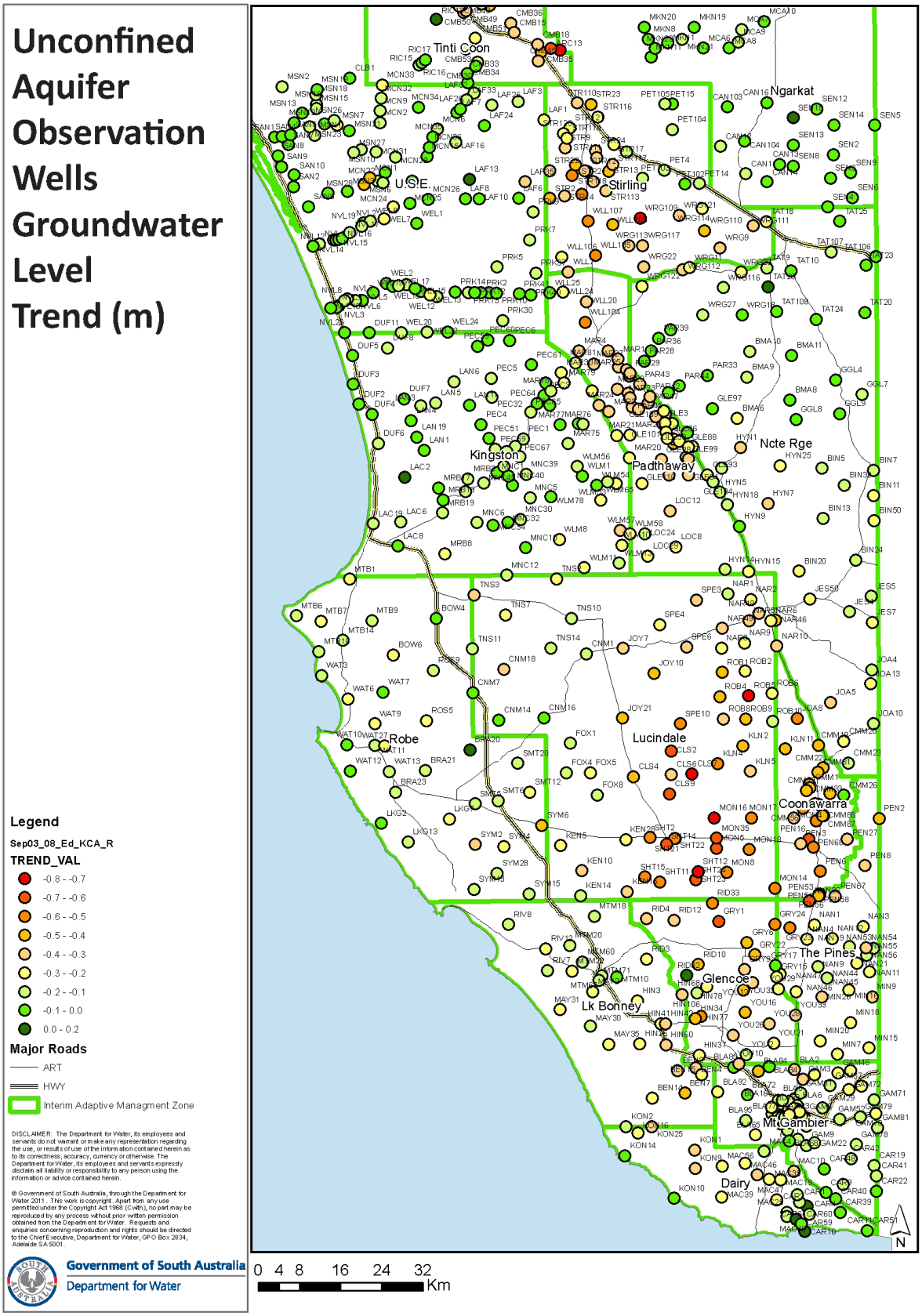
#Source: Hammer *et al.* (2007)
(E) Endangered; (V) Vulnerable; (R) Rare; (P) Protected

** review of the status of these species at State level in 2009 indicates upgrading of conservation status from vulnerable to Endangered is warranted based on IUCN criteria.*

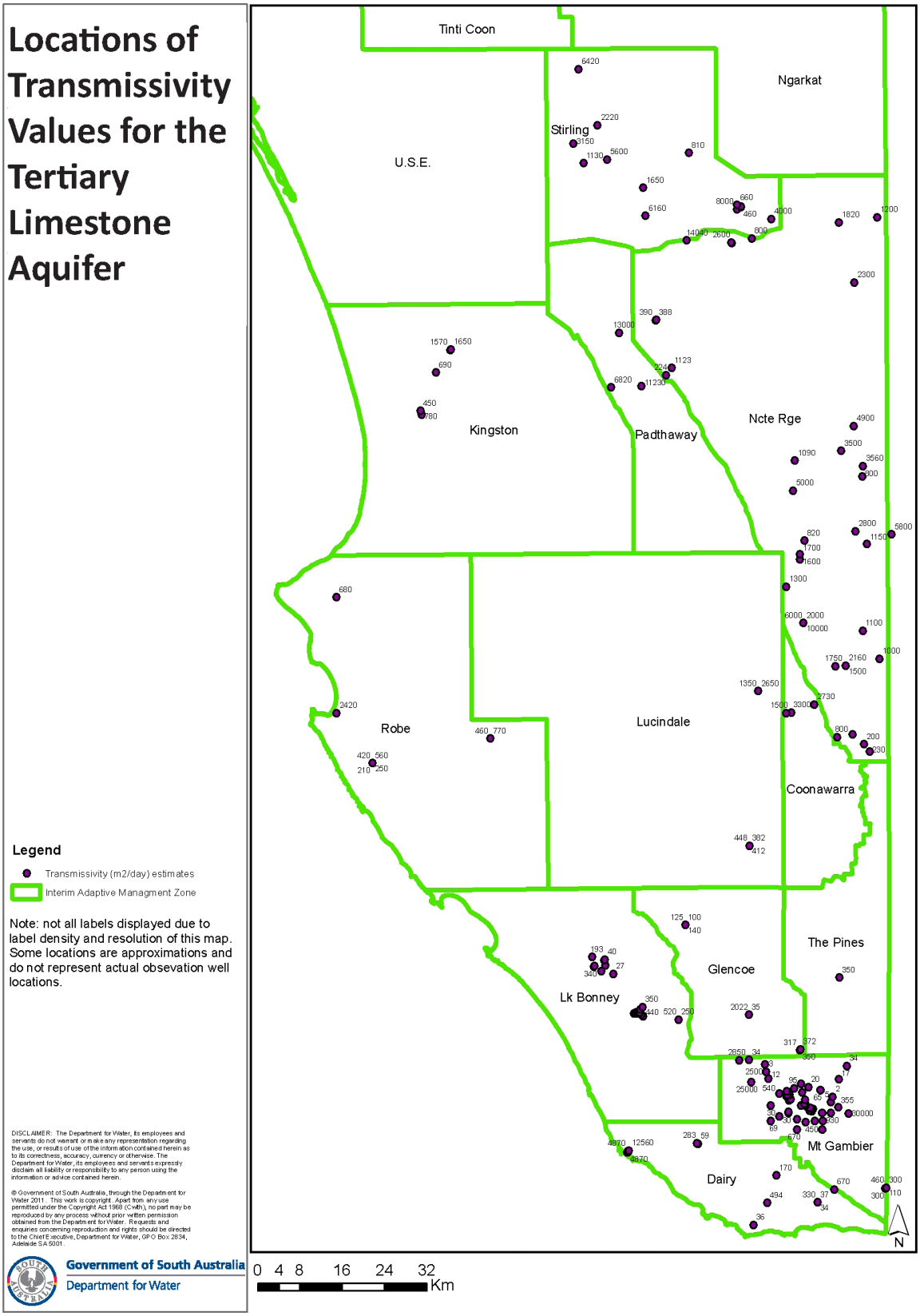
*** review of the status of these species at State level in 2009 indicates upgrading of conservation status from Endangered to Critically Endangered is warranted based on IUCN criteria.*

****review of the status of this species at State level in 2009 indicates upgrading of conservation status from Rare to Endangered is warranted based on IUCN criteria.*

E. LOCATIONS OF OBSERVATION WELLS USED IN GROUNDWATER LEVEL TREND ANALYSIS



F. TRANSMISSIVITY VALUES FOR THE TERTIARY LIMESTONE AQUIFER



Source of data: Stadter (1989); Mustafa & Lawson (2002); REM (2006)

G. TRANSMISSIVITY DATA FOR THE TERTIARY LIMESTONE AQUIFER

Map_Num	Unit_Num	UnitNum	Easting	Northing	Transmissivity (T m^2/d) reported	Transmissivity (T m^2/d) maximum	Source	Comments	IAMZ	Geometric Mean (T max)
			483422	5888053	>2730	2730	Stadter (1989)	position estimate based on figures in report	Coonawarra	2382
			479186	5886566	900–3300	3300	Stadter (1989)	position estimate based on figures in report		
			478146	5886476	>1500	1500	Stadter (1989)	position estimate based on figures in report		
7021	1334	70211334	471984	5789582	36	36	Not cited		Dairy	469
7021	1407	70211407	474550	5793752	141–494	494	Not cited			
7022	522	70220522	487278	5796320	670	670	Cobb (1979)			
7022	2283	70222283	476283	5798940	170	170	Cobb (1979)			
6922	47	69220047	448231	5803534	4870	4870	Barnett (1976)			
6922	49		448364	5803637	12 560	12 560	Barnett (1976)			
7022	2677		461487	5804932	59	59	Smith (1978)			
7022	4708		461332	5805090	265-283	283	Not Cited			
			484102	5793839	34	34	REM (2006) EPZ Report	position based on centre of Management Area		
			484102	5793839	37	37	REM (2006) EPZ Report	position based on centre of Management Area		
			484102	5793839	330	330	REM (2006) EPZ Report	position based on centre of Management Area		
		70221152	480762	5822660	350	350	Not Cited		Glencoe	218
		70221152	480762	5822660	317	317	Not Cited			
7022	1152		480884	5822837	317–372	372	Read et al. (1974)			
0	0		459136	5846343	140	140	REM (2006) EPZ Report	position based on centre of Management Area		
0	0		459136	5846343	125	125	REM (2006) EPZ Report	position based on centre of Management Area		
0	0		459136	5846343	100	100	REM (2006) EPZ Report	position based on centre of Management Area		
0	0		471142	5829357	2022	2022	REM (2006) EPZ Report	position based on centre of Management Area		
0	0		471142	5829357	35	35	REM (2006) EPZ Report	position based on centre of Management Area		
0	0	69241107	409166	5942975	780	780	Not Cited		Kingston	911
0	0	68241126	408974	5943674	450	450	Not Cited			

0	0	69242656	411912	5950925	690	690	Not Cited			
0	0	69242602	414605	5955177	1570	1570	Not Cited			
0	0	69242638	414715	5955296	1650	1650	Not Cited			
6922	2128		451071	5829047	440	440	Williams et. al (1976)		Lake Bonney	341
6922	2118		450795	5829420	550	550	Williams et al. (1976)	S for the unconfined subaquifer		
0	0	69222117	449369	5829604	1600	1600	Not Cited			
6922	2112		449831	5829788	960	960	Bleys (1965)			
6922	2117		450169	5829792	1600	1600	Bleys (1965)			
6922	2111		450147	5829794	350	350	Bleys (1965)			
6922	2106		450477	5829794	990	990	Bleys (1965)			
6922	2512		450552	5830363	950	950	Lawson (1991)	S estimated for the unconfined subaquifer		
6922	221		451031	5830841	130–194	194	Williams (1979)	T and S for the unconfined subaquifer		
6922	221		451031	5830841	310–350	350	Williams (1979)	T and S for the confined subaquifer		
6922	2578		445473	5837108	27	27	Smith (1979)			
6922	1510		443152	5837623	560	560	Barnett (1975)			
0	0	69222161	441822	5838442	340	340	Not Cited			
6922	2161		441944	5838620	340	340	Harris (1969)			
6922	2174		444004	5838715	413-780	780	Smith (1979)			
		69221075	443770	5839639	40	40	Not Cited			
6922	1075		443892	5839817	40	40	Bleys (1966)			
6922	1075		443892	5839817	142-210	210	Smith (1979)			
6922	1042		441426	5840314	193	193	Smith (1979)	Millicent Town Water Supply 2		
			457783	5828447	520	520	REM (2006) EPZ Report	position based on centre of Management Area		
			457783	5828447	250	250	REM (2006) EPZ Report	position based on centre of Management Area		
			472816	5890645	1350	1350	REM (2006) EPZ Report	position based on centre of Management Area	Lucindale	759
			472816	5890645	2650	2650	REM (2006) EPZ Report	position based on centre of Management Area		
			471225	5861375	412	412	REM (2006) EPZ Report	position based on centre of Management Area		
			471225	5861375	448	448	REM (2006) EPZ Report	position based on centre of Management Area		
			471225	5861375	382	382	REM (2006) EPZ Report	position based on centre of Management Area		
		70220538	496935	5796455	300	300	Not Cited		Mt Gambier	375

7022	538	497057	5796632	110	110	Cobb (1979)
7022	538	497057	5796632	210–460	460	Barnett (1976)
7022	538	497057	5796632	300	300	Bradley et al. (1995)
7022	76	480231	5807613	160	160	Cobb (1979)
7022	76	480231	5807613	670	670	Lawson et al. (1993)
7022	252	484978	5807626	180	180	Cobb (1979)
7022	252	484978	5807626	212	212	Lawson et al. (1993)
7022	293	481833	5809030	510	510	Cobb (1979)
7022	293	481833	5809030	450	450	Lawson et al. (1993)
7022	2570	475255	5809220	130	130	Cobb (1979)
7022	2570	475255	5809220	69	69	Lawson et al. (1993)
7022	261	485133	5809283	930	930	Cobb (1979)
7022	261	485133	5809283	1035	1035	Lawson et al. (1993)
7022	284	483537	5809309	1400	1400	Cobb (1979)
7022	284	483537	5809309	1140	1140	Lawson et al. (1993)
7022	59	480256	5809602	7700	7700	Cobb (1979)
7022	59	480256	5809602	3460	3460	Lawson et al. (1993)
7022	2566	476910	5810161	30	30	Cobb (1979)
7022	2566	476910	5810161	30	30	Lawson et al. (1993)
7022	161	489964	5810667	30 000	30 000	Cobb (1979)
7022	283	484977	5810777	240	240	Cobb (1979)
7022	283	484977	5810777	412	412	Lawson et al. (1993)
7022	264	486587	5810821	1340	1340	Lawson et al. (1993)
7022	4148	478643	5810827	4000	4000	Lawson et al. (1993)
7022	2924	478569	5810987	1612	1612	Lawson et al. (1993)
7022	1532	483082	5811060	440	440	Cobb (1979)
7022	1532	483082	5811060	433	433	Lawson et al. (1993)
7022	1538	482621	5811176	28	28	Cobb (1979)
7022	1533	483274	5811563	20	20	Cobb (1979)
7022	1533	483274	5811563	20	20	Lawson et al. (1993)

7022	2818	482351	5811622	42	42	Cobb (1979)	
7022	1539	482928	5811691	215	215	Lawson et al. (1993)	
7022	1537	482678	5811761	230	230	Cobb (1979)	
7022	1537	482678	5811761	64	64	Lawson et al. (1993)	
7022	2262	487992	5811871	355	355	Smith (1979)	
7022	1486	481799	5812132	14 800	14 800	Lawson et al. (1993)	Drainage Well–Dolomite Unit of Gambier
7022	1973	480976	5812140	10 500	10 500	Lawson et al. (1993)	Drainage Well–Dolomite Unit of Gambier
7022	2710	475259	5812234	250	250	Cobb (1979)	
7022	1476	481849	5812412	7910	7910	Lawson et al. (1993)	Drainage Well–Dolomite Unit of Gambier
7022	2823	481608	5812548	190	190	Cobb (1979)	
7022	2823	481608	5812548	370	370	Lawson et al. (1993)	
7022	1686	486649	5812800	5	5	Lawson et al. (1993)	
7022	6584	478754	5813201	50 000	50 000	Lawson et al. (1993)	Dolomite Unit of Gambier Limestone
7022	2828	481690	5813308	190	190	Cobb (1979)	
7022	2828	481690	5813308	290	290	Lawson et al. (1993)	
7022	2864	479050	5813355	280	280	Cobb (1979)	
7022	2864	479050	5813355	280	280	Lawson et al. (1993)	
7022	1687	486946	5813825	10	10	Cobb (1979)	
7022	1687	486946	5813825	2	2	Lawson et al. (1993)	
7022	2785	478855	5814242	30 000	30 000	Cobb (1979)	Dolomite Unit of Gambier Limestone
7022	2785	478855	5814242	24 000	24 000	Lawson et al. (1993)	
7022	2777	478328	5814253	11 200	11 200	Harris (1970)	Dolomite Unit of Gambier Limestone
7022	2721	476864	5814443	400	400	Cobb (1979)	
7022	2721	476864	5814443	540	540	Lawson et al. (1993)	
7022	2801	481149	5814652	500	500	Cobb (1979)	
7022	2801	481149	5814652	450	450	Lawson et al. (1993)	
7022	2773	478221	5814837	280	280	Cobb (1979)	
7022	2773	478221	5814837	1572	1572	Lawson et al. (1993)	
7022	1682	484682	5815158	65	65	Cobb (1979)	
7022	1682	484682	5815158	157	157	Lawson et al. (1993)	

7022	2794		479733	5815437	80	80	Cobb (1979)		
7022	2794		479733	5815437	95	95	Lawson et al. (1993)		
7022	2737		482351	5815690	20	20	Lawson et al. (1993)		
7022	2732		480970	5816252	2800	2800	Cobb (1979)	Dolomite Unit of Gambier Limestone	
7022	2732		480970	5816252	3970	3970	Lawson et al. (1993)		
7022	2411		471578	5816632	25 000	25 000	Cobb (1979)		
7022	813		488101	5817137	17	17	Lawson et al. (1993)		
7022	2489		474852	5817228	12	12	Lawson et al. (1993)		
7022	2459		474384	5818617	3	3	Lawson et al. (1993)		
7022	837		489586	5819652	34	34	Lawson et al. (1993)		
7022	2460		474184	5819997	2500	2500	Cobb (1979)		
7022	2460		474184	5819997	17 723	17 723	Lawson et al. (1993)		
7022	2397		469304	5820785	2850	2850	Cobb (1979)		
7022	4539		471169	5820816	26–34	34	Not Cited		
		70230541	493997	5879165	230	230	Not Cited	Naracoorte Ranges	1373
		70244102	480760	5915574	1600	1600	Not Cited		
		70240700	493447	5918487	1150	1150	Not Cited		
		70243921	492650	5933245	3560	3560	Not Cited		
		70244136	488557	5936065	3500	3500	Not Cited		
		70241225	490944	5940796	4900	4900	Not Cited		
		70241297	455387	5950425	224	224	Not Cited		
		70241291	456466	5951793	1123	1123	Not Cited		
		69251151	453518	5960817	390	390	Not Cited		
		69251150	453621	5960855	388	388	Not Cited		
		70252883	491018	5967978	2300	2300	Not Cited		
		70250678	467759	5975561	2600	2600	Not Cited		
		70252720	459350	5975900	14 040	14 040	Not Cited		
		70250954	471707	5976282	800	800	Not Cited		
		70250953	471676	5976297	800	800	Not Cited		
		70252781	488172	5979301	1820	1820	Not Cited		

70252245	495393	5980315	1200	1200	Not Cited			
	489439	5895418	1500	1500	REM (2006) EPZ Report	position based on centre of MA		
	489439	5895418	2160	2160	REM (2006) EPZ Report	position based on centre of MA		
	422223	5881658	460	460	REM (2006) EPZ Report	position based on centre of MA		
	422223	5881658	770	770	REM (2006) EPZ Report	position based on centre of MA		
	490677	5882420	270	270	Stadter (1989)	position estimate based on figures in report		
	492885	5880572	200	200	Stadter (1989)	position estimate based on figures in report		
	487838	5881924	500–800	800	Stadter (1989)	position estimate based on figures in report		
	487433	5895354	800–1750	1750	Stadter (1989)	position estimate based on figures in report		
	495770	5896751	500–1000	1000	Stadter (1989)	position estimate based on figures in report		
	492615	5902023	1100	1100	Stadter (1989)	position estimate based on figures in report		
	481439	5903510	>6000	6000	Stadter (1989)	position estimate based on figures in report		
	481439	5903510	>10000	10000	Stadter (1989)	position estimate based on figures in report		
	481439	5903510	>2000	2000	Stadter (1989)	position estimate based on figures in report		
	478194	5910405	>1300	1300	Stadter (1989)	position estimate based on figures in report		
	480718	5916534	1700	1700	Stadter (1989)	position estimate based on figures in report		
	481619	5919103	>820	820	Stadter (1989)	position estimate based on figures in report		
	491218	5920861	>2800	2800	Stadter (1989)	position estimate based on figures in report		
	498113	5920275	>350–5800	5800	Stadter (1989)	position estimate based on figures in report		
	492525	5931271	>800	800	Stadter (1989)	position estimate based on figures in report		
	479501	5928567	>5000	5000	Stadter (1989)	position estimate based on figures in report		
	479816	5934245	>1090	1090	Stadter (1989)	position estimate based on figures in report		
69241680	444998	5948109	6820	6820	Not Cited		Padthaway	9985
69241790	450799	5948323	11 230	11 230	Not Cited			
69241936	446586	5958462	13 000	13 000	Not Cited			
68230572	393081	5886445	2420	2420	Not Cited		Robe	462
	399867	5876983	260	260	REM (2006) EPZ Report	position based on centre of MA		
	399867	5876983	395	395	REM (2006) EPZ Report	position based on centre of MA		
	399867	5876983	210	210	REM (2006) EPZ Report	position based on centre of MA		
	399867	5876983	250	250	REM (2006) EPZ Report	position based on centre of MA		

	399867	5876983	420	420	REM (2006) EPZ Report	position based on centre of MA		
	399867	5876983	560	560	REM (2006) EPZ Report	position based on centre of MA		
	393056	5908389	680	680	REM (2006) EPZ Report	position based on centre of MA		
70252588	475300	5979950	4000	4000	Not Cited		Stirling	2441
69252771	451550	5980550	6160	6160	Not Cited			
70250857	468871	5981802	8000	8000	Not Cited			
70250865	469582	5982229	460	460	Not Cited			
70250864	469614	5982315	4820	4820	Not Cited			
70250863	468899	5982619	660	660	Not Cited			
69252732	451104	5985874	1650	1650	Not Cited			
69252730	439800	5990550	1130	1130	Not Cited			
69252736	444300	5991250	5600	5600	Not Cited			
70252736	459800	5992500	810	810	Not Cited			
69252731	437872	5994252	3150	3150	Not Cited			
69252717	442500	5997750	2220	2220	Not Cited			
69252744	438857	6008310	6420	6420	Not Cited			
	488259	5836420	350	350	REM (2006) EPZ Report	position based on centre of MA	The Pines	350

H. COMPARISON OF BUFFER ZONE CALCULATIONS FOR GROUNDWATER-DEPENDENT ECOSYSTEMS

				Glover & Balmer (1954) Analytical Model			Theis Solution (REM 2006)	Hotspots Model (Merrick 2006)		
Interim Adaptive Management Zone (this report)	Groundwater Management Zone (REM 2006)	Transmissivity Geometric mean (T)		Buffer 10% impact	Buffer 5% impact	Buffer 1% impact	EPZ	100 mm drawdown impact	10 mm drawdown impact	1 mm drawdown impact
		(REM 2006)	(this report)	(m)	(m)	(m)	(m)	(m)	(m)	(m)
Dairy	MacDonnell	145	469	1083	1531	3424	487	690	1190	1460
Dairy	Donovans	129	469	1083	1531	3424	460	670	1100	1440
Lake Bonney	Hindmarsh	604	341	923	1306	2920	996	830	1870	2820
Glencoe	Riddoch	121	218	738	1044	2335	445	670	1030	1430
Glencoe	Young	266	218	738	1044	2335	661	800	1410	2030
The Pines	Zone 2A	350	350	935	1323	2958	758	830	1460	2110
Lucindale	Bool	1711	759	1377	1948	4356	1680	600	2320	4040
Lucindale	Monbulla	413	759	1377	1948	4356	820	840	1620	2140
Robe	Mt Benson	680	462	1075	1520	3399	1060	830	1920	2910
Robe	Waterhouse	329	462	1075	1520	3399	735	820	1450	2090
Ncte Ranges	Comaum	595	1373	1853	2620	5859	990	830	1860	2800
Ncte Ranges	Joanna	1800	1373	1853	2620	5859	1720	580	2360	4100

I. SUMMARY OF LAYERS USED WITHIN WATER-RAT AND RESPONSIBLE AGENCIES

Layer	Currency of data	Agency
Assets		
Significant Wetlands Layer	Generated from data (SAWID) 1980 – Feb 2009	DENR
Threatened aquatic flora and fauna and migratory birds	SAWID and Native Fish Australia data (1980 – Feb 2009)	DENR / Native Fish Australia
Permanent Pools	2007	DENR
Significant Surface water Catchments	2008	DFW
Wetland of International and National Importance	Feb 2009	DENR
Natural Streams	Feb 2009	DENR / DFW
Likelihood of Groundwater Dependence		
GDE mapping (SKM 2009)	Data provided to SKM November 2008	DFW
Threats		
Groundwater level trend (5 year trend)	December 2008	DFW
Intensity of Irrigation	June 2008	DFW
Intensity of forestry	November 2005	DFW / FSA
High water usage area	June 2008	DFW
Forestry	November 2005	DFW / FSA
Risk Zones		
Groundwater Development Risk Zones	February 2009	DFW

UNITS OF MEASUREMENT

Units of measurement commonly used (SI and non-SI Australian legal)

Name of unit	Symbol	Definition in terms of other metric units	Quantity
day	d	24 h	time interval
gigalitre	GL	10^6 m^3	volume
hectare	ha	10^4 m^2	area
hour	h	60 min	time interval
kilolitre	kL	1 m^3	volume
kilometre	km	10^3 m	length
litre	L	10^{-3} m^3	volume
megalitre	ML	10^3 m^3	volume
metre	m	base unit	length
milligram	mg	10^{-3} g	mass
millimetre	mm	10^{-3} m	length
minute	min	60 s	time interval
second	s	base unit	time interval
year	y	365 or 366 days	time interval

GLOSSARY

Aquatic community — An association of interacting populations of aquatic organisms in a given water body or habitat

Aquatic ecosystem — The stream channel, lake or estuary bed, water, and/or biotic communities, and the habitat features that occur therein

Aquatic habitat — Environments characterised by the presence of standing or flowing water

Aquifer — An underground layer of rock or sediment that holds water and allows water to percolate through

Aquifer, confined — Aquifer in which the upper surface is impervious (see 'confining layer') and the water is held at greater than atmospheric pressure; water in a penetrating well will rise above the surface of the aquifer

Aquifer, unconfined — Aquifer in which the upper surface has free connection to the ground surface and the water surface is at atmospheric pressure

Baseflow — The water in a stream that results from groundwater discharge to the stream; often maintains flows during seasonal dry periods and has important ecological functions

Biodiversity — (1) The number and variety of organisms found within a specified geographic region. (2) The variability among living organisms on the earth, including the variability within and between species and within and between ecosystems

Biota — All of the organisms at a particular locality

Buffer zone — A neutral area that separates and minimises interactions between zones whose management objectives are significantly different or in conflict (eg. a vegetated riparian zone can act as a buffer to protect the water quality and streams from adjacent land uses)

CAMBA — China – Australia Migratory Bird Agreement

Catchment — That area of land determined by topographic features within which rainfall will contribute to run-off at a particular point

COAG — Council of Australian Governments; a council of the Prime Minister, State Premiers, Territory Chief Ministers and the President of the Australian Local Government Association which exists to set national policy directions for Australia

CSIRO — Commonwealth Scientific and Industrial Research Organisation

DEH — Department for Environment and Heritage (Government of South Australia)

DENR — Department of Environment and Natural Resources (Government of South Australia)

DEM — Digital Elevation Model

DFW — Department for Water (Government of South Australia)

DWLBC — Department of Water, Land and Biodiversity Conservation (Government of South Australia)

EC — Electrical conductivity; 1 EC unit = 1 micro-Siemen per centimetre (µS/cm) measured at 25°C; commonly used as a measure of water salinity as it is quicker and easier than measurement by TDS

Ecological processes — All biological, physical or chemical processes that maintain an ecosystem

Ecological values — The habitats, natural ecological processes and biodiversity of ecosystems

Ecology — The study of the relationships between living organisms and their environment

Ecosystem — Any system in which there is an interdependence upon, and interaction between, living organisms and their immediate physical, chemical and biological environment

Emerging environmental problems — Problems that may be new and/or are becoming known because of better monitoring and use of indicators

GLOSSARY

Endangered species — (1) Any species in danger of extinction throughout all or a significant portion of its range

Environmental values — The uses of the environment that are recognised as being of value to the community. This concept is used in setting water quality objectives under the Environment Protection (Water Quality) Policy, which recognises five environmental values — protection of aquatic ecosystems, recreational water use and aesthetics, potable (drinking water) use, agricultural and aquaculture use, and industrial use. It is not the same as ecological values, which are about the elements and functions of ecosystems.

Environmental water provisions — That part of environmental water requirements that can be met; what can be provided at a particular time after consideration of existing users' rights, and social and economic impacts

Environmental water requirements (**EWR)** — The water regimes needed to sustain the ecological values of aquatic ecosystems, including their processes and biological diversity, at a low level of risk

EPA — Environment Protection Authority (Government of South Australia)

EPBC(act) — Environment Protection and Biodiversity and Conservation Act 1999.

Ephemeral streams or wetlands — Those streams or wetlands that usually contain water only on an occasional basis after rainfall events. Many arid zone streams and wetlands are ephemeral.

FSA – ForestrySA

GDE — Groundwater-dependent Ecosystem

GIS — Geographic Information System; computer software linking geographic data (for example land parcels) to textual data (soil type, land value, ownership). It allows for a range of features, from simple map production to complex data analysis

GMA – Groundwater Management Area (South East)

GRASE – Groundwater Resource Assessment South East (Team)

Groundwater — Water occurring naturally below ground level or water pumped, diverted and released into a well for storage underground; see also 'underground water'

HaIE – Irrigation Equivalent (hectares) (units of measurement)

Habitat — The natural place or type of site in which an animal or plant, or communities of plants and animals, live

Hydraulic conductivity (K) — A measure of the ease of flow through aquifer material: high K indicates low resistance, or high flow conditions; measured in metres per day

Hydrogeology — The study of groundwater, which includes its occurrence, recharge and discharge processes, and the properties of aquifers; see also 'hydrology'

Hydrology — The study of the characteristics, occurrence, movement and utilisation of water on and below the Earth's surface and within its atmosphere; see also 'hydrogeology'

IAMZ— Interim Adaptive Management Zone (Groundwater)

Irrigation — Watering land by any means for the purpose of growing plants

Irrigation season — The period in which major irrigation diversions occur, usually starting in August–September and ending in April–May

JAMBA — Japan – Australia Migratory Bird Agreement

Lake — A natural lake, pond, lagoon, wetland or spring (whether modified or not) that includes part of a lake and a body of water declared by regulation to be a lake. A reference to a lake is a reference to either the bed, banks and shores of the lake or the water for the time being held by the bed, banks and shores of the lake, or both, depending on the context.

Macro-invertebrates — Aquatic invertebrates visible to the naked eye including insects, crustaceans, mollusks and worms that inhabit a river channel, pond, lake, wetland or ocean

m AHD — Defines elevation in metres (m) according to the Australian Height Datum (AHD)

GLOSSARY

Metadata — Information that describes the content, quality, condition, and other characteristics of data, maintained by the Federal Geographic Data Committee

ML — Mega Litre (unit of measurement)

NFA — Native Fish Australia (SA) Inc

Native species — Any animal and plant species originally in Australia; see also 'indigenous species'

Natural resources — Soil, water resources, geological features and landscapes, native vegetation, native animals and other native organisms, ecosystems

NPW(Act) — National Parks and Wildlife Act (1972)

NRM – Natural Resource Management

NWI – National Water Initiative

Observation well — A narrow well or piezometer whose sole function is to permit water level measurements

Obswell — Observation Well Network

Phreatophytic vegetation — Vegetation that exists in a climate more arid than its normal range by virtue of its access to groundwater

Prescribed water resource — A water resource declared by the Governor to be prescribed under the Act, and includes underground water to which access is obtained by prescribed wells. Prescription of a water resource requires that future management of the resource be regulated via a licensing system.

PWA — Prescribed Wells Area

Ramsar Convention — This is an international treaty on wetlands titled *The Convention on Wetlands of International Importance Especially as Waterfowl Habitat*. It is administered by the International Union for Conservation of Nature and Natural Resources. It was signed in the town of Ramsar, Iran in 1971, hence its common name. The convention includes a list of wetlands of international importance and protocols regarding the management of these wetlands. Australia became a signatory in 1974.

SA – South Australia

SA Geodata — A collection of linked databases storing geological and hydrogeological data, which the public can access through the offices of PIRSA. Custodianship of data related to minerals and petroleum, and groundwater, is vested in PIRSA and DFW, respectively. DFW should be contacted for database extracts related to groundwater

SAWID – South Australian Wetland Inventory Database

SE – South East (South Australia)

SENRMB – South East Natural Resource Management Board

SERIC – South East Resource Information Centre

SEWCDB – South East Water Conservation and Drainage Board

Surface water — (a) water flowing over land (except in a watercourse), (i) after having fallen as rain or hail or having precipitated in any another manner, (ii) or after rising to the surface naturally from underground; (b) water of the kind referred to in paragraph (a) that has been collected in a dam or reservoir

Sustainability — The ability of an ecosystem to maintain ecological processes and functions, biological diversity, and productivity over time

TLA — Tertiary Limestone Aquifer (South East NRM Region)

Tertiary aquifer — A term used to describe a water-bearing rock formation deposited in the Tertiary geological period (1–70 million years ago)

Threatened species — Any species that is likely to become an endangered species within the foreseeable future

Underground water (groundwater) — Water occurring naturally below ground level or water pumped, diverted or released into a well for storage underground

GLOSSARY

Volumetric allocation — An allocation of water expressed on a water licence as a volume (eg. kilolitres) to be used over a specified period of time, usually per water use year (as distinct from any other sort of allocation)

Water-affecting activities — Activities referred to in Part 4, Division 1, s. 9 of the Act

Water allocation — (1) In respect of a water licence means the quantity of water that the licensee is entitled to take and use pursuant to the licence. (2) In respect of water taken pursuant to an authorisation under s.11 means the maximum quantity of water that can be taken and used pursuant to the authorisation

Water allocation, area based — An allocation of water that entitles the licensee to irrigate a specified area of land for a specified period of time usually per water–use year

WAP — Water Allocation Plan; a plan prepared by a CWMB or water resources planning committee and adopted by the Minister in accordance with the Act

Water body — Includes watercourses, riparian zones, floodplains, wetlands, estuaries, lakes and groundwater aquifers

Watercourse — A river, creek or other natural watercourse (whether modified or not) and includes: a dam or reservoir that collects water flowing in a watercourse; a lake through which water flows; a channel (but not a channel declared by regulation to be excluded from the this definition) into which the water of a watercourse has been diverted; and part of a watercourse

Water-dependent ecosystems (**WDE**) — Those parts of the environment, the species composition and natural ecological processes, that are determined by the permanent or temporary presence of flowing or standing water, above or below ground; the in-stream areas of rivers, riparian vegetation, springs, wetlands, floodplains, estuaries and lakes

Water licence — A licence granted under the Act entitling the holder to take water from a prescribed watercourse, lake or well or to take surface water from a surface water prescribed area; this grants the licensee a right to take an allocation of water specified on the licence, which may also include conditions on the taking and use of that water; a water licence confers a property right on the holder of the licence and this right is separate from land title

Water plans — The State Water Plan, catchment water management plans, water allocation plans and local water management plans prepared under Part 7 of the Act

Water-RAT – Water-dependent Ecosystem Risk Assessment Tool

Water resource monitoring — An integrated activity for evaluating the physical, chemical, and biological character of water resources, including (1) surface waters, groundwaters, estuaries, and near-coastal waters; and (2) associated aquatic communities and physical habitats, which include wetlands

Well — (1) An opening in the ground excavated for the purpose of obtaining access to underground water. (2) An opening in the ground excavated for some other purpose but that gives access to underground water. (3) A natural opening in the ground that gives access to underground water

Wetlands — Defined by the Act as a swamp or marsh and includes any land that is seasonally inundated with water. This definition encompasses a number of concepts that are more specifically described in the definition used in the Ramsar Convention on Wetlands of International Importance. This describes wetlands as areas of permanent or periodic to intermittent inundation, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tides does not exceed six metres.

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