TECHNICAL REPORT

DELIVERING A STRATEGIC APPROACH FOR IDENTIFYING WATER-DEPENDENT ECOSYSTEMS AT RISK

A PRELIMINARY ASSESSMENT OF RISK TO WATER-DEPENDENT ECOSYSTEMS IN SOUTH AUSTRALIA FROM GROUNDWATER EXTRACTION

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Government of South Australia
Department for Water

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A PRELIMINARY ASSESSMENT OF RISK TO WATER-DEPENDENT ECOSYSTEMS IN SOUTH AUSTRALIA FROM GROUNDWATER EXTRACTION

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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

Background

The Department for Water (DFW), has the responsibility for ensuring water is managed sustainably in South Australia, to support our health, our economy and the environment. In order for DFW to advise on the quantity, quality, use and availability of water resources, it is critical to identify current and potential sources of risks to environmental water requirements. Specifically, strategic objectives for the DFW are to ensure water-dependent ecosystems (WDEs) are protected and can adapt to climate change.

This report provides for a strategic framework to identify vulnerable water-dependent ecosystems as well as key sources of risk, and tools to guide sustainable and appropriate water resource development in South Australia. This will to assist in defining environmental water requirements and securing environmental water provisions for water-dependent ecosystems.

This report also identifies priority data and knowledge gaps that can inform how future work can be targeted to improve the spatial accuracy and confidence in the risk assessment.

Development of a preliminary risk identification and assessment method

The risk assessment relies on the identification of *Assets*, *Vulnerability* and *Likelihood* of impact from existing *sources of risk* to these assets. The preliminary risk assessment is based on the concept that vulnerability of a WDE is a function of changes to WDE processes or drivers. Given the department's current shift towards a risk-based approach to water planning and management effort has been made to align this method to the current departmental draft Risk Management Framework for water planning and management. It is recognised that this was done retrospectively so some inconsistencies may exist.

The assessment focussed on identifying sources of risks to one major WDE process and type—groundwater quantity and discharge to wetlands. In order to preliminarily assess wetlands at risk from groundwater resource development, a four step risk identification and assessment method was applied which included:

Step 1 – South Australia was divided into regional analysis units, based on similarities in aquifer characteristics, groundwater processes and relative homogeneity of hydrogeological, ecological and climatic conditions.

Step 2 – existing spatial and non-spatial data were collated, reviewed and processed to identify and display locations and characteristics of WDE assets and threats to WDE processes posed by water resources development within each analysis.

Step 3 – the vulnerability of wetland assets to changes in processes caused by groundwater resources development was assessed by developing a method to determine the likelihood of groundwater dependency of each mapped WDE asset.

Step 4 – the spatial coincidence of wetlands assessed as being likely to be vulnerable to changes in groundwater (GDEs) and threats posed by groundwater resources extraction was examined to produce a map of wetlands potentially at risk.

Confidence levels for each output were generated to reflect the spatial coverage and accuracy of the original data inputs.

SUMMARY

Preliminary findings

Ground-Water Dependent Ecosystem Classification

A preliminary classification of the likelihood of groundwater dependency of mapped wetlands was completed with use of available existing spatial and non-spatial data. Literature and data relating specifically to the identification of groundwater-dependent ecosystems (GDEs) were collated. Existing landscape scale classifications, varying in purpose, detail and accuracy, account for less than 35% of the number of all mapped wetlands in South Australia. Site scale GDE studies have been initiated at less than 1% of the States wetlands. Shallow groundwater mapping (depth to watertable) was developed and used as the key dataset for determining potential groundwater dependence for much of the State where more detailed data were insufficient.

Significantly, only 13% of the total wetland area in South Australia was found to occur over watertables greater than 10 metres, with 65% of the area occurring over watertables less than 2 metres, suggesting a generally high dependence of wetlands on groundwater resources across the State. Of the 60 782 wetlands mapped for South Australia, 64% were regarded as having a potential for groundwater interaction (14% very high, 36.6% high and 13.4% moderate likelihood of groundwater dependency). This equates to 70.2% of the total area of wetlands currently identified in the State.

The classification is however of low confidence for 48.2% of the total number of wetlands classified, or 57.2% of the total area. Additionally, confidence in the accuracy and completeness of wetland mapping was identified as poor throughout much of the State.

Risk Assessment

Existing high intensity groundwater extraction coinciding with the presence of identified GDEs indicates that 32.3% of the number of all mapped wetlands are potentially at risk from reduced groundwater quantity (discharge) due to high levels of current groundwater extraction. This equates to 25.7% of total wetland area, or 50.5% of the number of all identified GDEs. The majority of the number of wetlands identified as potentially at risk from existing groundwater extraction occurs within the South East (66.69%), Mount Lofty Ranges (45.99%) and Lake Eyre Basin (39.96%) Analysis Units. The potential risk to GDEs from high levels of extraction has not been verified as part of this assessment.

The highest intensity of groundwater extraction was shown to generally occur where groundwater salinity is of suitable quality for irrigation and stock or domestic consumption, although hotspots from industries such as mining are also significant. Consequently, GDEs that are more likely to be freshwater ecosystems due to fresh groundwater discharge have been shown to be at highest risk. Of the 9395 wetland GDEs (less than 3% of all wetlands) occurring in shallow freshwater (<3000 EC) groundwater regions, 90.27% are identified as being at risk from existing high intensity groundwater usage. This also suggests that the majority of the State's GDEs are likely to be brackish to saline as a result of groundwater discharge.

The preliminary identification of future groundwater resource development risk areas for WDEs was broadly determined by applying a 5 km buffer on WDEs likely to be groundwater dependent. A 5 km buffer was chosen as the maximum buffer zone for environmental protection of GDEs in existing water allocation plans (SAAL NRM Board 2009; SE NRM Board 2010) and for the South East (Harding 2009).

Priority Regions

The state-scale preliminary risk identification and assessment highlighted priority regions for improving and verifying the outputs of the preliminary analysis and to assist in focussing efforts for more detailed investigation in the future. Priority areas were determined based on areas of potentially high risk to GDEs, low confidence in mapping and GDE classification and areas of low groundwater salinity (considered to be an indicator of areas of potential higher risk from future groundwater resource development). The analysis indicated several regions of specific interest including Lower South East; Mount Lofty Ranges and Southern Fleurieu Peninsula; Willochra and Mambray Coast; Torrens and Flinders; Eyre Peninsula; Lake Eyre and Musgrave Ranges.

Actions and Conclusions

The preliminary outputs identifyed in this report provide some of the essential spatial data layers that will assist in informing conservation, management and administration. Protection and management of groundwater-dependent ecosystems are hindered by lack of information on their diversity, abundance and location (Howard & Merrifield 2010). By developing a method that uses existing datasets to locate potential GDEs at risk, this assessment has begun to address that knowledge gap and enabled the identification of priorities for improving the confidence of the assessment outputs in regions where potential risks are greatest.

The analysis was effective in highlighting the prevalence of potential GDEs throughout South Australia and identifying key areas likely to be at risk from current levels of groundwater extraction. Testing and verifying groundwater dependence through groundtruthing, or determining whether potential high risk equates to actual ecosystem function or driver loss, was not within scope for this report. However, the preliminary analysis provides a useful prioritisation tool for targeting verification activities and identifying areas of risk.

A number of important aspects were unable to be addressed within the scope of this report that were considered essential for delivery of a robust risk assessment of WDEs in the Sate, including:

- consideration of consequence in the risk assessment method
- adequate consideration of other sources of risk such as water affecting activities likely to pose potential risks to WDEs, including surface water extraction and interception, groundwater and surface water quality impacts and climate change
- consideration of different levels of vulnerability to sources of risk of different WDE types (or typologies)
- verifying the assessment by identifying current ecological status or health of WDEs identified to be at high risk
- further alignment with DFW's Risk Management Framework for Water Planning and Management.

The outputs of this report form the integral data layers required for recognising and assessing potential risks to WDEs from water resource development. There was low confidence in many of the outputs of the assessment. Use of the outputs from this report, including the administration of policy, assessment of development applications, water allocation planning and use in ancillary reports or projects, should consider the limitations of the data and the assessment of confidence of the derived data outputs.

Priority Actions

The objective of this report was to develop preliminary products to assist in informing investment in furthering knowledge and information on risks to WDEs and to support appropriate policy administration and development. Priority actions have been identified to improve the applicability, accuracy and confidence in the risk assessment of WDEs as summarised below:

- expansion of the risk assessment method to include other sources of risk such as surface water extraction, climate change and water quality (salinity, pollution and contamination); consequence of risk and ecosystem vulnerability
- improving the confidence and rigour in the classification and attribution of groundwater dependency for both wetlands and watercourses

- developing a more detailed understanding of groundwater and surface water interactions and sources of risk to assist in informing environmental water requirements and guiding future water allocation policy to protect GDEs in high risk regions
- improving the accuracy and completeness of maps identifying WDE features in data poor regions
- verification of the map outputs
- the development of ecological monitoring of GDEs to complement existing DFW monitoring of groundwater and surface water resources in high priority regions.

1. INTRODUCTION

1.1. DELIVERING A STRATEGIC APPROACH FOR IDENTIFYING WATER-DEPENDENT ECOSYSTEMS AT RISK

Water-dependent ecosystems (WDE) may be defined as those parts of the environment, the species composition and natural ecosystem processes, which are determined by the permanent or temporary presence of flowing or standing water, above or below ground. WDEs as defined by this report, including mapped wetlands, watercourses (rivers and streams), springs, waterholes and karst features known to intersect the groundwater table.

Increasing recognition of the need to ensure the requirements of water-dependent ecosystems are met and provided for in water allocation planning has been articulated within the National Water Initiative Intergovernmental Agreement. Explicitly, states are required to secure ecological outcomes for water systems, identify surface and groundwater ecosystems of high conservation value and manage these systems to protect and enhance those values (Inter-Governmental Agreement on a National Water Initiative, Clause 25x). A National Atlas of Groundwater-Dependent Ecosystems (GDE's) is currently being scoped on behalf of the National Water Commission (SKM 2010a) for the purpose of better managing environmental water resources across Australia. Protection and management of water-dependent ecosystems are often hindered by lack of information on their significance, environmental water requirements and location.

The Department for Water (DFW), as the lead agency for managing South Australia's water resources, has the responsibility for ensuring water is managed sustainably in South Australia, to support our health, our economy and the environment. In order for DFW to advise on the quantity, quality, use and availability of water resources, it is critical to identify current and potential sources of risks to environmental water requirements. Specifically, strategic objectives for the DFW are to ensure water-dependent ecosystems (WDEs) are protected and can adapt to climate change and that environmental water is transparently evaluated and accounted for. Additionally, a goal of the South Australian Natural Resources Management Plan (2006) is to ensure planning policy addresses the importance and value of WDEs, particularly watercourses, floodplains and wetlands and prevents development that would impact upon ecosystem function or habitat value.

Within South Australia significant demand on both surface water and groundwater resources resulted in significant impact on the ecological function of WDEs. Extraction and interception of surface water and groundwater resources for human use changes the equilibrium between rainfall, recharge, discharge, vegetation and other physical parameters, potentially resulting in ecological degradation of WDEs. Additionally water resources are threatened by deterioration in water quality due to diffuse and point-source pollutants (e.g. nutrients, pesticides and salinity), which subsequently flow into these dependent ecosystems.

Effective strategies to manage risks to dependent ecosystems from deteriorating groundwater and surface water quantity and quality must be based on solid scientific information. Currently, there is limited and varied information across South Australia which identifies water-dependent ecosystems and where and how ecosystems depend upon ground or surface water and how or whether this supply is at risk. However, progress has been made in South Australia towards developing spatial risk assessment tools for assessing the potential impacts of development and water affecting activities on WDEs at a regional scale, known as the Water-dependent ecosystem Risk Assessment Tool (Water-RAT) and is currently available for the Mount Lofty Ranges (Scholz 2007) and the South East (Harding in press). In order to extend the Water-RAT framework to other regions of South Australia, key spatial datasets are required.

Groundwater and surface water interactions in wetlands are highly dynamic, are both temporally and spatially complex and often extend beyond the surface water boundaries of a wetland. The maintenance of wetland ecological function and character largely depends on water regime and water quality. Arid/semi-arid environments exist throughout much of South Australia, where average annual rainfall is seasonal, highly variable and significantly less than evaporation. Groundwater discharge can be a major component of the water budget in these environments. It can also be a significant source of salt and hence a major driver of wetland ecology (McEwen et al. 2008).

Given the importance of groundwater discharge to maintaining ecological function, it is essential in managing WDEs to recognise relative dependencies on surface water and groundwater inflows.

The overall objective of this report was to detail a process for a preliminary Statewide GIS-based assessment of water-dependent ecosystems, including a preliminary assessment of the likelihood of groundwater dependency and identification and assessment of the level of groundwater extraction, to assess the potential risk to the sustainability of water-dependent ecosystems. This process included an analysis of data limitations, scale dependencies and knowledge gaps relating to this information.

1.2. PRELIMINARY ASSESSMENT OF RISK TO WATER-DEPENDENT ECOSYSTEMS IN SOUTH AUSTRALIA FROM GROUNDWATER EXTRACTION

1.2.1. AIM AND OBJECTIVES

In order to achieve the objectives of as stated above in 1.1 the following steps were taken:

- Compile and review existing datasets and spatial information identifying water-dependent ecosystems and groundwater extraction across the State.
- Develop a preliminary risk assessment methodology that can be applied with use of existing data.
- Develop a classification of all spatially identified water-dependent ecosystems in terms of likelihood of groundwater water dependency, using current existing datasets.
- A preliminarily assessment of potential high risk areas for groundwater resource development to water-dependent ecosystems in South Australia was undertaken.
- Recommendations were provided based on the scoping of existing information and the preliminary risk assessment on priorities for refining future assessment of risks to WDEs

1.2.2. LIMITATIONS

The preliminary risk assessment was completed with use of easily obtainable existing spatial and non-spatial datasets, with methodology development, review and analysis of data limited to a four month period (March–June 2010). The preliminary analysis recognised that the cumulative impacts of the development of surface water and groundwater resources on WDEs needs to be assessed. However, given the short timeframe for carrying out the preliminary analysis, assessing groundwater resources and their dependent ecosystems were prioritised, with surface water impacts a focus of future assessments. The preliminary assessment does not include an assessment of risks from other threatening processes to WDEs, such as water quality, land use change, climate change and variability and other processes such as exotic species invasion. The preliminary outputs of this report have been used in the DFW project: Impact of climate change on water resources (Wood & Green 2011).

The review and analysis, aims to use the most accurate data source for each region, with use of National 1:250 000 scale data where no other data were able to be located. The outputs consist of derived data. No new data were produced for this report.

Water-dependent ecosystems, as defined by this report, included mapped wetlands, watercourses (rivers and streams), springs, waterholes and karst features known to intersect the groundwater table. Terrestrial vegetation, estuarine (where not mapped as wetlands) and subsurface ecosystems were not included. No groundtruthing of resulting derived data was undertaken.

2. METHODS

A number of recent studies (Krause et al. 2007; Brown et al. 2007; Howard & Merrifield 2010) have developed methodologies for assessing landscape scale risk to water-dependent ecosystems with use of limited existing data and specifically overcoming data shortfalls to provide useful outputs from which decisions on sustainable use of water resources can begin to be made. These recent studies demonstrated the use of GIS and derived indicators of groundwater dependency, ecological type, threats, likelihood of impact (or vulnerability) and consequence (ecological value) have been used to assess the likelihood of impacts from human activities on groundwater-dependent ecosystems.

In South Australia, Scholz (2007) and Harding (2009) developed a GIS spatial risk assessment tool (WaterRAT) which was applied to the relatively data rich areas of the Southern Mount Lofty Ranges and South East of South Australia. A simplified risk assessment methodology was developed to create some of the key spatial datasets required for the Water-RAT at a statewide scale.

More recently DFW has developed a Risk Management Framework for Water Planning and Management which aims to provide a consistent approach to risk assessment in the area of water planning and management. The assessments and outputs detailed in this report contribute to appropriate assessment of risks to natural resources which include water-dependent ecosystems. Water allocation plans are progressively adopting a risk-based approach and guidelines have been developed to support this.

2.1. A RISK ASSSESSMENT PROCESS

The risk assessment process (Fig. 1) was based on the concept that potential risk to the ecological functioning of a WDE is the result of sources of risk influencing one or more processes that control the dynamics, function and ecological characteristics of a WDE. The vulnerability of a WDE is characterised by its sensitivity to change as a result of alteration to WDE processes or drivers. In this context the risk assessment therefore relies on the identification of WDEs, degree of ground water dependence and the intensity of ground water extraction. It is acknowledged that other sources of risk are also important to WDEs but given the time available this was the scope of the current assessment.

The analysis focussed on assessing groundwater quantity, or discharge. Changes in groundwater discharge as a result of watertable lowering influences the water regime, frequency duration, water quality, water chemistry and timing of inundation and subsequently causes detrimental impacts to the ecological functioning of WDE systems.

In order to preliminarily assess WDEs at risk from groundwater resource development, a four step risk assessment process (Fig. 1) was applied:

> Step 1 –The State was divided into regional analysis units, based on similarities in aquifer characteristics, groundwater processes and relative homogeneity of hydrogeological, ecological and climatic conditions.
>
> Step 2 – Existing spatial and non-spatial data were collated, reviewed and processed to identify and display locations and characteristics of WDE assets and sources of risk to WDE processes posed by water resource development within each analysis.
>
> Step 3 – The vulnerability of WDE assets to changes in processes caused by groundwater resource development was assessed by determining the likelihood of groundwater dependency of each mapped WDE asset.

Step 4 – The spatial coincidence of WDE assets assessed as being likely to be vulnerable to changes in groundwater (GDEs) and the level of groundwater resource extraction was examined to produce a map of WDEs potentially at risk. The combination of these two factors was used to assess the preliminary level of risk associated with different GDE areas.

Confidence levels for each output were generated to reflect the spatial coverage and accuracy of the original data inputs. Priorities for refining the assessment in the future were made based on the outputs of the examination of potential risk. Detailed methods and resulting outputs for each step are described below.

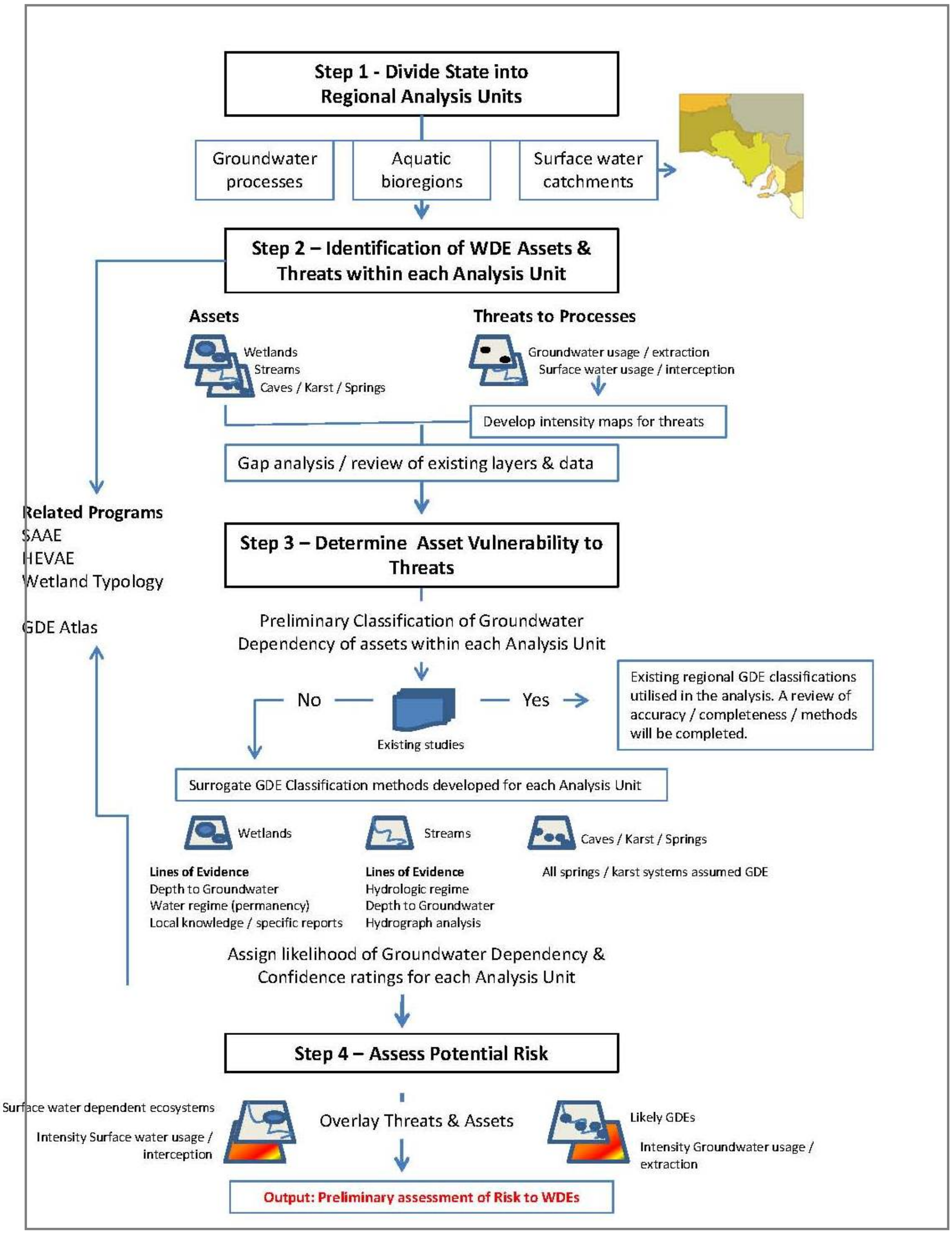
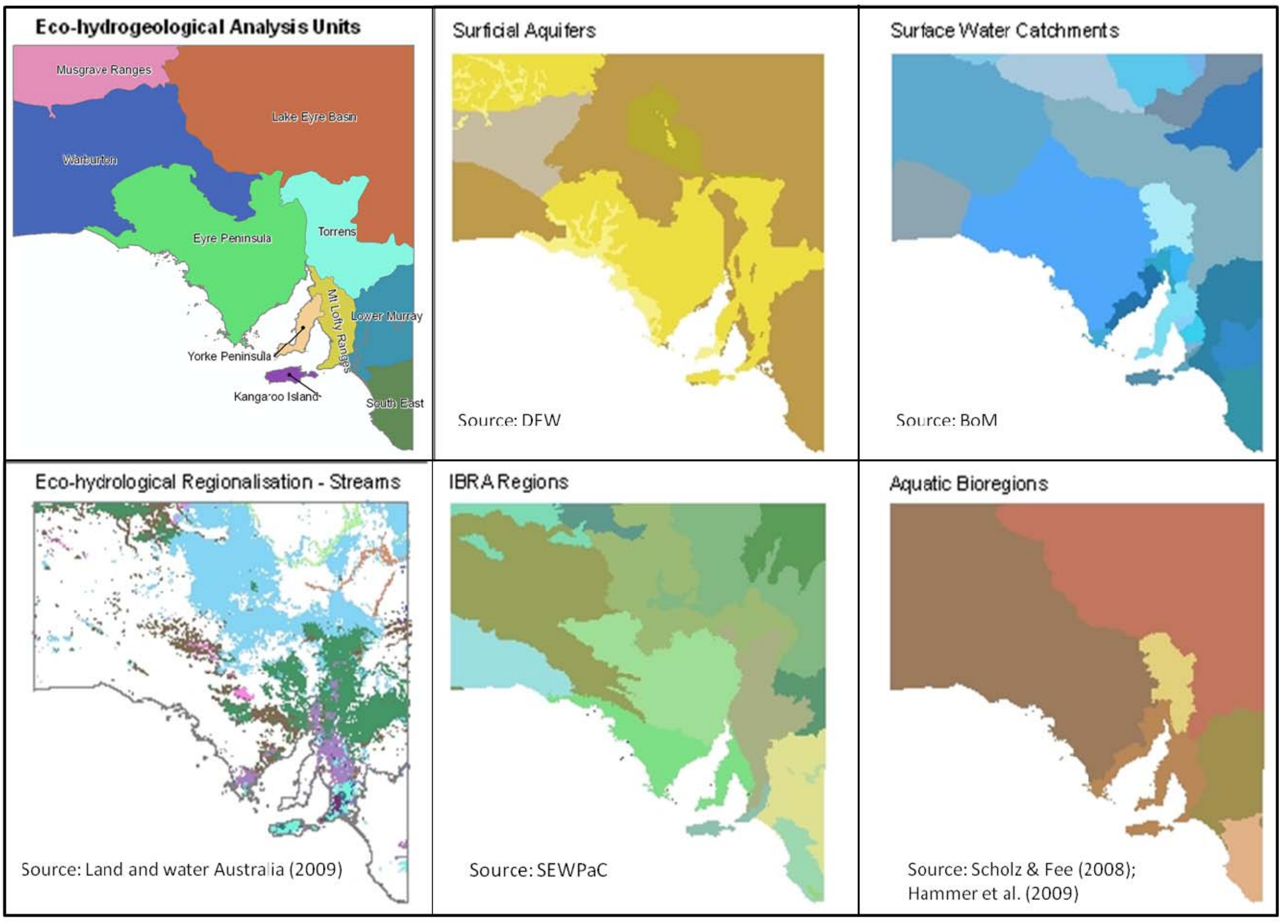


Figure 1. Process for risk assessment of water-dependent ecosystems

2.2. STEP 1 – DEFINING REGIONAL ECO-HYDROGEOLOGICAL ANALYSIS UNITS

In order to facilitate management and interpretation of data and information, the State was divided into regional analysis units. Ten eco-hydrogeological analysis units were defined, based on similarities in aquifer characteristics (sedimentary or fractured rock), groundwater processes and relative homogeneity of hydrogeological, ecological and climatic conditions (Fig. 2). The analysis units also form the basis for reporting on priorities and knowledge gaps across the State.

The analysis units were derived from existing statewide datasets, including aquifer, water catchment, IBRA and aquatic bioregion layers (based on Scholz & Fee 2008; Hammer et al. 2009) and National eco-hydrological regionalisation of Australia (Land & Water Australia 2009). The aquatic hydrological regionalisation (Land & Water Australia 2009) subdivided Australia into river catchments that have distinctive landscapes and ecological characteristics. Whilst the concept of the regional eco-hydrogeological analysis units for this report are similar, the final analysis units are a coarse simplification to aid in data processing time, with an emphasis on groundwater and aquifer properties.



Eco-hydrogeological Analysis Units

Surficial Aquifers

Source: DFW

Surface Water Catchments

Source: BoM

Eco-hydrological Regionalisation - Streams

Source: Land and water Australia (2009)

IBRA Regions

Source: SEWPaC

Aquatic Bioregions

Source: Scholz & Fee (2008); Hammer et al. (2009)

Figure 2. Eco-hydrogeological Analysis Units – derived from existing biophysical and environmental regionalisations

2.3. STEP 2 – IDENTIFICATION OF WATER-DEPENDENT ECOSYSTEMS AND POTENTIAL SOURCES OF RISK

2.3.1. WATER-DEPENDENT ECOSYSTEMS

Existing spatial layers identifying the extents of wetlands, streams, rivers and spring, cave or karst systems were collated into a spatial geodatabase. Figure 3 illustrates the distribution of spatial data for water-dependent ecosystems in South Australia. Appendix 1 lists the data sources compiled.

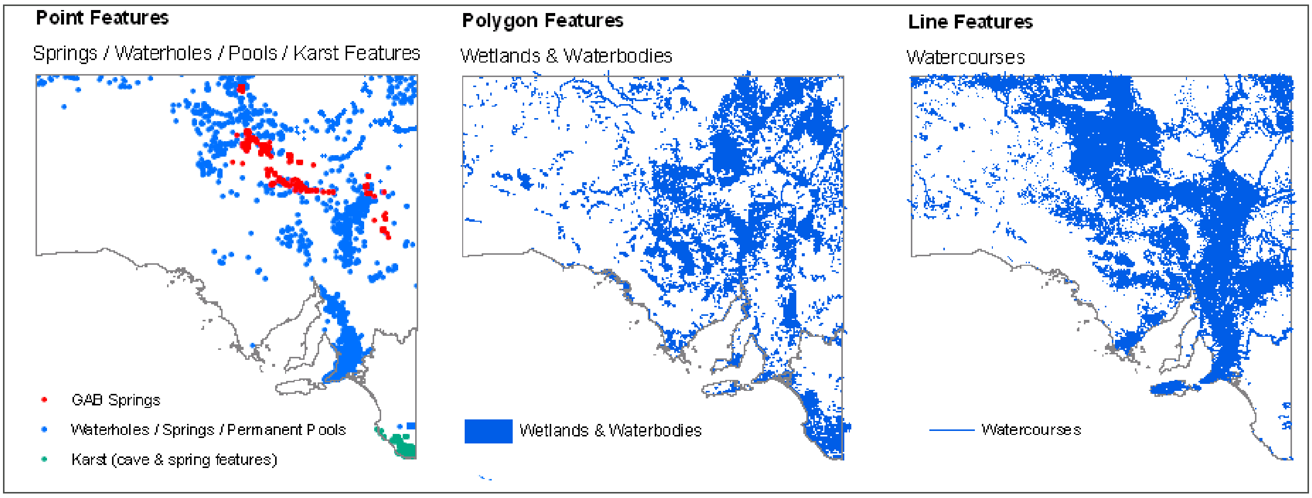


Figure 3. **Water-dependent ecosystems spatial data existing for South Australia**

2.3.1.1. Wetland Mapping – Polygon Features

The statewide wetlands mapping for South Australia was developed as an integration of all previous wetlands and waterbodies mapping efforts (DENR 2010). The layer contains polygons mapped at varying scales and accuracies and resulting from several different methods. An agreed definition and method of delineating wetland features has not been approached (Jones & Miles 2009) and floodplain extents are generally not well defined. Errors of omission and commission were assessed as part of the Hydrological Geofabric Audit (DEH 2009), indicating that errors of omission were significant, particularly in 1:250 000 scale wetland mapping.

Each wetland polygon has a unique wetland number (AUSWETNR) and minimum dataset attribution. For the purposes of the risk assessment, polygons identified as man-made dams (Feature Code 4182) and features outside of South Australia were removed. The resulting layer included a total of 60 712 individual polygons, covering an area of approximately 66 661 square kilometres. Average wetland polygon size is 109 hectares, with a median of 2.9 hectares.

2.3.1.2. Watercourse Mapping – Line Features

Watercourse line features were sourced from National 1:250 000 scale and State 1:50 000 scale data available for the southern agricultural districts. Errors, omission and commission were assessed as part of the Hydrological Geofabric Audit (DEH 2009), indicating that errors of omission were significant.

Permanent waterholes in the Lake Eyre Basin (Cooper Creek and Georgina Diamantina Catchment) were mapped by Silcock (2009).

2.3.1.3. Karst and GAB and Fractured Rock Spring Features – Point Features

Spring features in the Great Artesian Basin (GAB) are currently mapped through a National Water Initiative program, Allocating Water and Maintaining Springs in the Great Artesian Basin, being delivered by the SAAL NRM Board (2008–12). Spatial data including the location, elevation and flow patterns of springs are also being assessed (Gotsch, T. pers comm.). The most current point feature GAB spring data were sourced through South Australia's drillhole database.

Additional spring and waterhole features are identified in the South Australian Gazetteer and National 1:250 000 scale waterhole mapping and were filtered to create a spring and waterhole feature layer for the State. Permanent pools have been mapped within stream features within the Broughton, Light, Wakefield (Favier et al. 2004) Mosquito Creek (Sheldon 2007) and Mambray Coast (Deane et al. 2005) Catchments and for the Mount Lofty Ranges and Fleurieu Peninsula (Vanlaarhoven 2006a). Identification of sources of risk to water-dependent ecosystems

2.3.2. IDENTIFICATION OF SOURCES OF RISK TO WATER-DEPENDENT ECOSYSTEMS

The preliminary assessment of risk to water-dependent ecosystems was limited to an assessment of the effect of existing groundwater affecting activities (including plantation forestry and mining) on groundwater quantity. Groundwater delivery to WDEs can be altered by either groundwater extraction or reduction in groundwater recharge. To determine existing levels of groundwater extraction, land-parcel based water allocation licences were converted to point features and modelled to create continuous spatial coverages for prescribed water resources. These include irrigation and industrial water allocations. Unlicensed groundwater extraction, including stock, domestic and town water supply, was assessed using the Drillhole Enquiry System (DES). Where data were available, direct groundwater extraction by plantation forestry and mining was also assessed. Figure 4 presents the outputs of the analysis of prescribed and non-prescribed groundwater resources, including best available data sourced from DFW and PIRSA on forestry and mining groundwater usage, as described below.

The resulting groundwater extraction maps are relative and do not include any assessment of the capacity of the resource. The maps produced therefore do not necessarily indicate areas of potential aquifer stress due to groundwater resource development or aquifer sensitivity to use.

2.3.2.1. Prescribed Groundwater Resources

Groundwater extraction intensity within prescribed wells areas was generated from total licensed annual taking allocation data per land parcel as of June 2009, with the exception of the Far North PWA which was assessed as of June 2010. The data were sourced through the Resource Allocation Division of the DFW. All licensed allocations were converted to megalitres (ML), where necessary, using Hectare Irrigation Equivalents (HaIE) conversion values identified in respective water allocation plan for each PWA. Where an allocation was attributed to more than one parcel, the allocation was divided between the parcels. The point of extraction, unless otherwise documented, was assumed to be the centroid of the parcel. Interpolation of the data was completed for each PWA using Geostatistical Analyst (ordinary kriging) within ESRI ArcMap®.

2.3.2.2. Non-prescribed Groundwater Resources

Groundwater extraction intensity in the unprescribed remainder of the State was estimated with use of the DES. Drillholes were first filtered to exclude:

drillholes where no water was found

- drillholes prior to 1970
- drillholes no longer in use (including those identified as abandoned, backfilled, blocked, collapsed, dry, not located, plugged or suspended)
- drillholes where the purpose description is not extraction (including those identified as combinations of exploration, observation, investigation, no data, drainage, monitoring, scientific and spring)
- drillholes where salinity exceeds 15 000 EC.

An estimation of average annual extraction for the remaining purposes was made with the use of average values for irrigation, stock and domestic use (Lawson & Stadter 2004). Interpolation of the data was completed for each PWA using Geostatistical Analyst (ordinary kriging) within ESRI ArcMap®. The resulting layer generally correlates with that produced by Mangelsdorf and Kawalec (2008) which used drillhole density, yield and salinity to determine relative groundwater development in southern unprescribed-regions of South Australia. Estimating water usage outside of the prescribed water resource areas was limited and should be considered a qualitative estimate. Obtaining water usage data for mining industry, including source of the water (deep or shallow aquifer) was also limited.

2.3.2.3. Plantation Forestry

Plantation forests in the Lower South East of South Australia have been shown to extract groundwater where the water table is shallow and there is no root impedance between the land surface and the watertable (Benyon & Doody 2004). An intensity map of groundwater extraction by plantation forestry was generated (Harding 2009) using annualised groundwater extraction estimates for forest plantation in the Lower South East based on Benyon & Doody (2004) and Latcham et al. (2007). The data produced by Harding (2009) was utilised in producing overall groundwater extraction in the South East Analysis Unit.

2.3.2.4. Mining

Aurecon Australia (2010) reports current and future water demands of major mining operations in South Australia. The figures presented in this report, including current volumes of extraction per year, were used in unprescribed regions or where volumes were not reflected in water licensing data available. Extraction values were spatially correlated to the mine site. The locations may not necessarily reflect the exact locations of the extraction well field.

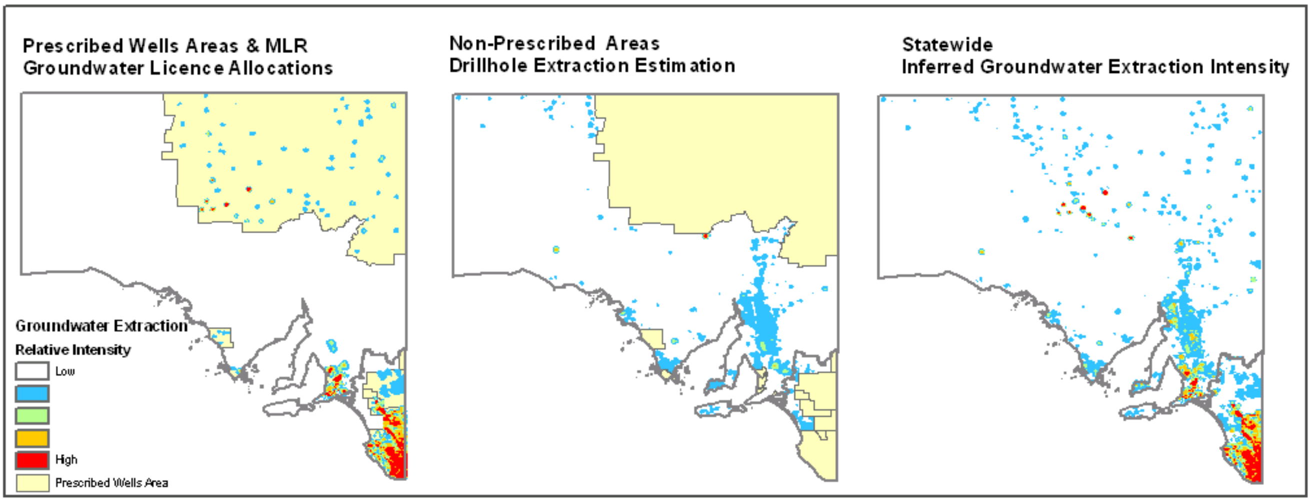


Figure 4. Relative groundwater extraction (ML/km^2) estimation for South Australia

2.4. STEP 3 – PRELIMINARY CLASSIFICATION OF GROUNDWATER DEPENDENCY

As identified in the previous section key sources of risk to water-dependent ecosystems are likely to be: groundwater extraction for the purposes of irrigation, forestry and mining. However, as these sources of risk affect predominantly groundwater, the level of risk contributed by these sources will also be dependent on the extent to which the water-dependent ecosystems are dependent on groundwater compared to surface water. In order to assess risk from water affecting activities it was essential to determine the level of groundwater extraction and the groundwater dependence of the resource.

The process for assessing likelihood of groundwater dependency at a state scale with existing data included:

- A review and collation of existing landscape scale GDE classifications and site specific information. The findings of existing studies were attributed to the specific WDE feature where possible. WDE types, which by definition are groundwater dependent, including springs, permanent waterholes in arid areas, caves and karst features that intersect the groundwater table, were automatically identified as having a high likelihood of groundwater dependence.
- Surrogate groundwater dependence indicators were developed for each Analysis Unit which included mapping of shallow groundwater and groundwater salinity, existing information on water regime (permanency) of WDEs and existing soils mapping.
- Rules were developed to assign likelihood of groundwater dependency classification and confidence in the assessment.

2.4.1. REVIEW OF EXISTING GDE STUDIES AND REGIONAL CLASSIFICATIONS IN SOUTH AUSTRALIA

Groundwater–surface water interactions in South Australia and nationally, are a relatively recent and rapidly growing field of research. Much of the existing research has occurred over the previous ten years (2000–10), with increasing investment in GDE studies between 2009–10 (Table 2). The rapidly increasing interest in identifying and understanding groundwater–surface water interactions reflects the need to take into account environmental water requirements for GDEs in Water Allocation Planning.

Projects relating specifically to the identification of GDEs in South Australia have largely focussed on the South East of the State and include assessments of groundwater dependency of wetlands and to a lesser extent, of springs and baseflow streams. This work has been extended to include measures of the degree and nature of dependence and assessments of threats and risks (Harding 2009).

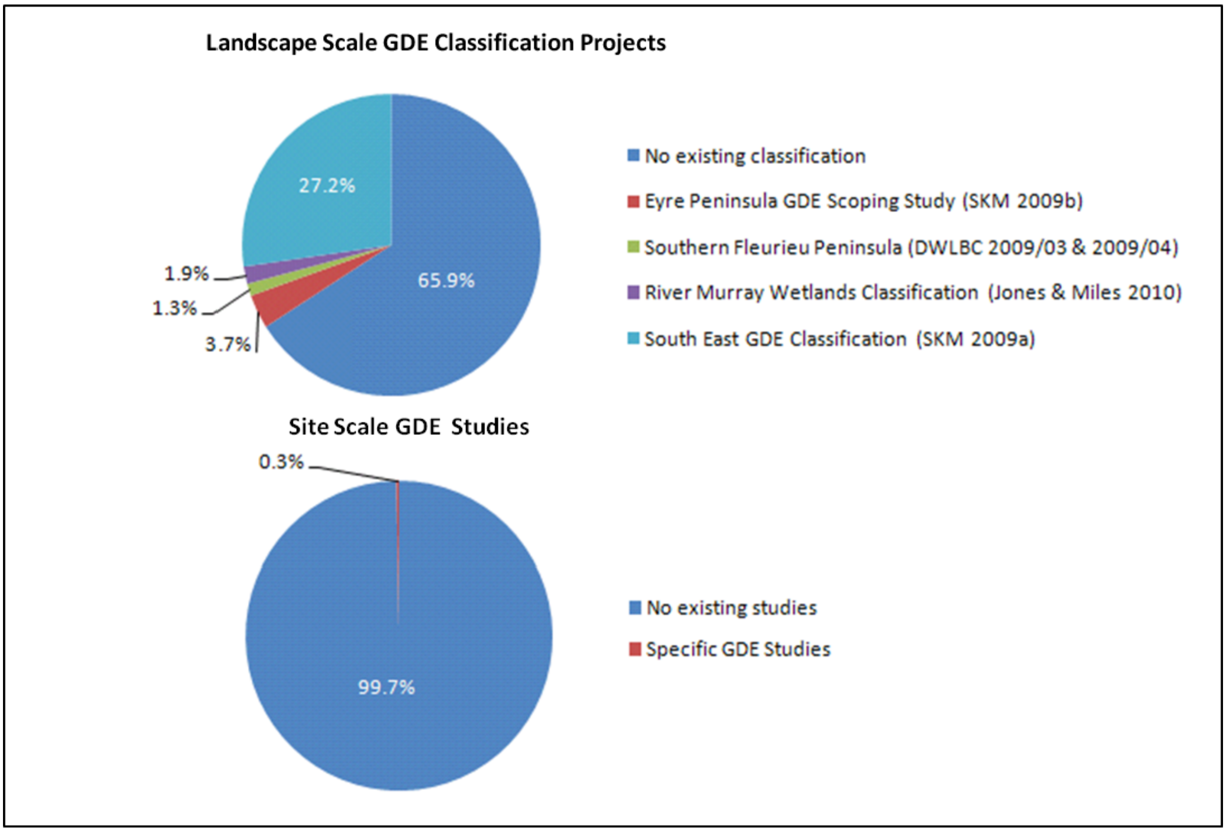


Figure 5. **Percentage of mapped wetlands in South Australia with existing information on groundwater–surface water interactions**

Landscape scale classifications of groundwater dependence have occurred in the South East (SKM 2009a), Eyre Peninsula (SKM 2009b) and Southern Fleurieu Peninsula (Vanlaarhoven 2006a & 2006b), all of which consider depth to groundwater, landscape setting, wetland type and aquifer properties. Additionally, Jones & Miles (2009) classify the potential for groundwater inputs to wetlands in the River Murray and Floodplain based on salinity as part of ecological typology classification. The existing landscape scale classifications vary in purpose, detail, accuracy and attribution and account for less than 35% of the number of all mapped wetlands in South Australia (Fig. 5).

A significant number of existing studies either directly or indirectly provide information on groundwater–surface water interaction for wetlands on a site scale, usually involving field-based data collection. Site scale GDE studies have been initiated at less than 1% of the State’s wetlands (Fig. 5) and include GDE case-study monitoring sites in the South East and specific field investigations utilising hydraulic and hydrochemistry methodologies to determine the presence of groundwater discharge (Fass & Cook 2004; Fass & Cook 2005; Wood 2006; Cook et al. 2008a; Cook et al. 2008b; Haese et al. 2008; Jolly et al. 2008; Wood 2009).

Indirectly, many studies describe the ecological values of permanent springs and waterholes, which are documented as receiving baseflow or obvious groundwater dependence (Risby et al. 2003; Sheldon 2007; Silcock 2009).

Appendix 2 chronologically lists and summarises available studies relating to the identification and classification of groundwater–surface water interactions for water-dependent ecosystems in South Australia.

2.4.1.1. Attribution of wetlands polygon layer

Studies identified and listed in Appendix 2 that specifically refer to a particular WDE or location, where possible, were attributed to individual polygon/s with a reference to the specific report (GDE_STUDY field – refer to Appendix 3). The categories of groundwater dependence arising from regional classifications were also attributed to individual polygons (GDE_CLASS) with the reference to the specific classification study (GDE_REF). Refer to Appendix 3 for metadata table of wetlands polygon fields.

The specific findings of the studies and existing regional classifications were used to inform the preliminary statewide classification of groundwater dependency as described in Section 2.4.5.

2.4.2. SHALLOW GROUNDWATER AND GROUNDWATER SALINITY MAPPING

The presence of shallow groundwater has been used as an indicator of potential groundwater–surface water interactions in aquatic ecosystems GDE classifications on a landscape scale (SKM 2006; SKM 2009a; SKM2009b). Depth to groundwater has been modelled from point data to produce a continuous spatial coverage of ground level (termed interpolated surface) for the South East, for use in classifying GDEs. A similar methodology was applied to other Analysis Units as was developed by SKM (2009a) using the DES and Landsat™ 30m DEM. The DES was used to develop a series of potentiometric surfaces for each of the Analysis Units. Drillholes were first filtered to exclude:

- drillholes with no depth to water information
- depth to water measurements taken prior to 1960
- drillholes with either no drill date or depth to groundwater measurement date
- drillholes greater than 100 m maximum depth
- drillholes completed in confined aquifers
- drillholes exhibiting artesian watertable conditions.

The filtered drillhole data were then reviewed and anomalous data removed. Figure 6 shows the location of drillholes indicating the presence of shallow groundwater after filtering.

Surfaces for depth to watertable data were created for each Analysis Unit through interpolation of the point feature class drillholes dataset. Given the distribution of the point data, the national digital elevation model (Landsat™ 30m DEM) was used to convert interpolated depth to watertable surfaces to Australian Height Datum (AHD). This process enables identification of shallow groundwater conditions in data poor areas and in relation to topography; however it resulted in low confidence of the interpolated surfaces for much of the State. More accurate digital elevation model data from Airborne Laser Survey (LiDAR) was used in the South East region where this was available.

The resulting layers were divided into depth to groundwater classes: 0–2, 2–5, 5–10 and >10 metres (Fig. 6). Given the low confidence in the majority of the mapping outputs, it was considered not appropriate to interpret the data to a finer scale.

2.4.2.1. Groundwater Salinity

In order to assess WDEs potentially at risk from further resource development, a broad assessment of groundwater quality was made. Additionally, the salinity of groundwater discharging into a WDE can be a significant determinant of the ecological character of the system.

The filtered drillhole layer used to produce the potentiometric surfaces was filtered again to exclude drillholes where no groundwater salinity information existed. An interpolated surface for groundwater salinity was then created for South Australia through interpolation of the point feature class drillholes dataset (Fig. 6).

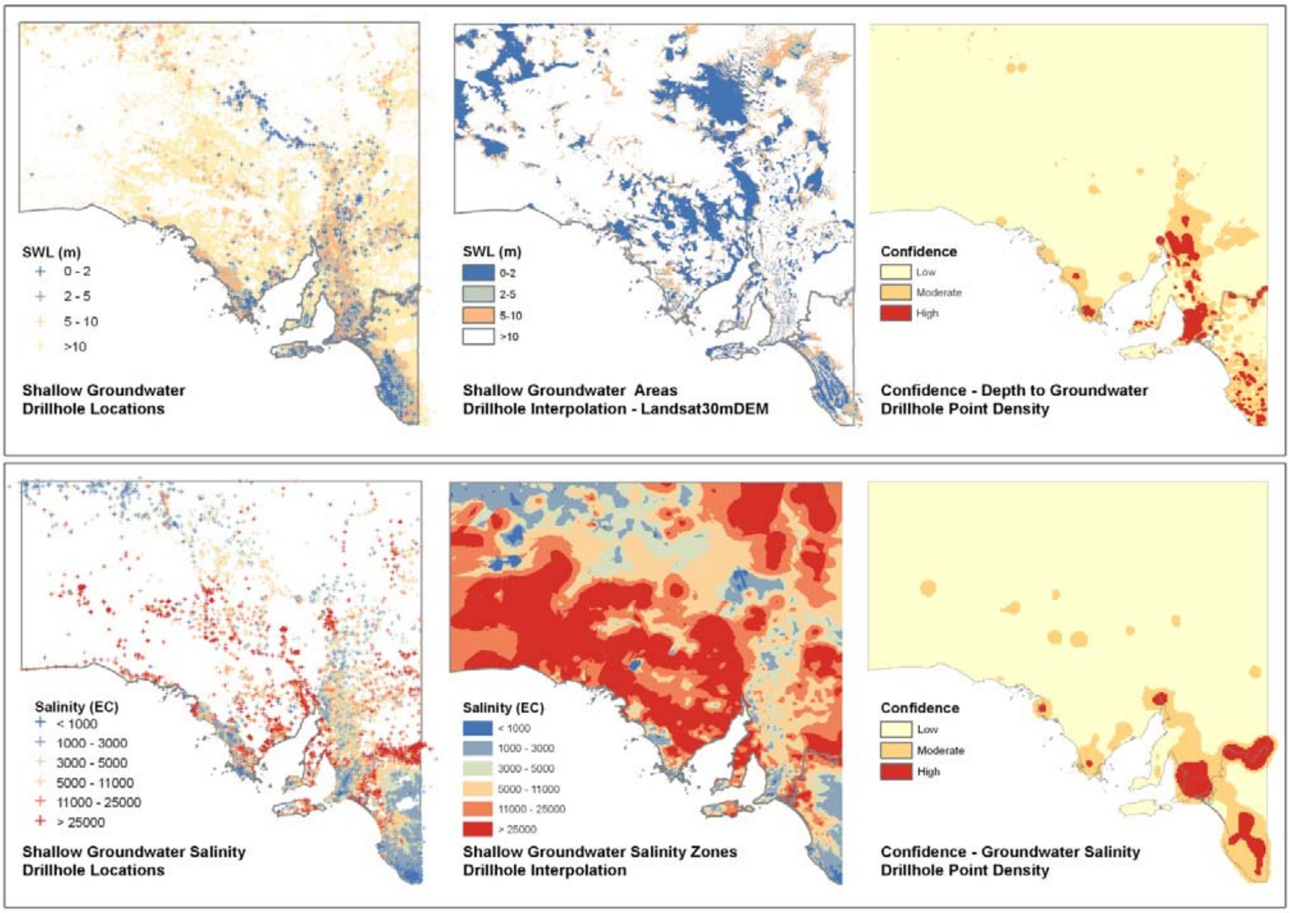


Figure 6. Shallow groundwater (<10 m) and salinity maps – South Australia

2.4.2.2. Confidence ratings – depth to groundwater and salinity

An analysis was undertaken to display the confidence level of the shallow groundwater potentiometric and salinity surface outputs using an analysis of point feature (drillhole) density of the input data.

Point feature (drillhole) density was calculated using a floating window, neighbourhood analysis technique. The technique calculates the density of drillhole sites in a neighbourhood around each grid cell. Density is defined as the number of drillhole sites per unit area.

Three ranges of confidence were defined based on the current level of drillhole data in the State (Fig. 6). The ranges were based on:

Low – less than the mean density
Moderate – greater than the mean and less than the mean plus one standard deviation (SD)
High – greater than the mean plus one SD.

2.4.2.3. Attribution of wetlands polygon layer

Fields were created in the wetlands polygon layer for Depth to Water (DTW_Zone) category, Depth to Water Confidence (DTW_Conf), Groundwater Salinity (GW_EC) and Groundwater Salinity Confidence (GW_EC_CF) (refer to Appendix 1 for metadata). Wetland polygons were attributed based on the spatial coincidence of the majority of the wetland polygon area intersecting depth to groundwater and groundwater salinity classes and confidence ranges.

2.4.3. WATER REGIME

The persistence of water within a WDE was identified as a potential indicator of the input of groundwater, where permanent waterbodies are more likely to have a groundwater component supporting the water regime during drier months. The statewide wetlands database (DENR 2010) includes Water Regime in the minimum dataset for wetland inventory and mapping. This field was attributed for the majority of wetlands mapped.

2.4.4. SOIL MAPPING

Shallow alluvial groundwater resources in the Lake Eyre Basin have been identified as having a high potential for groundwater–surface water interactions (SKM 2005). The ASRIS Land systems mapping of alluvial soils and shallow groundwater mapping were analysed with the WDE asset layer to determine where these conditions may co-exist, increasing the likelihood of potential groundwater dependency.

2.4.4.1. Attribution of wetlands polygon layer

A field was created in the wetlands polygon layer for identifying high frequency of alluvial soils from the ASRIS Land systems mapping (ASRIS_ALLUV) (refer to Appendix 1 for metadata). Wetland polygons were attributed based on the spatial coincidence of the majority of the wetland polygon area intersecting the ASRIS Land systems data where alluvial soils >50% were identified.

2.4.5. LIKELIHOOD OF GROUNDWATER DEPENDENCY CLASSIFICATION AND CONFIDENCE MATRIX

The shallow groundwater mapping (depth to watertable) was the key dataset used to determine the likelihood of groundwater–surface water interaction. Depth to watertable was the only fully attributed field available for the classification and therefore is the major determinant in assessing the likelihood of groundwater dependency.

Terrestrial and wetland GDEs in areas where watertables are shallow (<5 m) were identified as more likely to have a high degree of groundwater dependency than those where watertables are relatively deep (>10 m) (REM 2006).Therefore, it was assumed that low groundwater–surface water interaction occurs where watertables are greater than 10 m below a WDE, unless supported by other evidence.

A matrix was developed (Table 1) to classify wetlands based on both the depth to groundwater dataset and water regime (persistence). The confidence relating to the creation of the depth to groundwater layer (DTW) was applied to the confidence of the groundwater dependency likelihood classification. For example, a wetland can be classified as high potential for groundwater dependence, but with low confidence in the data used to determine that potential. This does not necessarily indicate that the WDE feature is less likely to be groundwater dependent, however further investigation may be required in order to verify or confirm groundwater dependence.

To improve this level of confidence additional lines of evidence were used from other studies (see landscape scale classifications 2.4.1) and applied to the relevant wetlands; South East (SKM 2009a), Eyre Peninsula (SKM 2009b) River Murray and Floodplain (Jones & Miles 2009) and Southern Fleurieu Peninsula (Vanlaarhoven 2006a & 2006b). The results of the initial application of the matrix were then compared to the ‘Additional Lines of Evidence’ (Table 1) and where more detailed data on specific wetlands were available, the likelihood and confidence level was adjusted accordingly. For example under the initial assessment a non-permanent wetland with 5–10 m depth to water would be classified as Low likelihood of groundwater dependence, with additional data from the ‘landscape classification projects’ confirming the same wetland as a GDE, the classification would be upgraded to High likelihood with moderate confidence.

2.4.5.1. Attribution of wetlands polygon layer

Fields were created in the wetlands polygon layer for GDE potential (GDE_POTL) and confidence of the GDE classification (GDE_CONF) and attributed as per the matrix presented in Table 1 (refer to Appendix 3 for metadata).

The matrix presented in Table 1 was then applied to update the initial determination of likelihood of groundwater dependency based on depth to watertable and persistence alone to reflect further lines of evidence. Both the GDE potential (GDE_POTL) and confidence (GDE_CONF) fields were updated to reflect this additional data.

The results of any site-specific studies were inferred to determine the level of potential groundwater dependency. These specific studies were generally considered more reliable than landscape approaches to classifying GDE likelihood and therefore both the GDE potential (GDE_POTL) and confidence (GDE_CONF) fields were updated to reflect the more accurate information.

Table 1. Groundwater Dependence Likelihood and Confidence Classification Matrix

	WATER REGIME				ADDITIONAL LINES OF EVIDENCE			
DEPTH TO GROUNDWATER (m)	**Permanent**	**Non-permanent**	**Unknown**	**Episodic**	Identified as GDE through landscape scale classification projects	Site Scale GDE Study	ASRIS Land systems frequency of alluvial soils spatial data	Springs and Karst
0–2	High likelihood DTW confidence	High likelihood DTW confidence (no higher than Moderate)	High likelihood DTW confidence (no higher than Moderate)	Moderate likelihood Low confidence	Very High likelihood High confidence	Likelihood inferred from data Confidence inferred from data	Alluvial soil ≥50% upgrades ‘Low’ to Moderate likelihood No change to confidence	Very High likelihood High confidence
2–5	High likelihood DTW confidence	Moderate likelihood DTW confidence (no higher than Moderate)	Moderate likelihood DTW confidence (no higher than Moderate)	Low likelihood Low confidence	Very High likelihood High confidence		Alluvial soil ≥50% upgrades ‘Low’ to Moderate likelihood No change to confidence	
5–10	Moderate likelihood DTW confidence	Low likelihood DTW confidence	Low likelihood DTW confidence (no higher than Moderate)	Low likelihood Low confidence	High likelihood Moderate confidence		Alluvial soil ≥50% upgrades ‘Low’ to Moderate likelihood No change to confidence	
>10	Low likelihood DTW confidence (no higher than Moderate)	Low likelihood DTW confidence	Low likelihood DTW confidence	Low likelihood DTW confidence	Moderate likelihood Low confidence		No alluvial soils No change to likelihood or confidence	

DTW – Depth to water

2.5. *STEP 4 – ASSESS POTENTIAL RISK TO WATER-DEPENDENT ECOSYSTEMS DEPENDENT ON GROUNDWATER*

2.5.1. LEVEL OF RISK POSED BY CURRENT GROUNDWATER EXTRACTION TO WATER-DEPENDENT ECOSYSTEMS

Having determined the level of reliance of WDE's on groundwater this spatial coverage was compared with sources of intensity of groundwater extraction and use (i.e. irrigation, forestry and mining). The groundwater extraction level dataset was intersected with the WDE polygons in order to assess the spatial relationship between WDE and potential sources of risk. A risk classification matrix (Table 2) was applied where WDEs (that have been assessed as having a likelihood of groundwater interaction) are identified to be at potential risk from current groundwater extraction pressures. From this analysis, priorities for more in depth analysis can be identified throughout the State.

Table 2. Classification matrix - Level of risk posed by groundwater extraction to water-dependent ecosystems (defined as the combination between the known groundwater extraction level and the likelihood of groundwater dependence)

		Groundwater Extraction Level				
		Negligible	Low	Moderate	High	Very High
Likelihood of Groundwater Dependence	Very High	Low Risk (L2)	Moderate Risk (M2)	High Risk (H3)	Very High Risk (VH2)	Very High Risk (VH1)
	High	Low Risk (L2)	Moderate Risk (M2)	High Risk (H3)	Very High Risk (VH2)	Very High Risk (VH1)
	Moderate	Low Risk (L2)	Moderate Risk (M3)	Moderate Risk (M1)	High Risk (H2)	High Risk (H1)
	Low	Low Risk (L1)	Low Risk (L1)	Low Risk (L3)	Low Risk (L3)	Low Risk (L3)

This matrix (Table 2) provides a basic high-level assessment of the level of risk potentially posed by groundwater extraction at a statewide scale. The assessment does not effectively take into account local resource sensitivity issues, where relatively low levels of groundwater extraction on sensitive aquifers may have a high impact on dependent ecosystems. A more detailed level of assessment of potential risk from local resource sensitivity was unable to be achieved within the scope and scale of the preliminary risk assessment.

2.5.2. LEVEL OF RISK POSED BY POTENTIAL GROUNDWATER RESOURCE DEVELOPMENT TO WATER-DEPENDENT ECOSYSTEMS

The preliminary identification of future groundwater resource development sources of risk for WDEs was broadly determined by applying a five kilometre buffer on WDEs likely to be groundwater dependent. A five kilometre buffer was chosen as the maximum buffer zone for environmental protection of GDEs in existing water allocation plans (SAAL NRM Board 2009; SE NRM Board 2010) and for GDE risk zones identified in the South East (Harding 2009). It should be noted that the buffer approach developed does not take into account the biological, social or ecosystem value of a WDE. Additionally, a 5 km buffer to identify potential areas of development risk may not be an adequate method to apply in fractured rock or artesian aquifers.

As groundwater resource development is generally reliant on suitable groundwater quality and yield, those areas with salinities less than 15 000 EC, identified as the upper level for stock water supply (PIRSA 2000), were identified as being more likely to be at risk.

2.5.2.1. Attribution of wetlands polygon layer for classifying risk from groundwater extraction

A field was created in the wetlands polygon layer for classifying risk from groundwater extraction (RISK_GW) and attributed as per the matrix presented in Table 2. Refer to Appendix 3 for metadata.

2.5.3. PRIORITISATION PROCESS TO DETERMINE AREAS OF HIGHEST RISK

A high-level risk-based prioritisation was conducted, intended to enable the identification of key priority areas to assist in focussing efforts more detailed and robust the risk assessments in the future. The prioritisation was based on ranking scores assigned to three components that were determined to indicate high risk to GDEs and inadequacies in currently available data:

potential risk from current levels of groundwater development
potential risk from future groundwater resource development
confidence in GDE classification.

2.5.3.1. Prioritisation scoring system

Potential risk from current levels of groundwater development: Potential levels of risk posed by current groundwater resource development were made for all WDEs (refer to Section 2.51). Scores were applied to each level of risk from zero to three. Scores of 1, 2 and 3 represent Moderate, High and Very High risk respectively. A score of zero was applied to Low risk assets.

Potential risk from future groundwater resource development: Potential for future groundwater resources development was considered highest where groundwater resources existed of suitable quality (salinity) for the majority of extractive purposes (industry, public water supply, irrigation, stock and domestic WDEs), (refer to Section 2.4.2 and 2.5.2). Suitable quantity (yield) for extractive purposes was not assessed for this report. Scores were applied for determined salinity ranges of one to four:

<25 000 EC (score of 1: suitable for industrial use only)
11–25 000 (score of 2: industry use, upper salinity for stock)
3–11 000 EC (score of 3: industry use, stock and domestic, upper salinity for some irrigation)
>3 000 EC (score of 4: industry use, stock and domestic, irrigation, public water supply).

Confidence in GDE classification: The technical confidence in the classification of potential for groundwater dependence was determined using methods described in Section 2.4.5. Scores were applied to each level of confidence from zero to three. Scores of 0, 1, 2 and 3 represent Very High, High, Moderate and Low confidence respectively.

The scores for each component were summed to produce a relative priority score for the purposes of highlighting potential areas of risk with poor data coverage.

3. PRELIMINARY RISK ASSESSMENT RESULTS AND DISCUSSION

3.1. CLASSIFICATION OF GROUNDWATER-DEPENDENT WETLANDS

Results from the assessment of groundwater dependence shows that 13% of the total wetland area in South Australia occurs over watertables greater than 10 metres, with 65% of the area occurring over watertables less than 2 metres, suggesting a generally high dependence of wetlands on groundwater resources across the State and therefore at risk from groundwater extraction.

Wetlands assessed to have a high to very high likelihood of groundwater dependence were shown to occur widely across South Australia and particularly within three major spatial groupings:

South East – coastal lakes and swamps
Fleurieu Peninsula – swamps and watercourses
Lake Eyre Basin – GAB springs.

Higher levels of likelihood of groundwater dependence were identified in these regions due to the existence of supporting evidence from studies of groundwater dependence.

Major inland saline lakes, e.g. Lake Eyre, Lake Torrens and Lake Gairdner have been identified as sites of saline groundwater discharge. Discharge of groundwater at major salt lakes is indicated by the build-up of salt crust on the surfaces or in subsurface brines (Waterhouse et al. 2000). Groundwater, although potentially contributing only a small volume of the overall water budget for these large episodic systems, may however be a major driver of the ecological character of the sites.

Of the 60 782 wetlands classified for South Australia, 64% were regarded as having a potential for groundwater dependency (14% very high, 36.6% high and 13.4% moderate likelihood). This equates to 70.2% of the total area of current wetland extent and those currently mapped in the State. The classification is however of low confidence for 48.2% of the total number of wetlands classified and 57.2% of the total area. Additionally, confidence in the accuracy and completeness of wetland mapping is poor throughout much of the State. Due to the preliminary high level assessment process performed, it is likely that many GDEs may not have been correctly classified as a result of insufficient data.

The preliminary classification of likelihood of groundwater dependence for wetlands is summarised in Figure 7 and presented in Figure 10 (MAP A). The risk zones produced (Fig. 7 Map D), should be regarded as an indication of potential risk zones, requiring further refinement of the risk assessment methods.

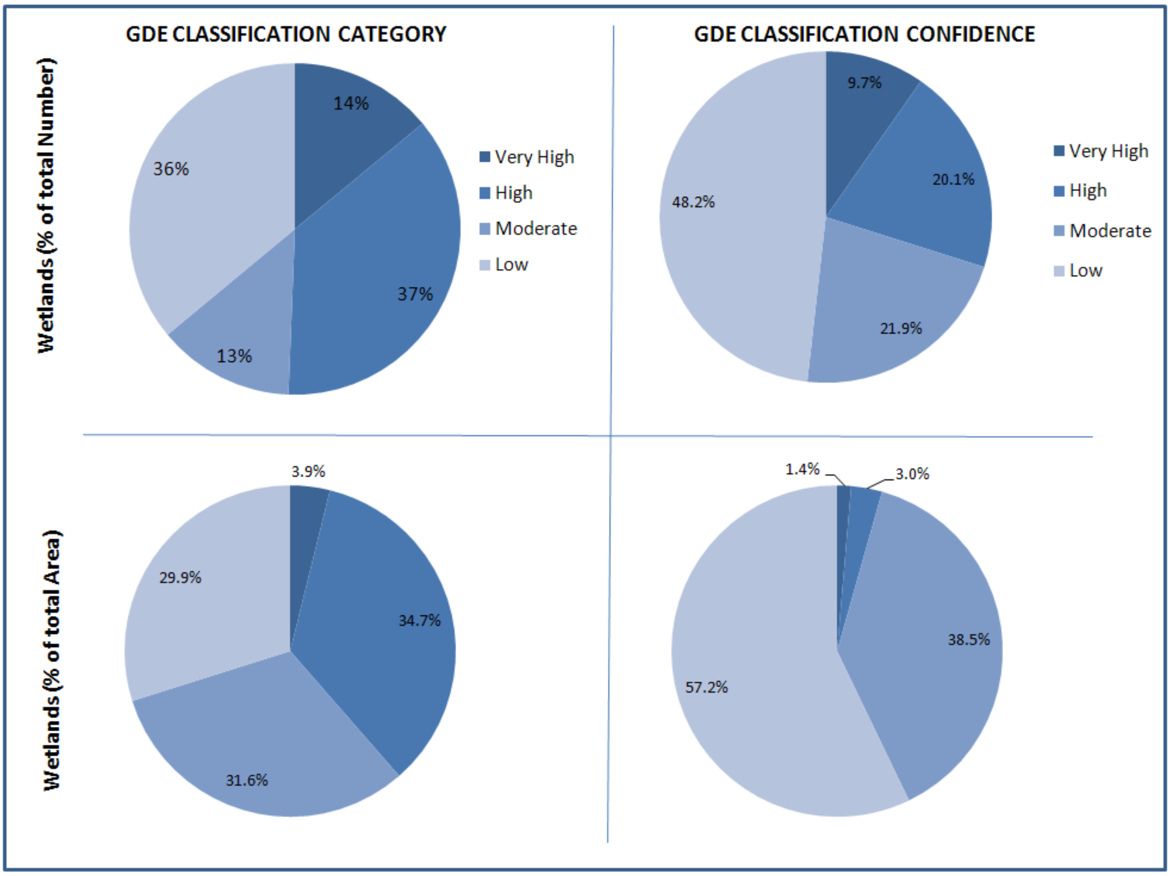


Figure 7. **Wetland Groundwater-dependent Ecosystems Classification – Summary statistics**

WETLAND WDE CLASSIFICATION

SUMMARY STATISTICS FOR SOUTH AUSTRALIA

- 64% of the number of all mapped wetlands are moderately to highly likely to be groundwater dependent
- Wetlands likely to be groundwater dependent equate to 70.2% of the total area of mapped current wetland extent
- 86% of the total mapped wetland area occurs over watertables less than 10 metres deep and 65% occurs over watertables less than 2 metres deep
- The majority of wetland WDEs occur in the South East, Lake Eyre Basin and Eyre Peninsula regions.

The majority of the total number of South Australia's wetlands dependent upon groundwater were identified in the South East (31.13%), Lake Eyre Basin (22.35%) and Eyre Peninsula (17.8%) Eco-hydrological Analysis Units. With the majority of these wetlands by area occurring in the Lake Eyre Basin, Eyre Peninsula and Torrens Analysis Units where large inland saline lakes occur (Table 3). This is supported by existing studies in which a high level of groundwater dependency of wetlands has been documented for the South East (SKM 2009a), the southern Eyre Peninsula (SKM 2009b) and southern Fleurieu Peninsula (Mount Lofty Ranges) (Vanlaarhoven 2006a & 2006b).

Table 3. Groundwater–dependence Classification – summary statistics for Analysis Units

ANALYSIS UNIT	Analysis Unit		Statewide		Confidence
	% of total wetland number	% of total wetland area	% of total wetland number	% of total wetland area	% Low Confidence
Eyre Peninsula	68.8%	93.44%	17.8%	24.92%	74.55%
Kangaroo Island	82.44%	92.46%	1.19%	0.26%	62.54%
Lake Eyre Basin	55.6%	60.23%	22.35%	48.03%	60.37%
Lower Murray	73.1%	53.7%	10.41%	3.11%	38.39%
Mt Lofty Ranges	66.0%	94.2%	4.38%	2.94%	22.21%
Musgrave Ranges	43.05%	37.11%	0.81%	0.12%	99.04%
South East	76.7%	95.62%	31.13%	4.48%	0.49%
Torrens	42.05%	80.91%	5.07%	13.18%	95.40%
Warburton	46.59%	47.84%	3.72%	2.38%	96.28%
Yorke Peninsula	84.6%	93.57%	3.14%	0.58%	47.60%

Analysis Units with high proportions (>70%) of wetlands that are likely to be groundwater dependent include Kangaroo Island, Lower Murray, South East and Yorke Peninsula. Significantly, the likelihood of groundwater dependency classification is of low confidence for majority of wetlands in the Eyre Peninsula (74.4%), Kangaroo Island (62.54%), Lake Eyre Basin (60.37%), Musgrave Ranges (99.04%), Torrens (95.4%) and Warburton (96.28%) Analysis Units (Table 3). Low confidence is attributed to lack of existing data and poor spatial accuracy of contributing data sources throughout much of the State. Appendix 4 provides an analysis of this data based on State NRM region boundaries.

Report cards, providing maps and summarising the preliminary GDE classification and confidence in outputs for each Analysis Unit are provided as Appendix 5.

Salinity is a major driver of the ecology of an aquatic ecosystem and can drive changes in the physical environment that affect ecosystem processes (Nielsen et al. 2003; McEvoy & Goonan 2003). Generally aquatic species diversity decreases as salinity increases, however there is a suite of saline tolerant species that are dependent on saline environments (McEvoy & Goonan 2003), which at times can be highly productive (i.e. brine shrimp). Groundwater discharge is often a major driver of surface water and soil salinity. Significantly, in South Australia, WDEs likely to be groundwater dependent, occurring over relatively fresh groundwater resources (< 3000 EC), account for only 2.2% of the States wetlands. The majority of the States GDEs are likely to be brackish to saline as a result of groundwater discharge as displayed in Figure 8.

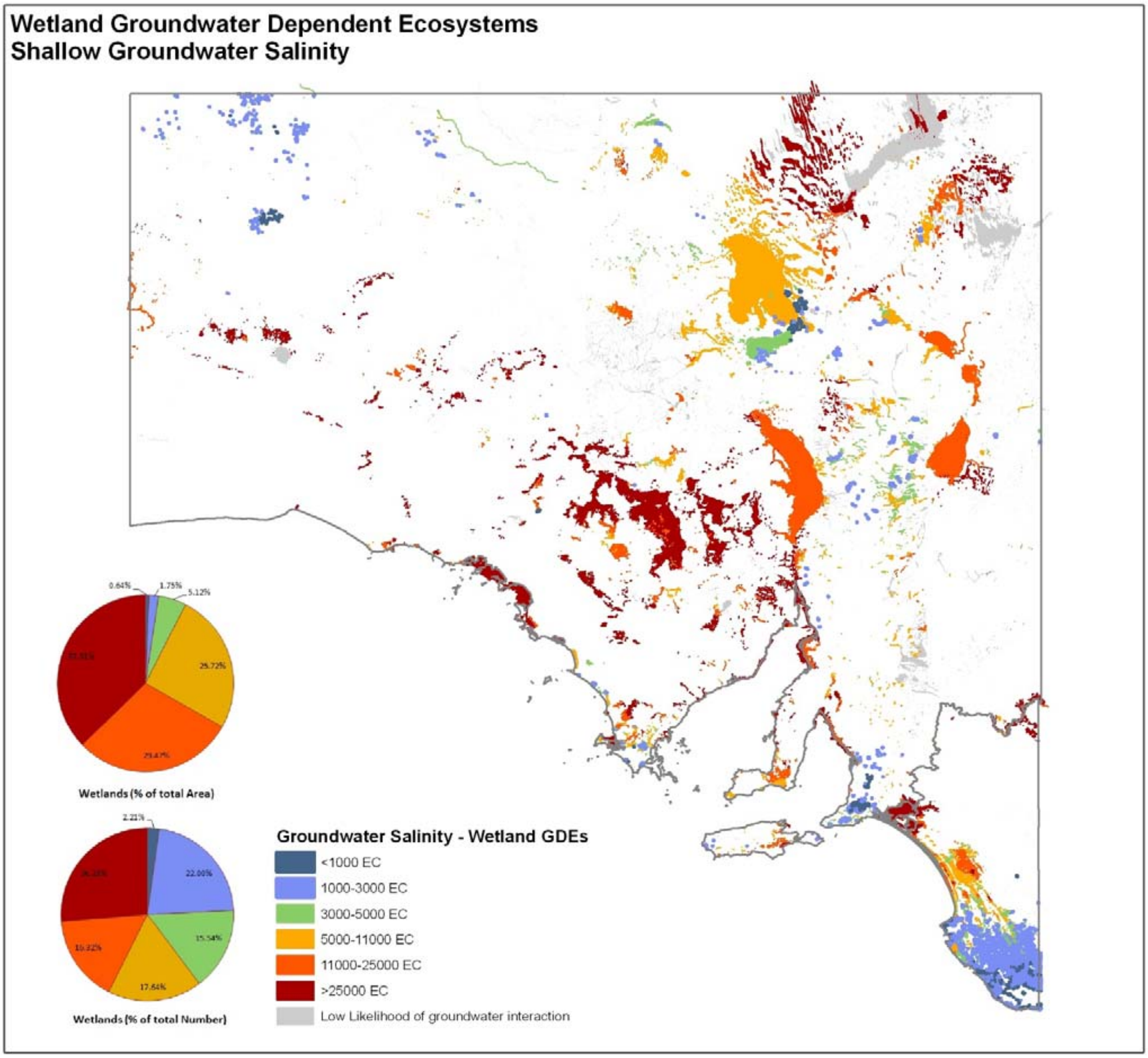


Figure 8. **Wetland GDEs located within groundwater salinity zones**

3.1.1. IDENTIFICATION OF WDES AT RISK FROM GROUNDWATER EXTRACTION

Existing high intensity groundwater extraction coinciding with the presence of identified GDEs indicates that 32.4% of the number of all mapped wetlands (WDEs) are potentially at risk from reduced groundwater quantity (discharge) due to levels of current groundwater extraction. This equates to 25.7% of total wetland area (WDEs) (Fig. 7 Map C, Fig. 9,), or 50.5% of those identified as likely to be groundwater dependent.

Table 4. **Risks to Wetland WDEs from Groundwater Extraction – summary statistics for individual Analysis Units**

ANALYSIS UNIT	WDEs at Risk from Groundwater Extraction % of total wetland number	 % of total wetland area
Eyre Peninsula	8.39%	15.47%
Kangaroo Island	16.49%	31.41%
Lake Eyre Basin	39.96%	30.60%
Lower Murray	8.24%	37.59%
Mt Lofty Ranges	45.99%	52.38%
Musgrave Ranges	0.41%	0.27%
South East	66.96%	82.21%
Torrens	5.98%	1.19%
Warburton	0.58%	0.46%
Yorke Peninsula	19.58%	24.63%

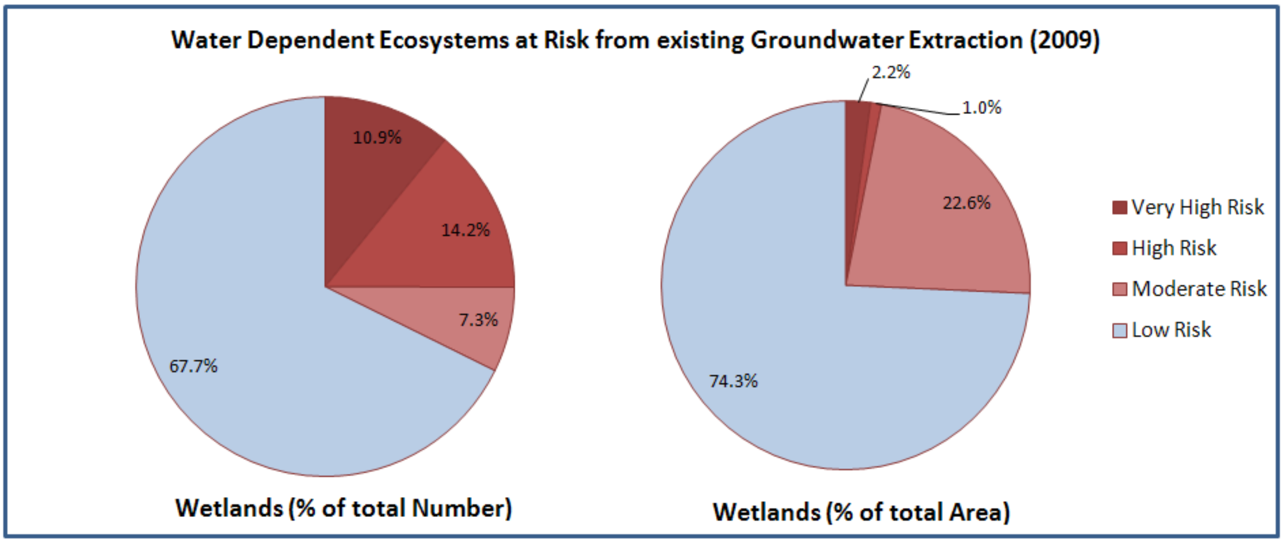


Figure 9. **Percentage of wetland WDEs at potential risk from high levels of groundwater extraction**

The majority of the number of WDEs identified as potentially at risk from existing groundwater extraction occur within the South East (66.69%), Mount Lofty Ranges (45.99%) and Lake Eyre Basin (39.96%) Analysis Units (Table 4).

The highest intensity of groundwater extraction generally occurs where groundwater salinity is of suitable quality for irrigation and stock or domestic consumption. Consequently, GDEs that are more likely to be freshwater ecosystems due to fresh groundwater discharge have been shown to be at highest risk. Of the 9395 wetland GDEs occurring in shallow freshwater (<10 m and <3000 EC) groundwater regions, 90.27% are identified as being at risk from existing high intensity groundwater usage.

RISKS TO WDEs FROM GROUNDWATER EXTRACTION

SUMMARY STATISTICS FOR SOUTH AUSTRALIA

- 32.4% of the number of all mapped wetlands (or 25.7% of total wetland area) are potentially at risk from current high levels of groundwater extraction
- Half of all identified potential WDEs (50.5%) are likely to be at risk from current groundwater extraction levels
- Of the WDEs occurring over shallow freshwater aquifers, the majority (90.27%), have been identified as potentially at risk from current groundwater extraction levels
- High proportions of WDEs at risk from groundwater extraction occur in the South East, Mount Lofty Ranges and Lake Eyre Basin Analysis Units.

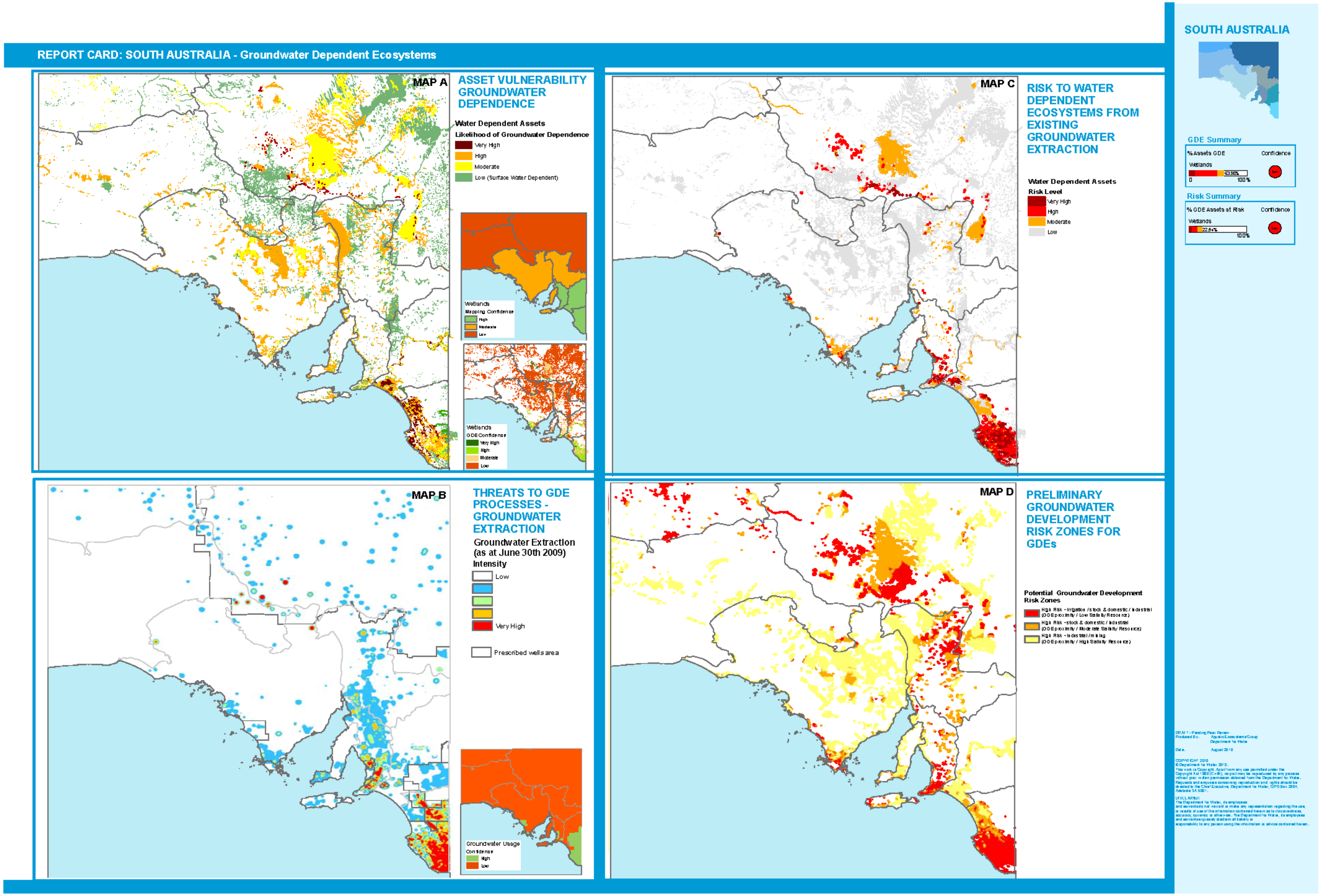


Figure 10. Preliminary Risk Assessment for Groundwater-dependent Ecosystems from groundwater extraction

3.2. IDENTIFICATION OF PRIORITY AREAS FOR FURTHER ASSESSMENT - WETLAND GROUNDWATER-DEPENDENT ECOSYSTEMS

3.2.1. SUMMARY OF PRIORITY REGIONS FOR FURTHER ASSESSMENT

The state-scale analysis highlighted priority regions for improving and verifying the outputs of the preliminary analysis and to assist in focussing efforts for future assessment of risk. The results of the analysis, presented in Figure 11, indicated several regions of specific interest:

Lower South East – Represents the largest concentration of likely GDEs in South Australia, occurring within intensively extracted, prescribed, fresh groundwater resource. Confidence in the assessment of groundwater dependency and mapping accuracy is generally higher in the South East than for other regions of the State due to a number of recent specific studies (Harding 2009; SKM 2009a; SKM 2010b). Declining groundwater levels as a result of high intensity usage and lower than average rainfall has been identified in the South East (Harding 2009). The potentially high risks warrant detailed investigations to determine the impacts of changes in hydrology caused by groundwater extraction, quantification of groundwater–surface water interactions at important WDEs and developing environmental water requirements to inform water allocation plans.

Mount Lofty Ranges and Southern Fleurieu Peninsula – Intensively extracted freshwater fractured rock and sedimentary aquifers of Adelaide and surrounds. Generally the confidence in GDE assessment is moderate. The high risks warrant detailed investigations to determine the impacts of changes in hydrology caused by groundwater extraction, and improved understanding of groundwater–surface water interactions to further inform environmental water requirements.

Willochra / Mambray Coast – Unprescribed region, which is moderately extracted and features fractured rock and sedimentary aquifer systems. Declining groundwater levels have been reported in both the Quaternary and Tertiary aquifers (Risby et al. 2003), which has anecdotally resulted in the loss of springs. There is generally low confidence in both the GDE classification and WDE asset identification (mapping). Significant aquatic ecological assets have been identified in the lower reaches of the Willochra Creek (Risby et al. 2003) and also in streams draining the southern to mid-western catchment, in the form of permanent pool refugia.

Torrens / Flinders – Unprescribed region of moderate to low level of groundwater extraction, of relatively fresh – brackish fractured rock aquifers. There was generally low confidence in the assessment of GDEs and WDE asset identification (mapping). The area is known to contain springs of importance (White & Scholz 2008) as aquatic refuges.

Eyre Peninsula – Partially prescribed, moderate to high level of groundwater extraction from relatively fresh fractured rock aquifers. These aquifers are low capacity, low flow and relatively small groundwater resources. The area contains GDEs identified with relatively high confidence through both this analysis and SKM (2009b). SKM (2009b) also identified GDEs likely to be vulnerable to groundwater extraction in the Southern Eyre Peninsula. Further investigations in this region are currenlty being undertaken by the Department and the EPNRMB to map vulnerable GDEs, identify aquatic ecosystems of high ecological value and link changes in groundwater condition with ecosystem condition.

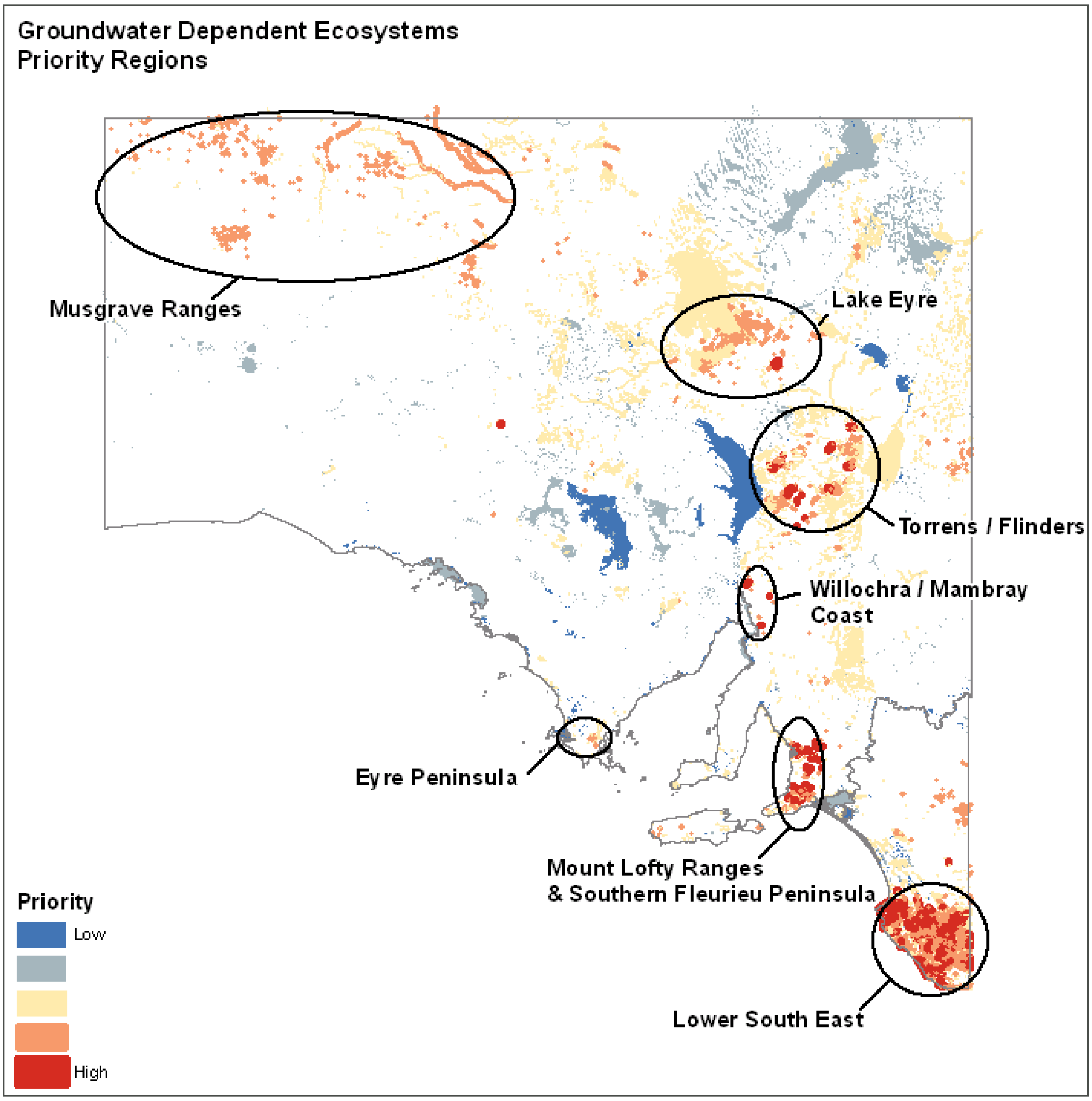


Figure 11. **Priority areas for additional assessment of risks to WDEs**

Lake Eyre – Partially prescribed groundwater resource of low to locally high levels of development of GAB. The area is known to contain GAB springs of high ecological significance listed as Threatened Ecological Communities under the EPBC Act 1999. Confidence in the assessment of groundwater–surface water interactions with large inland salt lake systems, i.e. Lake Eyre, is low. There is limited knowledge of the groundwater resource development of sedimentary aquifers.

Musgrave Ranges – Unprescribed groundwater resources of fractured rock and paleochannels containing relatively fresh groundwater, which are currently not intensively developed, may be at risk from future developments, including mining. This is an extremely remote and data poor region, with WDEs likely to be dependent on groundwater resources. Both the WDE asset mapping and GDE classification are of low confidence. The environmental significance of the WDEs is unknown.

4. CONCLUSIONS AND RECOMMENDATIONS

The objectives of this report were to develop methods for identifying where water-dependent ecosystems across South Australia are potentially at risk, with the use of existing datasets for the purposes of evaluating key knowledge and data gaps and identifying priorities for the concentration of more refined assessment in the future. The purpose was to highlight areas of potential concern as a preliminary assessment.

The preliminary outputs detailed in this report, although largely of low confidence, provide some of the essential spatial data layers that will assist in informing prioritisation, management, conservation and policy for protecting water-dependent ecosystems dependent on groundwater throughout the State. Protection and management of water-dependent ecosystems is hindered by lack of information on their diversity, abundance and location (Howard & Merrifield 2010). By developing a method that uses existing datasets to assess the dependence of water-dependent ecosystems on groundwater (and by inference surface water), this assessment has begun to address the knowledge gaps and enabled the identification of priorities for improving the confidence of the assessment outputs.

The analysis was effective in communicating the extensive distribution of those water-dependent ecosystems reliant on groundwater and identifying key areas likely to be at risk from current levels of groundwater extraction. Testing and verifying groundwater dependence through groundtruthing to establish whether potential high risk equates to actual ecosystem function or driver loss, was not within scope for this assessment. However, the preliminary analysis provides a useful prioritisation tool for targeting verification activities.

A Risk Management Framework to guide water planning and management for the Department for Water is currently being developed. Future risk assessments will follow this framework for methodology to ensure consistency of terminology and standard practise in procedure. A number of aspects of a risk assessment that were considered essential for delivery of a robust risk assessment of WDEs in this project were unable to be addressed within the scope of this preliminary analysis, including:

- determination of the degree of WDE extent loss since development and therefore the relative importance of remaining ecosystems
- consideration of consequence in the risk assessment method
- adequate consideration of other water-affecting activities likely to pose potential risks to WDEs, including surface water extraction and interception, groundwater and surface water quality impacts and climate change
- risks based on different WDE types (or typologies)
- verifying the assessment by identifying current ecological status or health of WDEs identified to be at high risk.

The preliminary outputs of this report have been used to inform the DFW project: Impact of climate change on water resources (Wood & Green 2011).

4.1. PRIORITY ACTIONS FOR REFINING THE RISK ASSESSMENT OUTPUTS

Priority actions have been identified to improve the applicability, accuracy and confidence in the risk assessment of WDEs as described below.

4.1.1. EXPANSION AND IMPROVEMENT OF THE RISK ASSESSMENT METHOD

This preliminary assessment considered risk from groundwater extraction only. The methods could be developed to include other sources of risk to WDE processes including:

> the impacts of surface water extraction, which need to be considered at a whole of catchment scale (cumulative), rather than point based extraction. This was not able to be achieved in the time frame available for this assessment, with existing data available.
>
> the impacts of climate change, water quality: salinity, pollution and contamination risks to WDEs.

The South Australian Aquatic Ecosystem typology classification methodology (Scholz & Fee 2008), which categorises wetland type and function, if applied widely across the State, would provide a solid framework to more robustly identify specific levels of risk of differing WDE types to certain sources of risk.

The development pressures on South Australia’s water resources into the future, particularly under climate change scenarios, have not been assessed as part of this report. Significantly, Aurecon (2010) identifies water demand across the mining resource industry in South Australia will increase from approximately 43 000 ML / year in 2010 to approximately 130 000 ML / year in 2019. It would also be expected that pressures on groundwater resources for irrigation, stock and domestic purposes would also increase. Identifying potential risk from future water resource development was not within the scope of this preliminary assessment; however the datasets produced could be used to identify these risks as data becomes available.

The potential impacts of future climate change scenarios were not considered in the preliminary risk assessment. The data from this assessment is supporting the Groundwater Program Impacts of Climate Change on Water Resources project (Wood & Green 2011).

4.1.2. IMPROVING THE CONFIDENCE OF THE MAPPING OUTPUTS

In order to improve the confidence levels new data will be required. Given the potentially large task involved in creating high confidence outputs for the whole of South Australia, the actions identified below (Table 5) were of highest priority. These correspond with areas of concern identified in Figure 11.

Higher levels of confidence in the assessment of groundwater dependence may be required for the purposes of developing and implementing policy and protection measures, particularly in highly developed groundwater resource areas. More detailed understanding of groundwater and surface water interactions, including integrated monitoring, are required to assist in determining robust environmental water requirements for WDEs.

Table 5. **Specific actions to improve the confidence of the WDE Risk Assessment in identified high priority regions.**

		Priority Actions					
		Improve WDE asset identification (mapping)	Improve ground water dependency assessment: Assign SAAE typologies	Improve GDE classification	Assessment and prioritisation of Ecological Value of WDEs	Detailed understanding of GW/SW interactions required	Integrated hydro-geological and ecological monitoring
Priority Areas - GDEs	Lower South East		*	✓		*	*
	MLR and Southern Fleurieu			✓	✓	*	*
	Willochra / Mambray Coast		✓	✓			
	Torrens / Flinders	*	✓	✓	✓	✓	
	Lake Eyre		✓	✓		✓	
	Musgrave Ranges	*	✓	✓	✓		
	Whole of South Australia		*	*	*	✓	

* indicates highest priority actions

4.1.2.1. Groundwater-Dependency Classification

The preliminary classification of likelihood of groundwater dependency produced through this assessment was largely of low confidence, owing to the limited data available throughout the majority of the state. In order to improve the confidence of the outputs, particularly in priority areas, the development of additional methods beyond the use of easily available existing datasets are required. As such, the preliminary GDE likelihood classification should be used with caution until further validation is completed. The assessment of groundwater dependency within watercourses was not explicitly undertaken (only components identified as wetlands) as part of this report and is a priority for future refinement of the assessing risks to WDEs.

The preliminary GDE classification identified likelihood or potential of groundwater interaction for mapped water-dependent ecosystems based on the interpretation of existing and derived datasets. The classification does not include other important information significant to water resource management including, identifying the specific aquifer or groundwater resource, level of dependency, type or seasonality of dependency. This further level of information exists for only a very small proportion of the State’s WDEs and was not collated as part of this report.

Further work on the identification of GDEs via satellite imagery interpretation and ancillary data is proposed as part of the National Water Commission funded Atlas of Groundwater-Dependent Ecosystems (SKM 2010a). This work will assist South Australia in improving the reliability of the GDE classification delivered for this report and identify common attributes for characterising GDEs at a National scale.

4.1.2.2. Detailed understanding of groundwater–surface water interactions

Optimally, methods for assessing the level of groundwater dependency of WDEs should be assessed using field based methods such as hydrochemistry and/or specific installation of groundwater and surface water monitoring equipment (e.g. Cook et al. 2008a). It is however impractical, given the large number of potential GDEs identified in South Australia to verify and characterise groundwater dependence with use of field based methods for all high likelihood GDEs. The use of conceptual diagrams (e.g. SKM 2009b; SKM 2010b) and classification of WDE typologies (Scholz & Fee 2008; Jones & Miles 2009) potentially provides the ability to upscale detailed site-based information to a broader landscape.

This report identified several high priority regions containing likely GDEs at risk from current high levels of groundwater usage. Priority areas were identified from this analysis to identify regions in higher need of specific information regarding groundwater–surface water interactions that could be up scaled and utilised in developing environmental water requirements and provisions and to guide future water resource decision-making and policy.

4.1.2.3. WDE asset identification (mapping)

Existing WDE mapping, including wetlands, rivers, streams, spring, cave and karst features were the primary data source for assessing risks to WDEs. Significantly, the accuracy and completeness of these datasets was considered poor for the majority of the State. The accurate identification of the location of WDE features and their dependency on groundwater, particularly in regions of high current or potential risk from water resource development, was identified as high priority.

4.1.2.4. Assessment of Consequence (ecological value assessment)

A risk assessment approach requires the consideration of consequence, as well as likelihood. The consequences of detrimental impacts on water resources are influenced by the value (significance) of the asset. Identifying ‘high’ value water-dependent ecosystems is therefore an integral element of a risk assessment. The assessment of high value WDEs was not within scope for this preliminary assessment, however was considered an essential component to be potentially pursued in future refinements of the assessment method.

A national framework has been developed for identifying High Conservation Value Aquatic Ecosystems (HCVAE) through the Aquatic Ecosystems Task Group (AETG). The overall goal of a National HCVAE Framework is to provide a nationally consistent approach to the identification, classification and management of high conservation value aquatic ecosystems and to provide a vehicle to facilitate the management of HCVAE’s for natural resource outcomes beyond water management obligations identified through the National Water Initiative (NWI). The national framework has established a core set of ecological criteria for identifying aquatic ecosystems of high conservation value at both a national and regional scale. The application of the criteria has been trialled in the Lake Eyre Basin (Hale 2010) and methods developed could be applied to other regions of South Australia.

4.1.2.5. Assessment of vulnerability (SAAE typologies)

The preliminary risk assessment, focussing on a single source of risk—groundwater extraction, assessed potential risk to WDE through the determination of likelihood of groundwater interaction. Different WDE or GDE types across South Australia are likely to have differing vulnerabilities to certain sources of risk. Krause et al. (2007) utilised wetland type classifications to determine the level of vulnerability to identified threats. In South Australia, Scholz and Fee (2008) developed a wetland typology classification based on landscape and landform processes and hydrological driving variables including climate, seasonality, water regime, water quality and substrate type. A total of 17 South Australian Aquatic Ecosystem (SAAE) wetland types were defined through this process and conceptual diagrams developed for each (Scholz & Fee 2008). The application of the typology classification has been trailed in the Murray River Floodplain (Jones & Miles 2009) and at the time of writing is being developed in the South East (L. Farrington, DENR, pers. comm.).

4.1.3. VERIFICATION OF RISK ASSESSMENT METHODS

Within the scope of this report, risk to identified WDEs reliant on groundwater was assumed to be high in areas of high intensity groundwater use. In order to verify whether relative high intensity usage impacts on groundwater resource condition, an assessment of groundwater level response in high intensity usage areas was required. This analysis existed for the South East region (Harding 2009), which verifies that high intensity usage of groundwater resources in the South East results in groundwater level declines significant to sustaining natural groundwater–surface water interactions. No such analysis was readily available in other regions of South Australia, however it could be achieved with use of the observation well network data.

Assessing the current ecological status or health of WDEs identified to be at high risk in order to verify risk assessment assumptions and evaluate current risk of damage has been applied in other GDE risk assessment projects (e.g. Krause et al. 2007). WDEs identified as being of very high risk from current groundwater extraction, if correctly assessed are likely to be demonstrating signs of ecosystem stress, deterioration in condition, or changes in ecological character.

It was not within the scope of the preliminary risk assessment to assess the ecological condition or health of identified high risk WDEs, although is potentially an important component for determining risks to WDE in the longer term and evaluating the validity of the assessment..

4.1.4. WATER-DEPENDENT ECOSYSTEM ECOLOGICAL MONITORING

Within the Department for Water, monitoring programs exist for quantifying groundwater and surface water resource condition and water usage (metering), which produce data used to determine the condition of water resources in the state and inform water resource allocation, policy and planning.

Groundwater-dependent ecosystems are largely dependent on the maintenance of shallow groundwater levels (either seasonally or constant). Currently, there is both a lack of knowledge of environmentally acceptable limits of change in shallow groundwater levels for aquatic ecosystems and a lack of monitoring and assessment of environmental water requirements to inform that process across most of the state. The outputs from this report could form the basis for prioritising integrated hydrological and ecological monitoring of WDEs for South Australia for guiding future development and water allocation planning and policy.

APPENDIXES

A. DATA SOURCES - SPATIAL WATER-DEPENDENT ECOSYSTEM DATA

Spatial Layer	Agency	Description	Scale / Accuracy	Coverage
Landscape_Wetlands	DENR	Polygon feature Wetlands and waterbodies composite spatial layer.	1:5000 – 1:250 000	SA Statewide
Topo_Watercourses	DENR	Line feature Watercourses, rivers and streams	1:50 000	SA, Southern Agricultural Districts
Topo_GeoData250K_ Watercourses	DENR	Line feature Watercourses, rivers and streams	1:250 000	National
Topo_GeoData250K_ Waterholes	DENR	Point feature Waterholes	1:250 000	National
LEB_Waterholes	DERM	Line feature Permanent and non-permanent waterhole mapping in the Lake Eyre Basin	1:50 000	Lake Eyre Basin, Qld & SA
GAB_SpringLocations	SAAL NRM Board	Point feature GPS locations of GAB springs	+/- 50m	SA, Lake Eyre Basin
Springs	DENR	Point feature Locations of Springs and Waterholes extracted from Statewide Gazetteer.	1:50 000	SA Statewide
LSE_Karst	Confidential and unpublished	Point feature GPS locations of cave and karst features in the Lower South East.	Unconfirmed (GPS)	SA, Lower South East
Permanent Pools – Broughton, Wakefield and Light Catchments	DFW	Point feature Locations of permanent pools within stream features.	1:5000	SA, Broughton / Wakefield / Light Catchments
Permanent Pools – Mount Lofty Ranges	DFW	Point feature Locations of permanent pools within stream features mapped from	1:5000	SA, Mount Lofty Ranges

Spatial Layer	Agency	Description	Scale / Accuracy	Coverage
		aerial videography		
Permanent Pools – Mosquito Creek	DENR	Point feature Locations of permanent pools within Mosquito Creek from GPS survey.	Unconfirmed (GPS)	SA and Vic, Mosquito Creek

B. A CHRONOLOGICAL REVIEW OF STUDIES WITH RELEVANCE TO IDENTIFYING AND CLASSIFYING GROUNDWATER-DEPENDENT ECOSYSTEMS IN SOUTH AUSTRALIA

Title	Reference / Agency	Description	Analysis Unit
Hydrogeology of the Stuart Shelf in South Australia: Impacts of the Olympic Dam Mine	Waterhouse *et al.* (2000)	Interpretation of the hydrogeology of the Stuart Shelf and assessment of the long-term impacts of the Olympic Dam Operation on the regional groundwater system. Identifies saline groundwater discharge sites, including Lake Torrens and Lake Gairdner.	Torrens
Willochra Catchment Hydrological and Ecological Assessment	Risby *et al.* (2003) DWLBC	Preliminary assessment and review of hydrological and ecological data in the Willochra Catchment. Likely groundwater dependency of permanent water-dependent ecosystems, particularly waterholes, is documented. Permanent pools and reaches receiving baseflow were mapped using aerial videography.	Torrens
Groundwater – Surface Water Interaction between Bonney's Camp North Wetland and the Northern Outlet Drain	Howieson (2003)	Groundwater–surface water interaction between the Northern Outlet Drain (northern part of Upper South East Drainage Scheme) and Bonney's Camp North Wetland were investigated. The impact of groundwater drawdown on the native wetland vegetation was assessed.	South East
Reconnaissance survey of groundwater-dependence of wetlands, South East, SA, Using a mass balance of radon and chloride	Fass & Cook (2004) CSIRO	37 wetlands sampled for chloride and radon in the South East of SA. Steady state, mass balance model developed where radon activity and chloride concentration are used to determine volumes of surface vs groundwater inflow.	South East
Hydrology of Lake Eyre Basin	SKM (2005)	Review of hydrology and hydrogeology of the Lake Eyre Basin. Includes a review of known surface water – groundwater interactions, including baseflow indexes for gauging stations.	Lake Eyre Basin
A Review of the Environmental Water Requirements of the GDEs of the South East Prescribed Wells Areas	REM (2005) SENRMB	Framework developed to assess ecosystem groundwater dependency and identify key groundwater-dependent ecosystems, threats and risks in the South East.	South East
Sources of groundwater discharging to Black	Fass & Cook (2005)	Determine water sources to Black Swamp and the Finniss River and the relative	Mount Lofty

Title	Reference / Agency	Description	Analysis Unit
Swamp, south-eastern Mount Lofty Ranges	River Murray Catchment Water Management Board CSIRO	contribution of groundwater using hydrochemistry tracers sampled from surface and groundwaters.	Ranges
The combined use of seepage meters and radon-222 to quantify groundwater fluxes in a wetland	Wood (2006)	A conceptual model of hydrology for a wetland in Honans Native Forest Reserve was developed using seepage meters and hydrochemistry tracers.	South East
Groundwater – surface water interactions in arid/semi-arid wetlands and the consequences of salinity for wetland ecology	McEwan *et al.* (2006)	Review of the current knowledge of the role that surface water – groundwater interactions play in semi-arid wetlands with an emphasis on water and salt balances and ecological response.	Murray River
Water resource and water-dependent ecosystem review for the Southern Fleurieu Peninsula.	Vanlaarhoven (2006a) Vanlaarhoven (2006b)	Analysis of groundwater flow systems to assign source aquifer and likely levels of groundwater dependence of mapped wetlands on the Fleurieu Peninsula.	Mount Lofty Ranges
Determining loss characteristics of arid zone river waterbodies	Costelloe *et al.* (2007)	The retention time of water in waterbodies during periods of no surface flow in dryland rivers was investigated. The use of water level data in conjunction with the modelled evaporation rates was able to provide important insights into controls on waterbody loss rates and persistence, including temporary groundwater connection.	Lake Eyre Basin
Northern and Yorke Natural Resources Management Region water monitoring review	Roberts (2007) DWLBC	Review of groundwater, surface water and environmental monitoring in the Northern Yorke and Yorke Peninsula.	Yorke Peninsula
Mosquito Creek permanent pool mapping and baseflow monitoring	Sheldon (2007)	Permanent pools were mapped from field investigation for Mosquito Creek. Four monitoring sites for significant permanent pools were established including peizometer transects and gaugeboards. Sampling for Radon and stable isotopes occurs during flow events.	South East
Groundwater inflow to a shallow, poorly mixed	Cook *et al.* (2008b)	Estimating groundwater inflow using a mass balance of radon in a wetland in	South East

Title	Reference / Agency	Description	Analysis Unit
wetland estimated from a mass balance of radon	Flinders University CSIRO	Honans Native Forest Reserve, South East, SA.	
Regional Groundwater-Dependent Ecosystems - our undiscovered assets at risk	Cook *et al.* (2008a)	Estimation of rates of groundwater infow into a wetland in Honans Native Forest Reserve using radon-222. A methodology was developed to identify disconnection / connection of wetlands to groundwater.	South East
Identifying groundwater discharge in the Coorong (South Australia)	Haese *et al.* (2008)	Evaluation of groundwater discharge into the Coorong and Lower Lakes using interpretation of remote sensing data and field observations and measurements of groundwater seepage.	Murray River South East
Surface Water–Groundwater Interactions in River Murray Wetlands and Implications for Water Quality and Ecology	Jolly *et al.* (2008)	A field study investigated three wetlands to determine surface water – groundwater interactions. Methods included EM surveys, analysis of hydrometric observations and hydrochemistry.	Murray River
Groundwater recharge and discharge dynamics in an arid-zone ephemeral lake system, Australia.	Costelloe *et al.* (2009)	Hydrogeological, chemical and isotopic observations, in conjunction with numerical modeling of groundwater responses to lake inundation events, have been used to identify the dominant processes linking shallow, unconfined groundwater with the hydrology of Coongie Lakes during wet and dry periods.	Lake Eyre Basin
Classification of groundwater - surface water interactions for water-dependent ecosystems in the South East, South Australia	SKM (2009a) DFW	Determining likelihood of groundwater interactions for mapped wetlands with use of LiDAR and modelled groundwater levels. A landscape scale classification of likelihood of dependence on the regional unconfined aquifer, seasonality of connection and confidence of the assessment.	South East
Identification of Permanent Refuge Waterbodies in the Cooper Creek and Georgina-Diamantina River Catchments for Queensland and South Australia	Silcock (2009) SAALNRMB	Mapping of waterholes including classification of water permanency.	Lake Eyre Basin

Title	Reference / Agency	Description	Analysis Unit
West Avenue Watercourse – Groundwater monitoring and radon / chloride sampling program.	USE Program	Peizometer transects and surfacewater hydrochemistry and tracer survey to determine groundwater input into West Avenue Watercourse.	South East
GDE Monitoring Program – South East	DFW	Groundwater and surfacewater monitoring infrastructure and a monitoring protocol for 14 wetland complexes in the South East.	South East
Eyre Peninsula Groundwater-Dependent Ecosystem Scoping Study	SKM (2009b) EPNRMB	Scoping study to identify the locations of potentially groundwater-dependent wetland and vegetation communities in the Southern Basins & Musgrave PWAs and Robinson Basin. Thresholds for environmental water requirements of groundwater of each identified GDE type were proposed.	Eyre Peninsula
River Murray Wetland Classification Project	Jones & Miles (2009)	Application of the SAAE classification to mapped aquatic ecosystems of the Murray River floodplain, South Australia. Attribution of Water Sources field as *groundwater* based on the salinity threat layer.	Murray River
Measurement and evaluation of Key Groundwater-Dependent Ecosystems in the Lower South East of SA	Wood (2009) DWLBC	Development of conceptual models of surface water—groundwater interactions at key GDE sites (rising springs) in the Lower South East, based on isotope and ion chemistry of water bodies.	South East
Monitoring the Ecological Response of High Value Wetlands to Changes in Groundwater	Ecological Associates (2010) DEH	Development of a monitoring framework and methodology for determining ecological response to changes in groundwater levels as part of the GDE Monitoring Program – South East.	South East
Conceptual Diagrams of Wetland Groundwater-Dependent Ecosystems	SKM (2010b) DFW	Part of the GDE Monitoring Program – South East. Conceptual diagrams of groundwater interaction for the 14 case study sites were developed from drill logs and data from the first year of monitoring using ArcHydro Groundwater.	South East
Groundwater-Dependent Ecosystem Monitoring Program – vegetation monitoring	Beacon Ecological (2010) DEH / DWLBC	Ecological monitoring for 5 of the 14 GDE case study sites as part of the GDE Monitoring Program – South East.	South East
Allocating water and maintaining springs in the	SAALNRMB	Hydrogeology and ecology components including development of improved	Lake Eyre Basin

Title	Reference / Agency	Description	Analysis Unit
Great Artesian Basin		spatial mapping of GAB springs and improved understanding of hydrogeological processes for key springs. Project delivered via several sub-programs.	
Spatial extent of submarine groundwater discharge to estuarine and nearshore environments within a karst landscape	Herpich (2010)	Airborne thermal imagery was used to identify thermal anomalies associated with groundwater discharge to marine, estuarine and nearshore environments (Glenelg River and Piccanninie Ponds) including collection of physical evidence and geochemical tracers.	South East
LEB Report	Hale		Lake Eyre Basin

C. METADATA – GDE CLASSIFICATION WETLANDS

DEPARTMENT FOR WATER
South Australian Wetlands GDE Classification Metadata
Risk Assessment of Water-Dependent Ecosystems – South Australia

CITATION

Unique Record ID: AUS_WETNR
File Name: Wetlands_GDE_Classification
Originator: C. Harding & P. O'Connor
Custodian: Department for Water, South Australia

Description

Abstract:

A Preliminary Risk Assessment of Water-Dependent Ecosystems in South Australia. The project includes compilation of existing data on the location of WDEs and an assessment of the likelihood of groundwater dependency and risk from existing groundwater resource development.

The wetlands layer Landscape_Wetlands (current as of March 2010) managed by DENR is the spatial polygon layer. A number of fields were generated for this layer within this project. Attribute data for new fields is detailed within this metadata. Refer to DENR for metadata for Landscape_Wetlands polygon layer.

Geographic Extent Name: South Australia

Bounding Coordinates:

North Bounding Coordinate: 2762284.543000 m
South Bounding Coordinate: 1313347.916000 m
East Bounding Coordinate: 1606857.311000 m
West Bounding Coordinate: 404124.721000 m

Data Currency

Beginning Date: Unknown
Ending Date: August 2010

Dataset Status

Progress: Current
Maintenance and Update Frequency: As Required

Access

Stored Data Format: ESRI Personal Geodatabase
Available Format Type: ESRI Shapefile
Access Constraints: Not for redistribution or production of derivative products without consent of custodian.

Data Quality

Lineage: Sourced from Landscape_Wetlands (DENR)
Positional Accuracy: Sourced from Landscape_Wetlands (DENR)
Attribute Accuracy: Sourced from Landscape_Wetlands (DENR)

Logical Consistency: Sourced from Landscape_Wetlands (DENR)
Completeness: Sourced from Landscape_Wetlands (DENR)

Contact Information

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Metadata Information

Metadata Date: 30August 2010

Supplementary Information

Description

Dataset Classification: Derived
Spatial Representation Type: Vector
Feature Type: Polygon
Dimension: x, y

Usage

Purpose: To display SA Wetlands GDE Classification

Use: Wetlands study, Hydrogeological investigations, Risk Assessment, Policy and Development Application Assessments.

Use Limitation: Confidence ratings of all fields have been generated (see Attribute Information). These rating should be viewed in conjunction with corresponding data. Attributes of Low confidence indicate that further research/investigation is required to confirm attribution.

Dataset Associations

Dependant Dataset Title: Landscape_Wetlands (DENR)
Attribute Information:
Attribute Table Type:

Origin

Dataset Size: 775MB
Projection: Lambert_Conformal_Conic
Datum: GDA_1994_South_Australia_Lambert

Metadata Management

Date Modified:
Modified Officer:
Date Authorised:
Authorisation Officer:

Attributes Information

Attribute name: AUS_WETNR
Attribute type: String
Attribute width: 8
Attribute definition: Unique wetland identifier. Sourced from Landscape_Wetlands (2010). All other attributes from Landscape_Wetlands layer not defined. Refer to metadata for Landscape_Wetlands (DENR).

Attribute name: INTERNATIO
Attribute type: String
Attribute width: 1
Attribute definition: Identifies wetlands currently listed as internationally important under the RAMSAR Convention.
Attribute domain:

Domain value: 1 or Y
Domain value desc: Identified as listed under the RAMSAR Convention.

Domain value: 0 or N
Domain value desc: Not listed.

Attribute name: NATIONALST
Attribute type: String
Attribute width: 1
Attribute definition: Identifies wetlands currently listed as nationally important on the Directory of Important Wetlands in Australia (DIWA).
Attribute domain:

Domain value: 1 or Y
Domain value desc: Identified as listed on DIWA.

Domain value: 0 or N
Domain value desc: Not listed.

Attribute name: GDE_POTL
Attribute type: String
Attribute width: 3
Attribute definition: Groundwater Dependent Ecosystem – Potential
Attribute definition desc: Assessment of likelihood or potential of groundwater interaction based on the methodology outlined in Section 2 and application of the matrix presented in Table 3.
Attribute domain:

Domain value: VH
Domain value def: Very High

Domain value desc: Very High Likelihood of Groundwater Dependency

Domain value: H
Domain value def: High
Domain value desc: High Likelihood of Groundwater Dependency

Domain value: M
Domain value def: Moderate
Domain value desc: Moderate Likelihood of Groundwater Dependency

Domain value: L
Domain value def: Low
Domain value desc: Low Likelihood of Groundwater Dependency (likely surface water dependent)

Domain value: <Null>
Domain value def: Not Assessed
Domain value desc: Wetlands not assessed (outside of study area)

Attribute name: GDE_CONF
Attribute type: String
Attribute width: 3
Attribute definition: Groundwater Dependent Ecosystem – Confidence
Attribute definition desc: Overall confidence of the assessment of likelihood or potential of groundwater interaction (GDE_POTL) based on the application of the matrix presented in Table 1. Confidence refers to the technical confidence of the level of assessment and does not indicate degree of confidence in the use of the data for policy and planning purposes.
Attribute domain:

Domain value: VH
Domain value def: Very High
Domain value desc: Very High Confidence in the assessment of GDE Likelihood (GDE_POTL)

Domain value: H
Domain value def: High
Domain value desc: High Confidence in the assessment of GDE Likelihood (GDE_POTL)

Domain value: M
Domain value def: Moderate
Domain value desc: Moderate Confidence in the assessment of GDE Likelihood (GDE_POTL)

Domain value: L
Domain value def: Low
Domain value desc: Low Confidence in the assessment of GDE Likelihood (GDE_POTL)

Domain value: <Null>
Domain value def: Not Assessed

Domain value desc: Wetlands not assessed (outside of study area)

Attribute name: DTW_ZONE
Attribute type: String
Attribute width: 10
Attribute definition: Depth to Water Zone
Attribute definition desc: Depth to groundwater zone derived from shallow groundwater potentiometric surface modelling. Refer to Section 2 for details of shallow groundwater mapping method. Attributed using spatial coincidence of centroid of polygon with depth to water zones.
Attribute domain:

Domain value: 0-2
Domain value def: 0 – 2 meters to groundwater

Domain value: 2-5
Domain value def: 2 – 5 meters to groundwater

Domain value: 5-10
Domain value def: 5 – 10 meters to groundwater

Domain value: >10
Domain value def: > 10 meters to groundwater

Attribute name: DTW_CONF
Attribute type: String
Attribute width: 3
Attribute definition: Depth to Water Confidence
Attribute definition desc: Overall confidence of the assessment of depth to groundwater zone (DTW_ZONE) derived from borehole point density of the data utilised to create shallow groundwater potentiometric models. Refer to Section 2 for details of shallow groundwater mapping method and borehole density. Attributed using spatial coincidence of centroid of polygon with borehole density layer.
Attribute domain:

Domain value: H
Domain value def: High
Domain value desc: High confidence in the DTW_ZONE attribute based on a point density of boreholes used for creation of shallow groundwater map of greater than the mean plus one SD.

Domain value: M
Domain value def: Moderate
Domain value desc: Moderate confidence in the DTW_ZONE attribute based on a point density of boreholes used for creation of shallow groundwater map of greater than the mean and less than the mean plus one SD.

Domain value: L
Domain value def: Low
Domain value desc: Low confidence in the DTW_ZONE attribute based on a point density of boreholes used for creation of shallow groundwater map of less than the mean density.

Attribute name: GW_EC
Attribute type: String
Attribute width: 10
Attribute definition: Groundwater Salinity Range (EC)
Attribute definition desc: Groundwater salinity range derived from drillhole database surface modelling. Refer to Section 2 for details of groundwater salinity mapping method. Attributed using spatial coincidence of centroid of polygon with salinity zones.
Attribute domain:

Domain value: <1000
Domain value def: < 1000 EC (groundwater)

Domain value: 1000-3000
Domain value def: 1000 – 3000 EC (groundwater)

Domain value: 3000-5000
Domain value def: 3000 – 5000 EC (groundwater)

Domain value: 5000-11000
Domain value def: 5000 – 11000 EC (groundwater)

Domain value: 11000-25000
Domain value def: 11000 – 25000 EC (groundwater)

Domain value: >25000
Domain value def: >25000 EC (groundwater)

Attribute name: GW_EC_CF
Attribute type: String
Attribute width: 3
Attribute definition: Groundwater Salinity Confidence
Attribute definition desc: Overall confidence of the assessment of groundwater salinity range (GW_EC) derived from borehole point density of the data utilised to create salinity maps. Refer to Section 2 for details of groundwater salinity mapping method and borehole density. Attributed using spatial coincidence of centroid of polygon with salinity borehole density layer.
Attribute domain:

Domain value: H
Domain value def: High
Domain value desc: High confidence in the GW_EC attribute based on a point density of boreholes used for creation of groundwater salinity map of greater than the mean plus one SD.

Domain value: M
Domain value def: Moderate
Domain value desc: Moderate confidence in the GW_EC attribute based on a point density of boreholes used for creation of groundwater salinity map of greater than the mean and less than the mean plus one SD.

Domain value: L
Domain value def: Low
Domain value desc: Low confidence in the GW_EC attribute based on a point density of boreholes used for creation of groundwater salinity map of less than the mean density.

Attribute name: ASRIS_ALLUV
Attribute type: String
Attribute width: 25
Attribute definition: ARIS Landsystems – Frequency of Alluvial Soils.
Attribute definition desc: Frequency of Alluvial soils per mapping unit (ARIS Landsystems) of >50% indicates areas of greater likelihood of unconfined groundwater aquifers and increased likelihood of groundwater – surface water interactions where groundwaters <10m. Assumption based on SKM (2005). Attributed using spatial coincidence of centroid of wetland polygon and ARIS Landsystems data (Alluvial soils >50%).

Attribute name: GDE_REF
Attribute type: String
Attribute width: 25
Attribute definition: Groundwater Dependent Ecosystem - Reference
Attribute definition desc: Title of pre-existing GDE Classification project where outputs relate specifically to mapped wetland polygons. Null fields indicate no GDE classification exists prior to this assessment.
Attribute domain:

Domain value: SE GDE Classification
Domain value desc: Polygon included as part of the South East GDE Classification.
SKM (2009). *Classification of groundwater-surface water interactions for water dependent ecosystems in the South East, South Australia*. Report to Department of Water, Land & Biodiversity Conservation. Sinclair Knight Merz Pty Ltd.

Domain value: Murray Classification
Domain value desc: Polygon included as part of the Murray River Wetland Classification Project.
Jones, L. & Miles, M. (2009). *River Murray Wetland Classification Project*. Report to the Riverine Recovery Project, Department of Water, Land & Biodiversity Conservation. Department for Environment & Heritage, Adelaide.

Domain value: FPS Classification
Domain value desc: Polygon included as part of the Southern Fleurieu Peninsula water dependent ecosystems Review.

Vanlaarhoven, J. (2006a). *Data Inventory: Water Dependent Ecosystems & Environmental Water Requirements of the Southern Fleurieu Peninsula*. DWLBC Report 2009/03. Department of Water, Land & Biodiversity Conservation, Adelaide.

Vanlaarhoven, J. (2006b). *Water Management Guidelines for the Protection of Water Dependent Ecosystems of the Southern Fleurieu Peninsula*. DWLBC Report 2009/04. Department of Water, Land & Biodiversity Conservation, Adelaide.

Domain value: EP GDE Classification

Domain value desc: Polygon included as part of the Eyre Peninsula GDE scoping study.

SKM (2009). *Eyre Peninsula Groundwater Dependent Ecosystem Scoping Study*. Report to Eyre Peninsula Natural Resource Management Board. Sinclair Knight Merz Pty Ltd.

Attribute name: GDE_CLASS
Attribute type: String
Attribute width: 100
Attribute definition: Groundwater Dependent Ecosystem - Classification
Attribute definition desc: Existing GDE Classification attributes sourced from GDE Classification Reference (GDE_REF). Null fields indicate no GDE classification exists prior to this assessment. Refer to documents referenced for GDE_REF for metadata and domain descriptions.

Attribute name: GDE_REFCONF
Attribute type: String
Attribute width: 100
Attribute definition: Groundwater Dependent Ecosystem – Reference Confidence
Attribute definition desc: Existing GDE Classification Confidence attributes sourced from GDE Classification Reference (GDE_REF). The SE GDE Classification is the only existing classification which includes confidence ratings. Refer to documents referenced for GDE_REF for metadata and domain descriptions.

Attribute name: GDE_STUDY1 ; GDE_STUDY2 ; GDE_STUDY3
Attribute type: String
Attribute width: 100
Attribute definition: Groundwater Dependent Ecosystem – Study Reference
Attribute definition desc: Reference of report/study / monitoring with specific information on groundwater dependency / interactions.
Attribute domain:

Domain value: Costelloe et al (2007)

Domain value desc: Reference to report:

Costelloe, J.F., Sheilds, A., Grayson, R.B. & McMahon, T. (2007). Determining loss characteristics of arid zone river waterbodies. *River Research and Applications* 23: 715-731.

Domain value: Costelloe et al (2009)

Domain value desc: Reference to report:

Costelloe, J.F., Irvine, E.C., Western, A.W. & Herczeg, L. (2009). Groundwater recharge and discharge dynamics in an arid-zone ephemeral lake system, Australia. *Limnol. Oceanogr.*, 54(1), 2009, 86-100.

Domain value: Fass & Cook (2004)
Domain value desc: Reference to report:
Fass, T. & Cook, P.G. (2004). *Reconnaissance survey of groundwater dependence of wetlands, SE, SA, using a mass balance of radon and chloride*. CSIRO Land & Water.

Domain value: Fass & Cook (2005)
Domain value desc: Reference to report:
Fass, T. & Cook, P.G. (2005). *Sources of groundwater discharging to Black Swamp, south-eastern Mount Lofty Ranges, South Australia*. Report for River Murray Catchment Water Management Board. CSIRO Land & Water.

Domain value: Haese et al. (2008)
Domain value desc: Reference to report:
Haese, R.R, Gow, L., Wallace, L. & Brodie, R.S. (2008). Identifying groundwater discharge in the Coorong (South Australia). *AUSGEO News* 91.

Domain value: Howieson (2003)
Domain value desc: Reference to report:
Howieson, P. (2003). *Groundwater – Surface Water Interaction between Bonney's Camp North Wetland and the Northern Outlet Drain*. Honours Thesis. Flinders University, Adelaide.

Domain value: Cook et al (2008)
Domain value desc: Reference to report:
Cook, P., Simmons, C.T. & Brunner, P. (2008a). *Regional Groundwater Dependent Ecosystems – our undiscovered assets at risk*. Report to the Centre for Natural Resource Management, CSIRO Land & Water, Flinders University, Adelaide.

Domain value: Herpich (2010)
Domain value desc: Reference to report:
Herpich, D. (2010) draft. *Spatial extent of submarine groundwater discharge to estuarine and nearshore environments within a karst landscape*. Interim report to EH Graham Centre. Department of Environment & Natural Resources.

Domain value: Jolly et al (2008)
Domain value desc: Reference to report:
Jolly, I., Crosbie, R., McEwen, K., Holland, K., Lamontagne, S., Moe, K. & Simmons, C. (2008). *Project 054121: Surface Water – Groundwater Interactions in River Murray Wetlands and Implications for Water Quality & Ecology*. Final Report to the Centre for Natural Resource Management. CSIRO: Water for a Healthy Country National Research Flagship.

Domain value: Risby et al. (2003)
Domain value desc: Reference to report:
Risby, L., Scholz, G., Vanlaarhoven, J. & Deane, D. (2003). *Willochra Catchment Hydrological and Ecological Assessment*. Department of Water, Land & Biodiversity Conservation. Report, DWLBC 2003/20-21.

Domain value: SE GDE Case Study Monitoring Site
Domain value desc: Wetland included as a GDE case study monitoring site. Department for Water.
Harding, C. (2009). Unpublished. Installation of GDE Monitoring Program equipment for 14 case study wetland complexes, South East South Australia. Department of Water, Land & Biodiversity Conservation.

SKM (2010b). *Conceptual Diagrams of Wetland Groundwater Dependent Ecosystems – GDE Monitoring Project South East, SA*. Report to Department for Water, Sinclair Knight Merz Pty Ltd.

Ecological Associates (2010). Monitoring the Ecological Response of High Value Wetlands to Changes in Groundwater. Ecological Associates report CC017-2-C prepared for Department for Environment and Heritage, South Australia.

Domain value: Silcock (2009)
Domain value desc: Reference to report:
Silcock, J. 2009. *Identification of Permanent Refuge Waterbodies in the Cooper Creek & Georgina-Diamantina River Catchments for Queensland and South Australia*. Final Report to South Australian Arid Lands Natural Resource Management Board. Queensland Herbarium. Department of Environment and Resource Management, Longreach.

Domain value: Waterhouse et al (2000)
Domain value desc: Reference to report:
Waterhouse, J.D., Puhalovich, A. & Garnham, R. (2000). *Hydrogeology of the Stuart Shelf in South Australia and Impacts of the Olympic Dam Mine*. Golder Associates Pty Ltd. & EWL Sciences.

Domain value: West Avenue Radon Chloride Survey
Domain value desc: Groundwater dependence of wetland monitored by USE Program. No published reports.
USE Program, Department for Water.

Domain value: Wood (2006)
Domain value desc: Reference to report:
Wood, C. (2006). *The combined use of seepage meters and radon-222 to quantify groundwater fluxes in a wetland*. Honours Thesis, School of Chemistry, Physics and Earth Sciences, Flinders University, South Australia.

Domain value: Wood (2009)
Domain value desc: Reference to report:
Wood, C. (2009). *Measurement and evaluation of Key Groundwater Dependent Ecosystems in the Lower South East of SA*. Department of Water, Land & Biodiversity Conservation, Mount Gambier.

Attribute name: RISK_GW
Attribute type: String

Attribute width: 3
Attribute definition: Risk - Groundwater
Attribute definition desc: Assessment of risk posed by groundwater resource development. Calculated using spatial coincidence of Groundwater Threat layers and GDE_POTL. Refer to Risk matrix Table 4.
Attribute domain:

> **Domain value:** VH1; VH2
> **Domain value desc:** Very High
> **Domain value desc:** Very High risk from groundwater resource development. Wetlands are of High or Very High likelihood of groundwater dependence, within High groundwater usage areas.
>
> **Domain value:** H1; H2; H3
> **Domain value desc:** High
> **Domain value desc:** High risk from groundwater resource development. Wetlands are of High or Very High likelihood of groundwater dependence, within Moderate groundwater usage areas.
>
> **Domain value:** M1; M2; M3
> **Domain value desc:** Moderate
> **Domain value desc:** Moderate risk from groundwater resource development. Wetlands are of Moderate likelihood of groundwater dependence, within High to Moderate groundwater usage areas.
>
> **Domain value:** L1; L2; L3
> **Domain value desc:** Low
> **Domain value desc:** Low risk from groundwater resource development.

Attribute name: RISK_SW
Attribute type: String
Attribute width: 3
Attribute definition: Risk – Surface Water
Attribute definition desc: Assessment of risk posed by surface water resource development. Attribute yet to be populated.
Attribute domain:

> **Domain value:** <null>
> **Domain value desc:** Not assessed

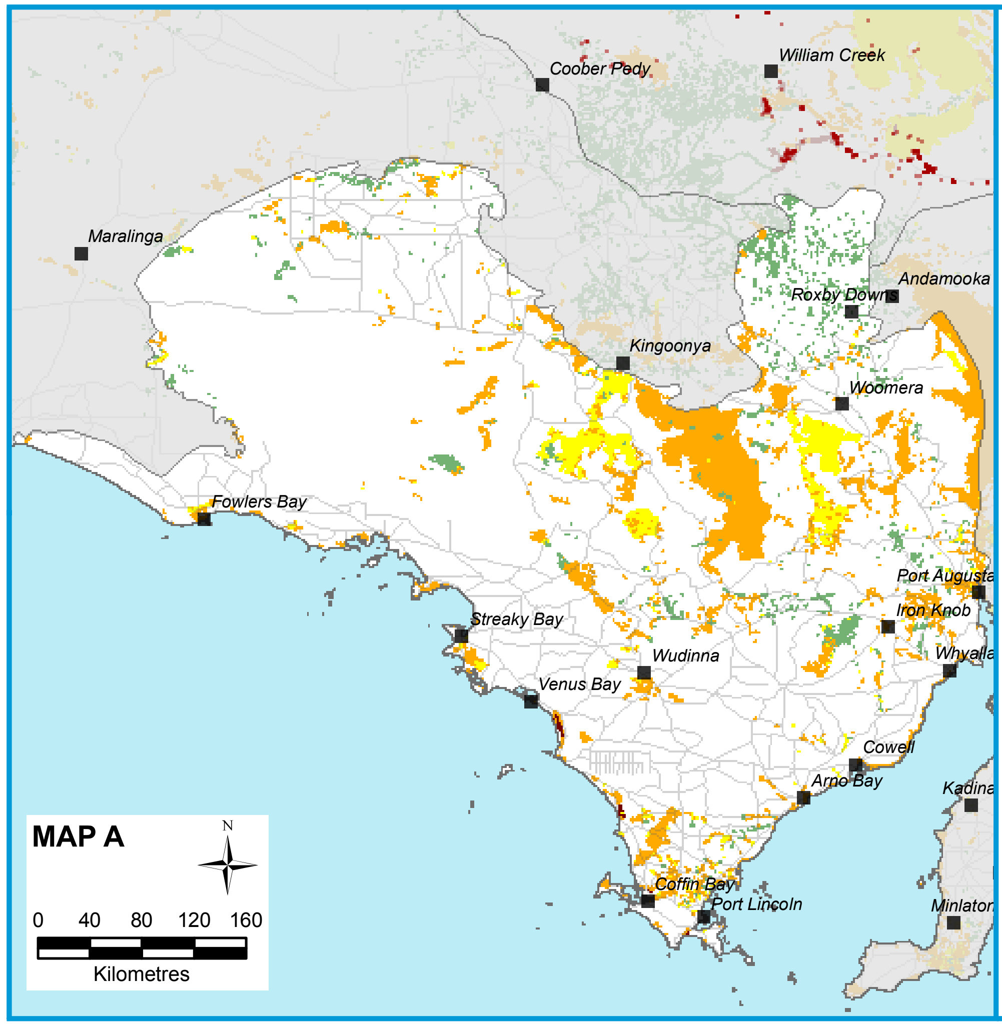
Attribute name: GDE_REGION
Attribute type: String
Attribute width: 30
Attribute definition: Groundwater Dependent Ecosystem Region
Attribute definition desc: Groundwater Dependent Ecosystem Analysis Unit Name

D. GDE CLASSIFICATION – SUMMARY STATISTICS FOR NRM REGIONS

NRM Region	GDEs NRM Region	GDEs Statewide	GDE Classification Confidence	WDEs at Risk from Groundwater extraction
	% of total wetland number	% of total wetland number	% Low Confidence	% of total wetland number
Adelaide and Mount Lofty Ranges	62%	2.3%	3.1%	53%
Alinytjara Wilurara	64.9%	4.7%	99.1%	0.8%
Eyre Peninsula	98.2%	7%	10%	30.2%
Kangaroo Island	82.4%	1.2%	62.8%	16.5%
Northern & Yorke	80.4%	5.4%	47.4%	22.9%
South Australian Arid Lands	51.4%	37.4%	78.5%	22%
South Australian Murray-Darling Basin	67.4%	10.6%	43%	9.8%
South East	77.67%	31.4%	0.1%	67.5%

E. ANALYSIS UNIT REPORT CARDS

REPORT CARD: EYRE PENINSULA ANALYSIS UNIT - Wetland Groundwater Dependent Ecosystems

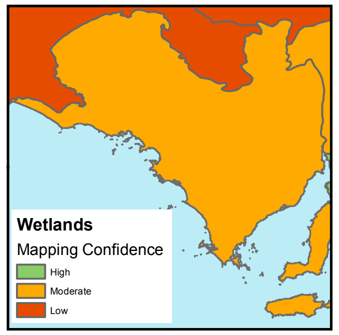


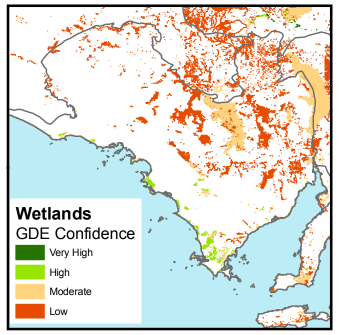
ASSET VULNERABILITY GROUNDWATER DEPENDENCE

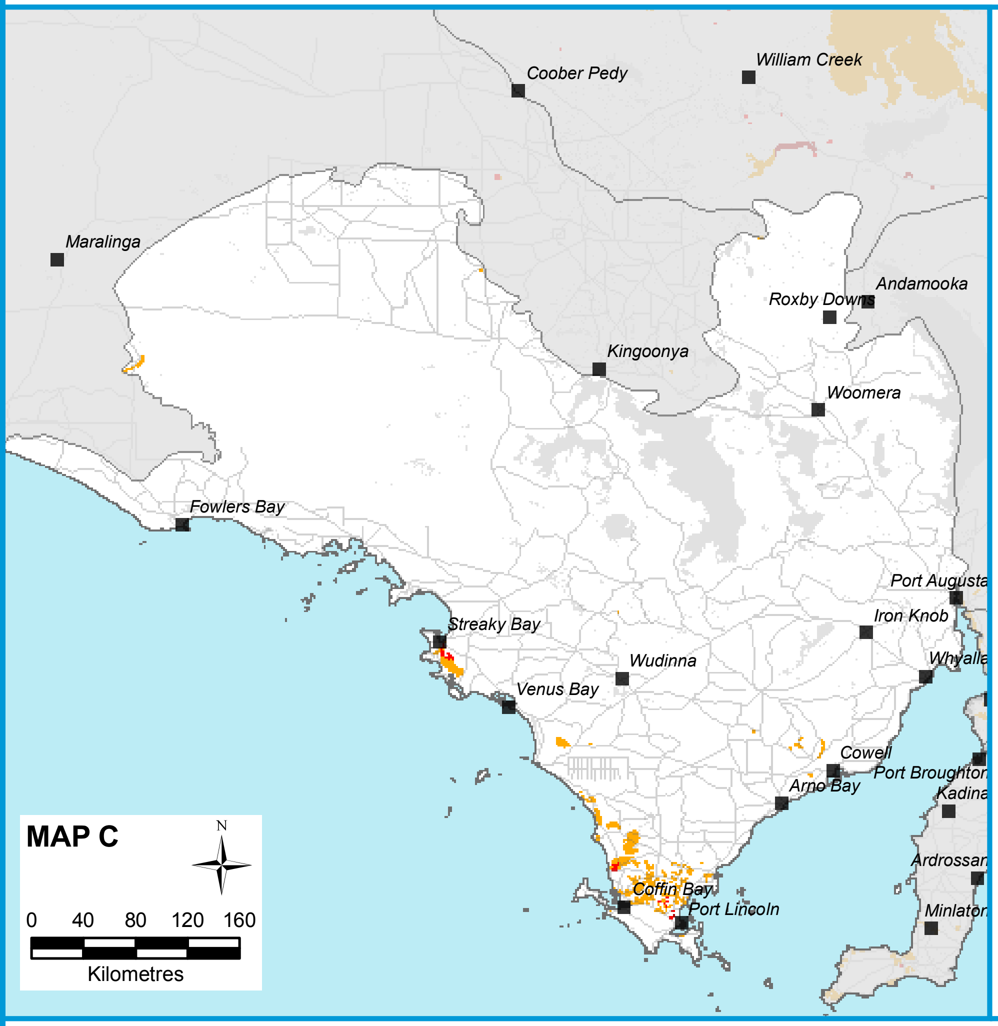
Water Dependent Assets

Likelihood of Groundwater Dependence

- 🟥 Very High
- 🟧 High
- 🟨 Moderate
- 🟩 Low (Surface Water Dependent)





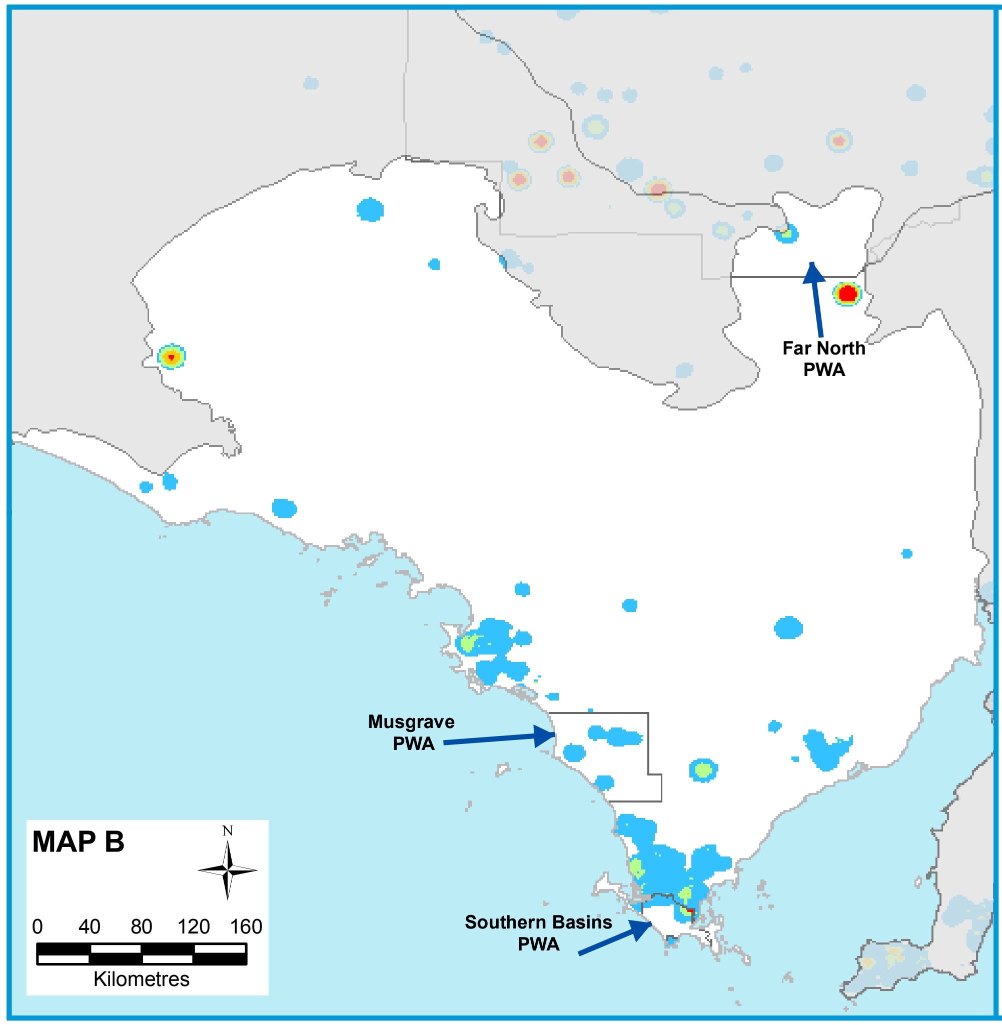


RISK TO WATER DEPENDENT ECOSYSTEMS FROM EXISTING GROUNDWATER EXTRACTION

Water Dependent Assets

Risk Level

- 🟥 Very High
- 🟥 High
- 🟧 Moderate
- ⬜ Low



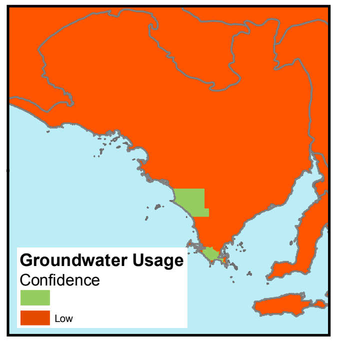
THREATS TO GDE PROCESSES - GROUNDWATER EXTRACTION

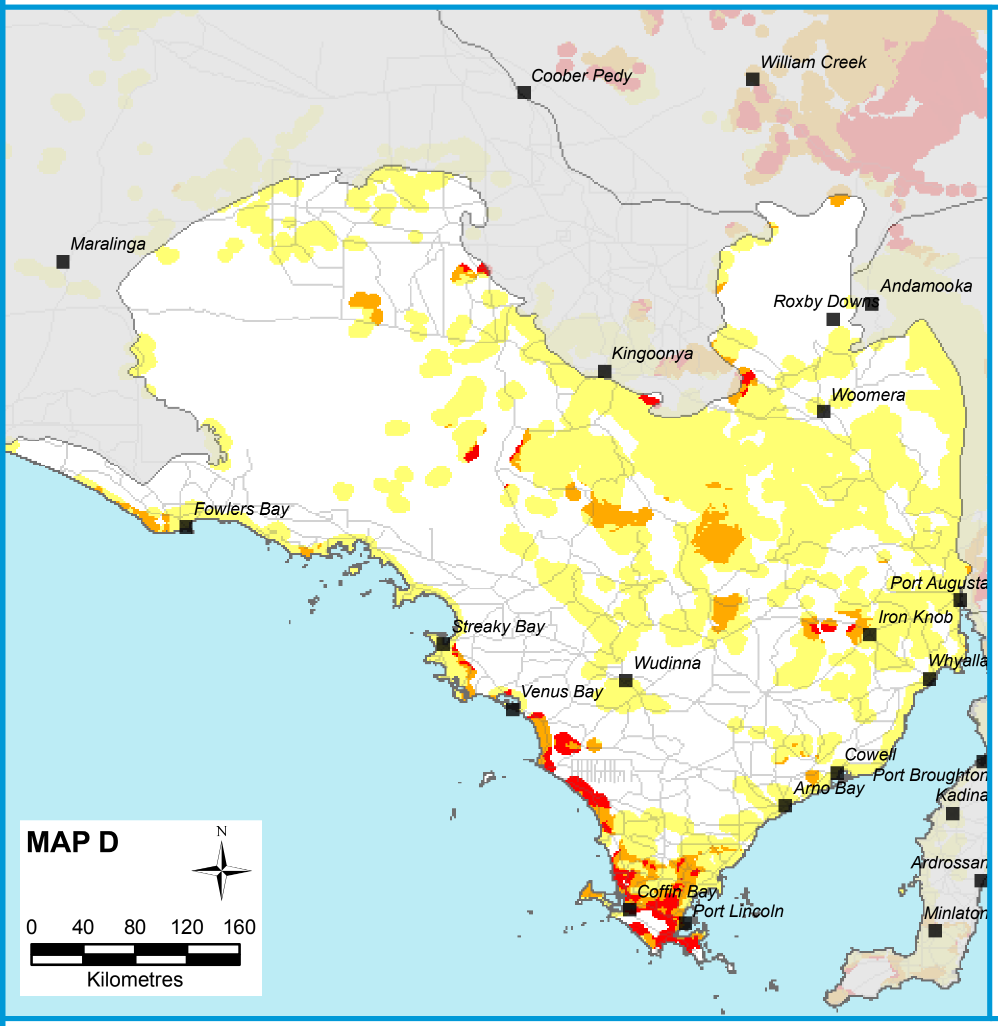
Groundwater Extraction (as at June 30th 2009)

Intensity

- ⬜ Low
- 🟦
- 🟩
- 🟧
- 🟥 Very High

⬜ Prescribed wells area



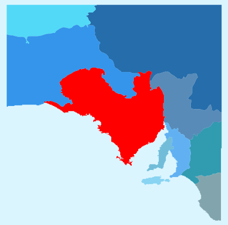


PRELIMINARY GROUNDWATER DEVELOPMENT RISK ZONES FOR GDEs

Potential Groundwater Development Risk Zones

- 🟥 High Risk - irrigation/stock & domestic/industrial (GDE proximity/Low Salinity Resource)
- 🟧 High Risk - stock & domestic/industrial (GDE proximity/Moderate Salinity Resource)
- 🟨 High Risk - industrial/mining (GDE proximity/High Salinity Resource)

EYRE PENINSULA



Asset Summary

% State Assets		Layer Accuracy
Wetlands	16.66% (0 – 50%)	Mod
Rivers & Streams	13.53% (0 – 50%)	Mod
Karst features	Not Applicable (0 – 50%)	N/A

Threat Summary

Extractive Use		Confidence
Groundwater	Low – High	Low

GDE Summary

% Assets GDE		Confidence
Wetlands	68.8% (0 – 100%)	Low
Rivers & Streams	Not Assessed (0 – 100%)	N/A
Karst features	Not Applicable (0 – 100%)	N/A

Risk Summary

% Assets at Risk		Confidence
Wetlands	8.39% (0 – 100%)	Low

Datum: Australian Geodetic Datum 1984
Produced By: Aquatic Ecosystems Group
Department for Water
Date: March 2011

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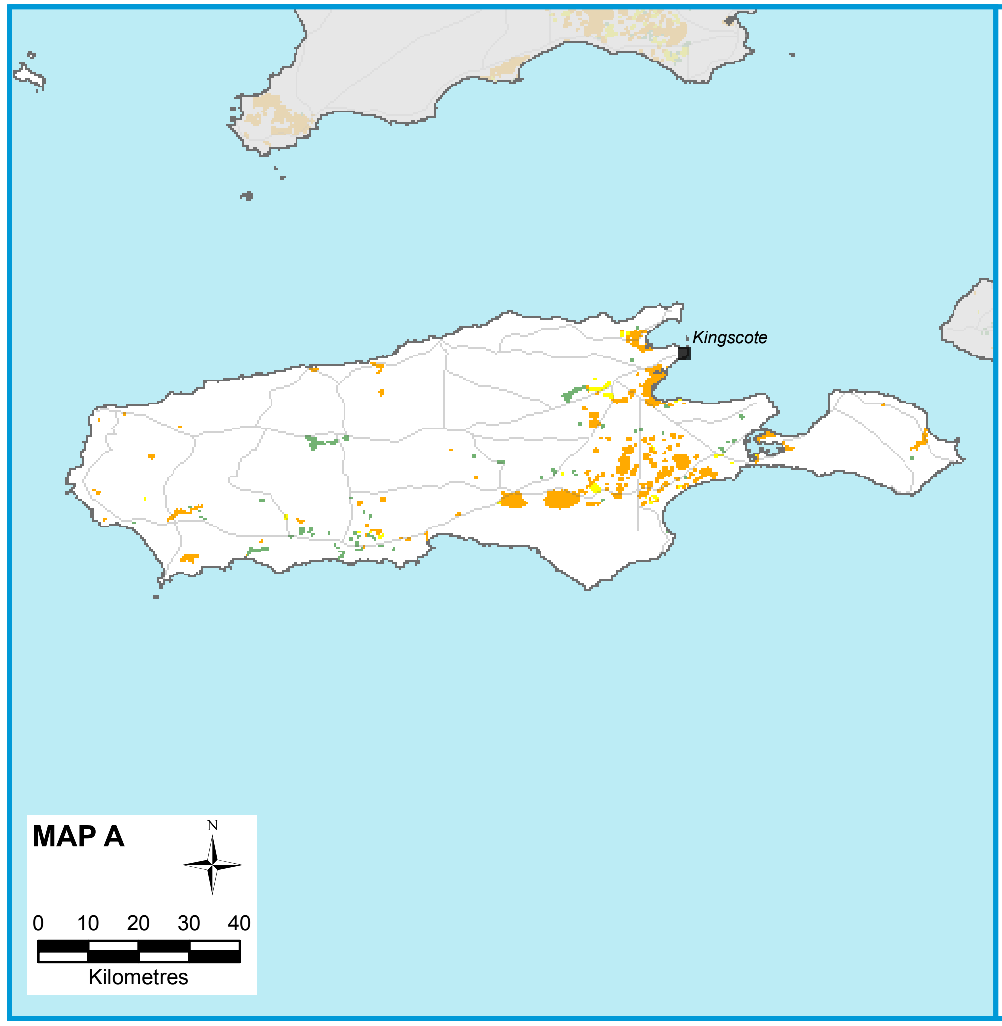
Data presented reflects modelled outputs and is subject to limitations and inaccuracies as described in Harding & O'Connor (2011).

REPORT CARD: KANGAROO ISLAND ANALYSIS UNIT - Wetland Groundwater Dependent Ecosystems

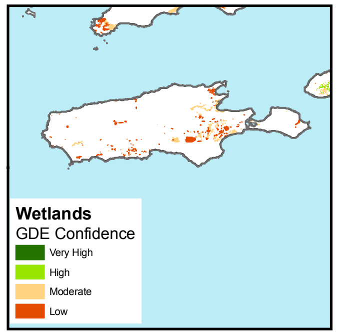


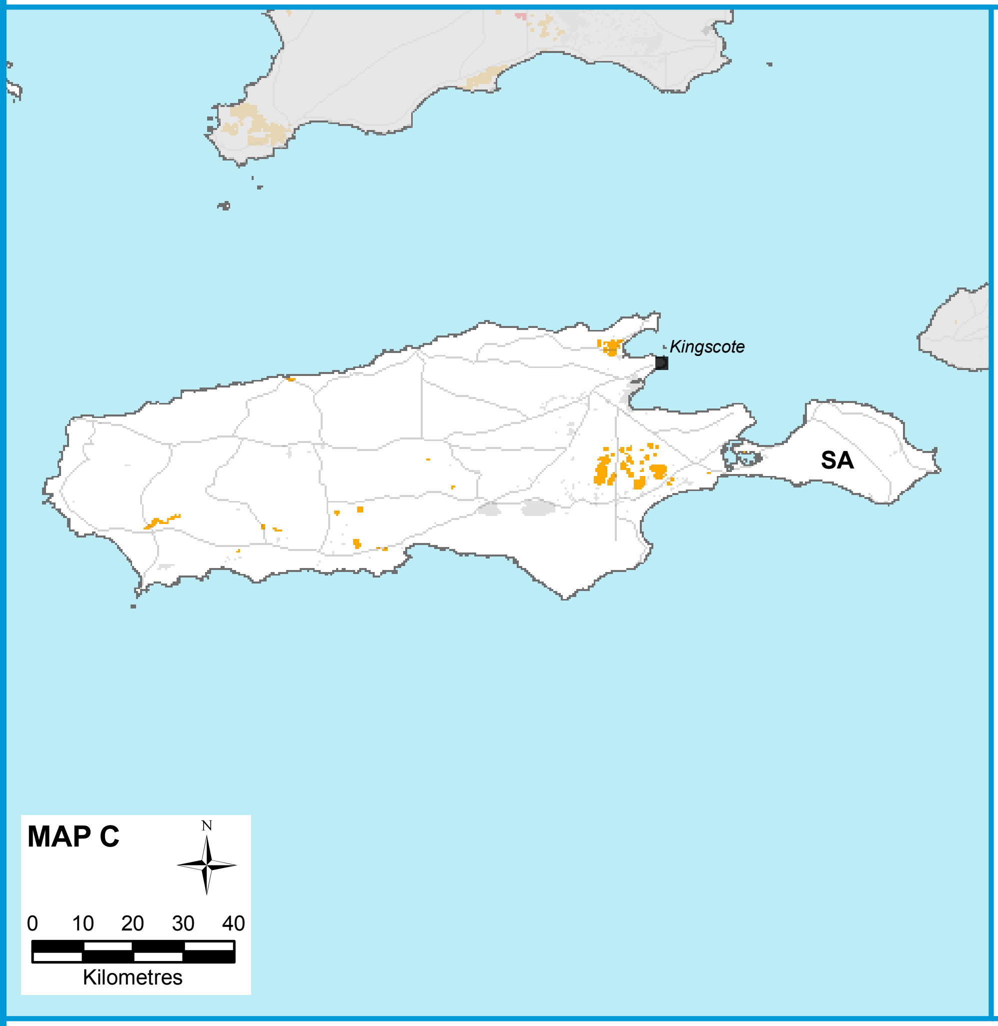
ASSET VULNERABILITY GROUNDWATER DEPENDENCE

Water Dependent Assets

Likelihood of Groundwater Dependence

- Very High
- High
- Moderate
- Low (Surface Water Dependent)



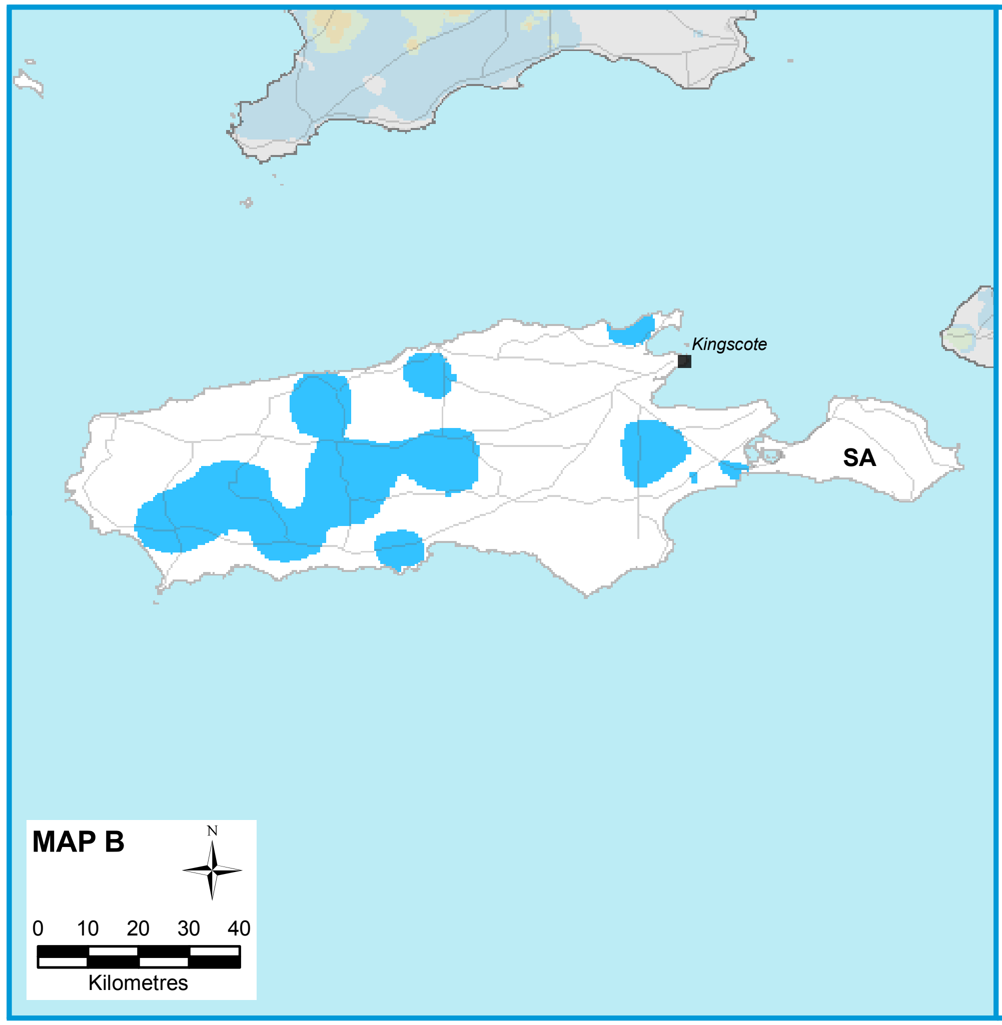


RISK TO WATER DEPENDENT ECOSYSTEMS FROM EXISTING GROUNDWATER EXTRACTION

Water Dependent Assets

Risk Level

- Very High
- High
- Moderate
- Low



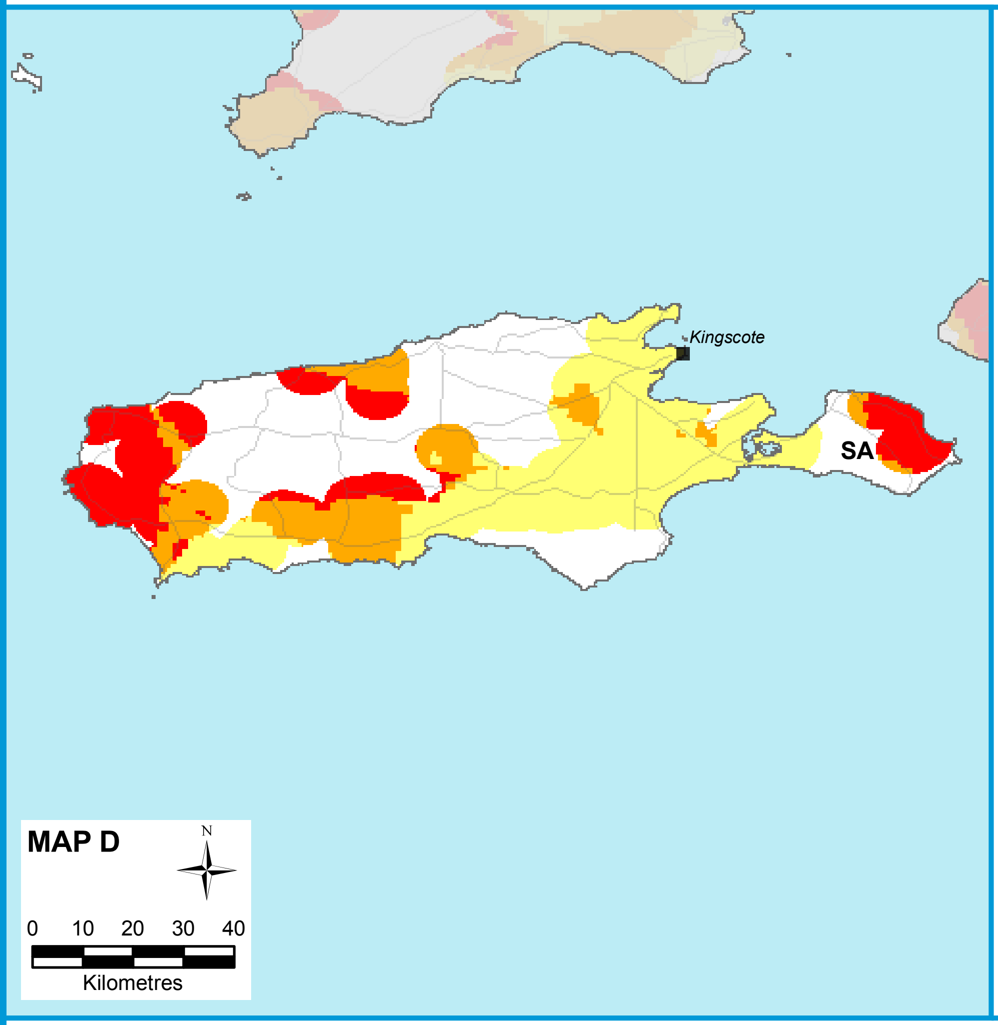
THREATS TO GDE PROCESSES - GROUNDWATER EXTRACTION

Groundwater Extraction (as at June 30th 2009)

Intensity

- Low
- Very High

Prescribed wells area



PRELIMINARY GROUNDWATER DEVELOPMENT RISK ZONES FOR GDEs

Potential Groundwater Development Risk Zones

- High Risk - irrigation/stock & domestic/ industrial (GDE proximity/Low Salinity Resource)
- High Risk - stock & domestic/industrial (GDE proximity/Moderate Salinity Resource)
- High Risk - industrial/mining (GDE proximity/High Salinity Resource)

KANGAROO ISLAND

Asset Summary

% State Assets	Layer Accuracy
Wetlands <1% (0 – 50%)	Mod
Rivers & Streams <1% (0 – 50%)	Mod
Karst features Not Applicable (0 – 50%)	N/A

Threat Summary

Extractive Use	Confidence
Groundwater Low – High	Low

GDE Summary

% Assets GDE	Confidence
Wetlands 82.44% (0 – 100%)	Mod
Rivers & Streams Not Assessed (0 – 100%)	N/A
Karst features Not Applicable (0 – 100%)	N/A

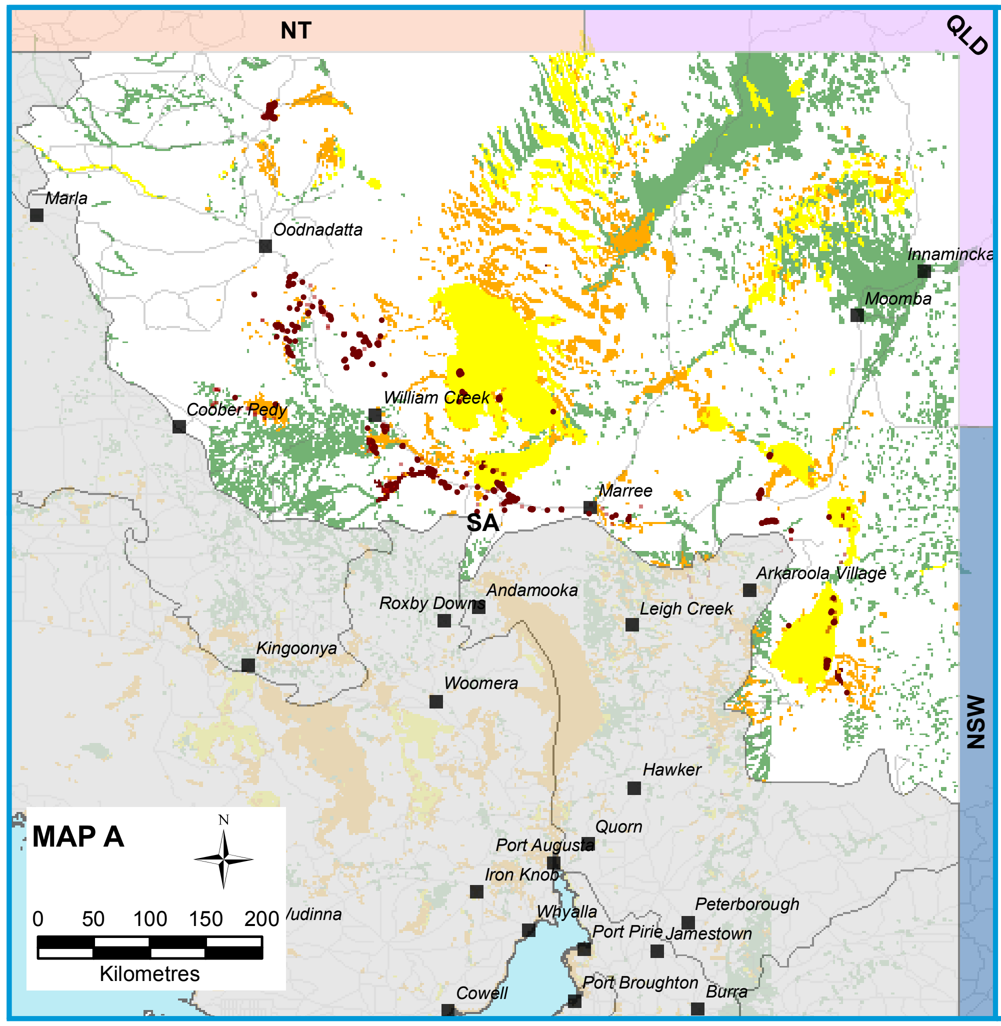
Risk Summary

% Assets at Risk	Confidence
Wetlands 16.49% (0 – 100%)	Low

Datum: Australian Geodetic Datum 1984
Produced By: Aquatic Ecosystems Group
Department for Water
Date: March 2011

Data presented reflects modelled outputs and is subject to limitations and inaccuracies as described in Harding & O'Connor (2011).

REPORT CARD: LAKE EYRE BASIN ANALYSIS UNIT - Wetland Groundwater Dependent Ecosystems

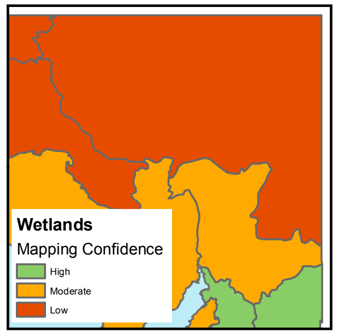


ASSET VULNERABILITY GROUNDWATER DEPENDENCE

Water Dependent Assets

Likelihood of Groundwater Dependence

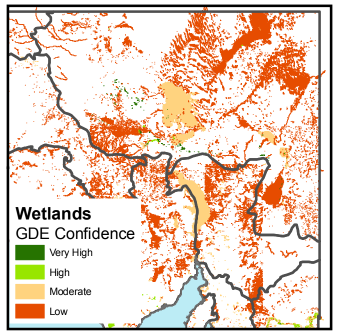
- 🟥 Very High
- 🟧 High
- 🟨 Moderate
- 🟩 Low (Surface Water Dependent)



Wetlands

Mapping Confidence

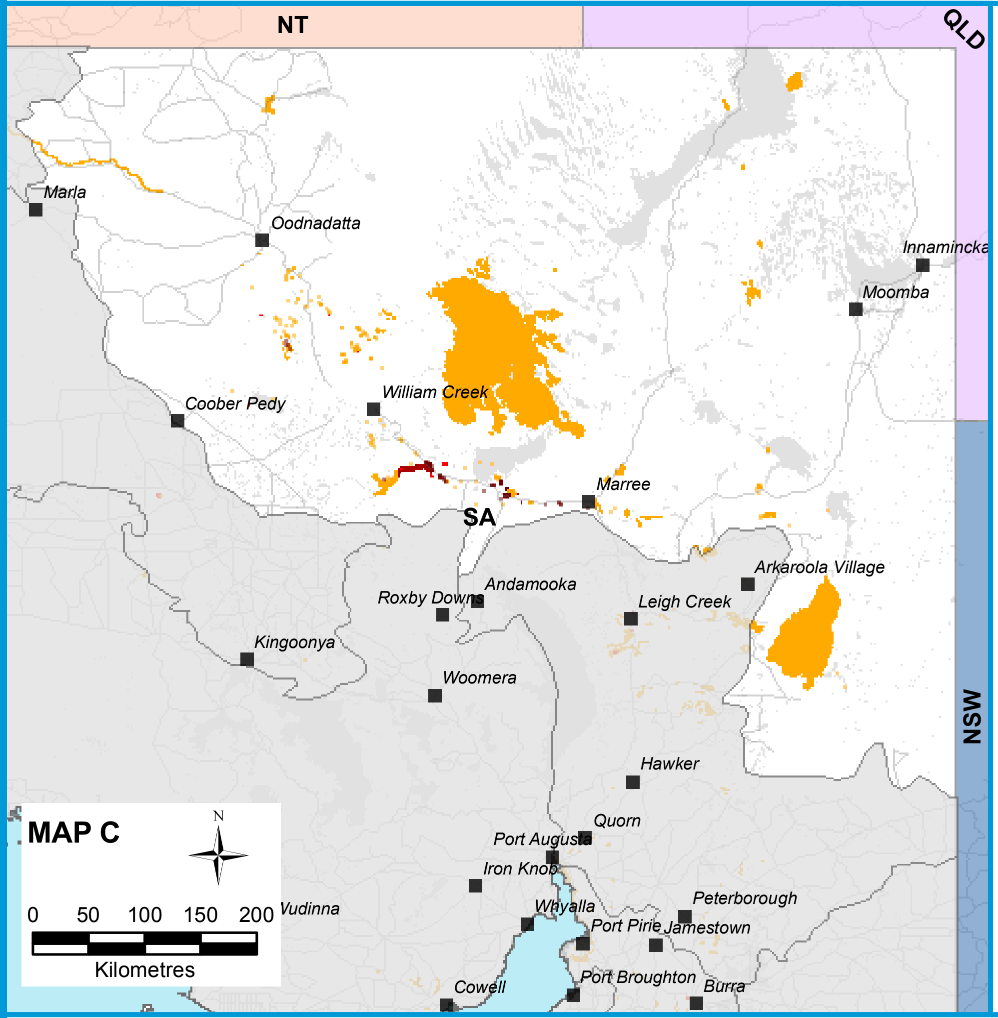
- 🟩 High
- 🟧 Moderate
- 🟥 Low



Wetlands

GDE Confidence

- 🟩 Very High
- 🟩 High
- 🟨 Moderate
- 🟥 Low

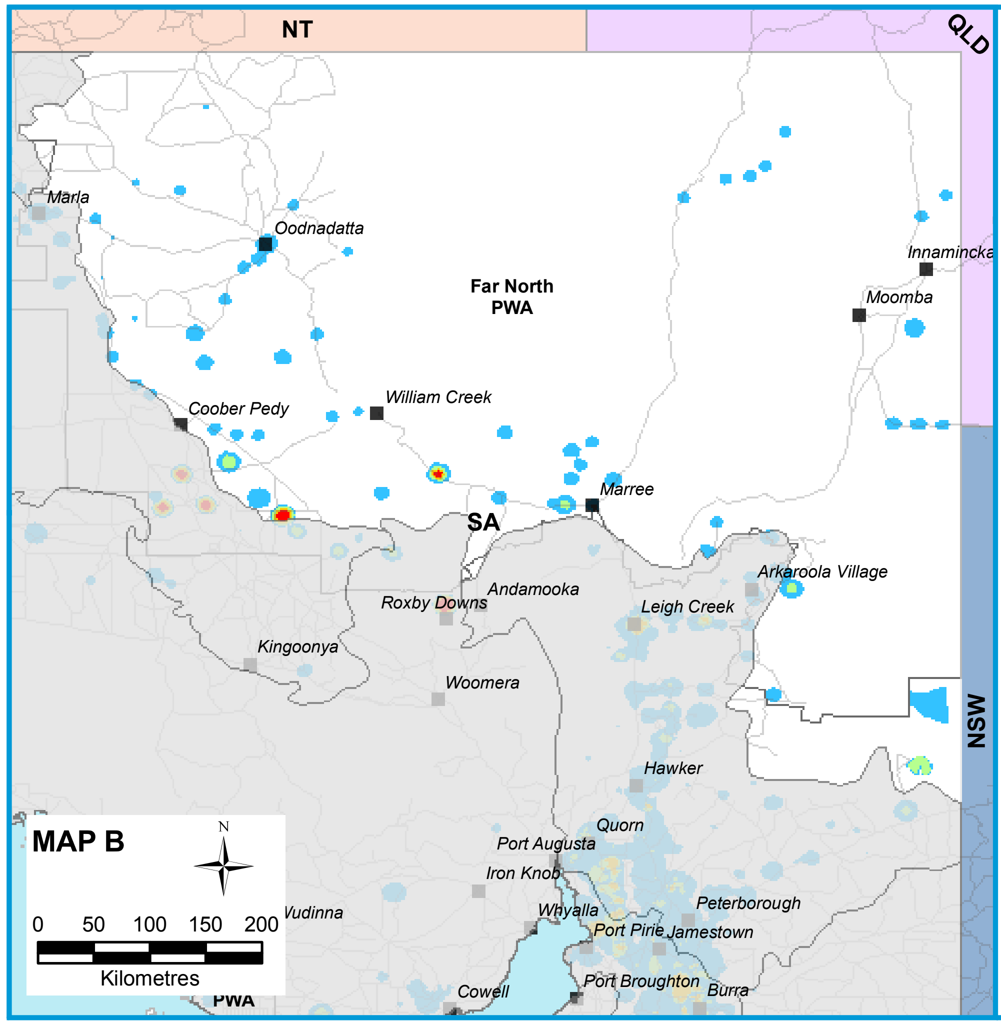


RISK TO WATER DEPENDENT ECOSYSTEMS FROM EXISTING GROUNDWATER EXTRACTION

Water Dependent Assets

Risk Level

- 🟥 Very High
- 🟥 High
- 🟧 Moderate
- ⬜ Low



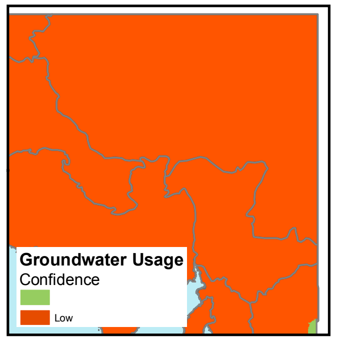
THREATS TO GDE PROCESSES - GROUNDWATER EXTRACTION

Groundwater Extraction (as at June 30th 2009)

Intensity

- ⬜ Low
- 🟦
- 🟩
- 🟨
- 🟥 Very High

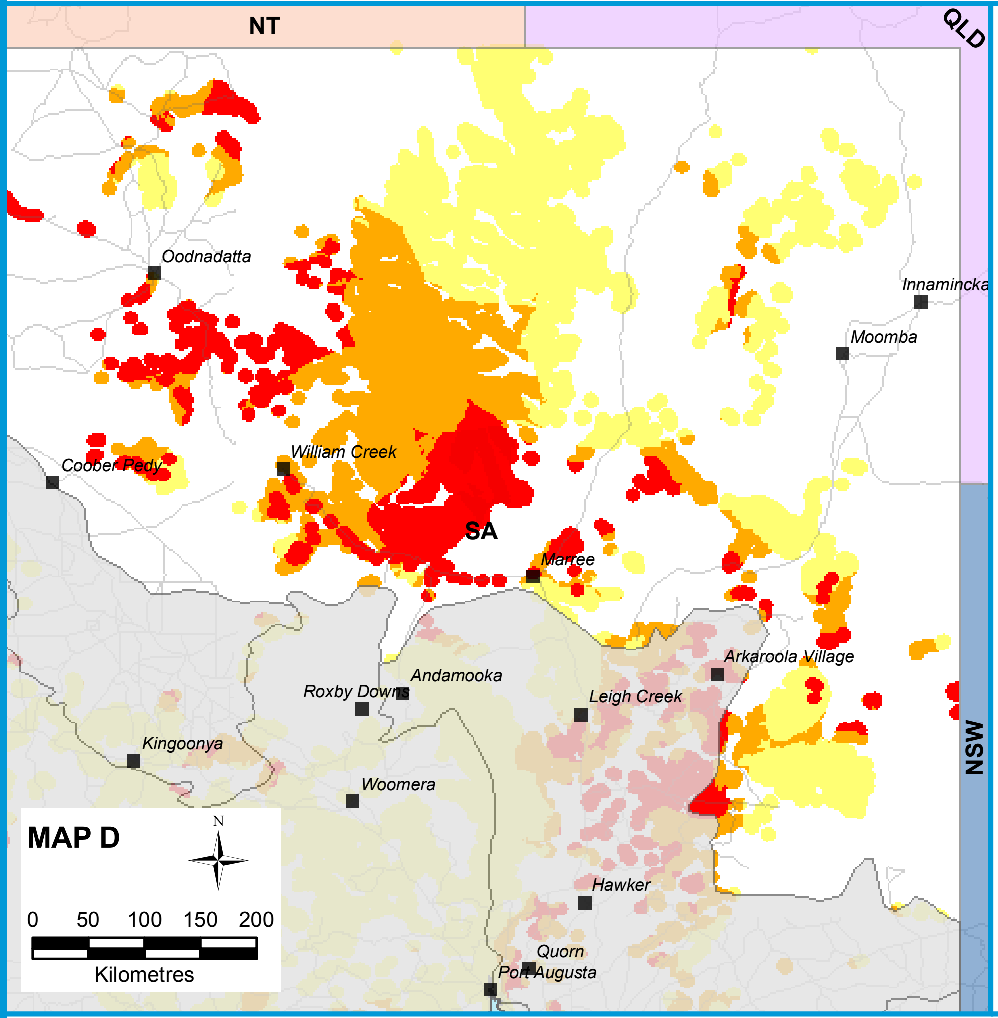
⬜ Prescribed wells area



Groundwater Usage

Confidence

- 🟩
- 🟥 Low



PRELIMINARY GROUNDWATER DEVELOPMENT RISK ZONES FOR GDEs

Potential Groundwater Development Risk Zones

- 🟥 High Risk - irrigation/stock & domestic/ industrial (GDE proximity/Low Salinity Resource)
- 🟧 High Risk - stock & domestic/industrial (GDE proximity/Moderate Salinity Resource)
- 🟨 High Risk - industrial/mining (GDE proximity/High Salinity Resource)

LAKE EYRE BASIN

Asset Summary

% State Assets — **Layer Accuracy**

Wetlands
24.73% (0 – 50%) — Low

Rivers & Streams
55.1% (0 – 50%) — Low

GAB Springs
100% (0 – 100%) — Mod

Threat Summary

Extractive Use — **Confidence**

Groundwater
Low – High — Low

GDE Summary

% Assets GDE — **Confidence**

Wetlands
55.6% (0 – 100%) — Low

Rivers & Streams
Not Assessed (0 – 100%) — N/A

GAB Springs
(0 – 100%) — High

Risk Summary

% Assets at Risk — **Confidence**

Wetlands
39.96% (0 – 100%) — Low

Datum: Australian Geodetic Datum 1984
Produced By: Aquatic Ecosystems Group
Department for Water
Date: March 2011

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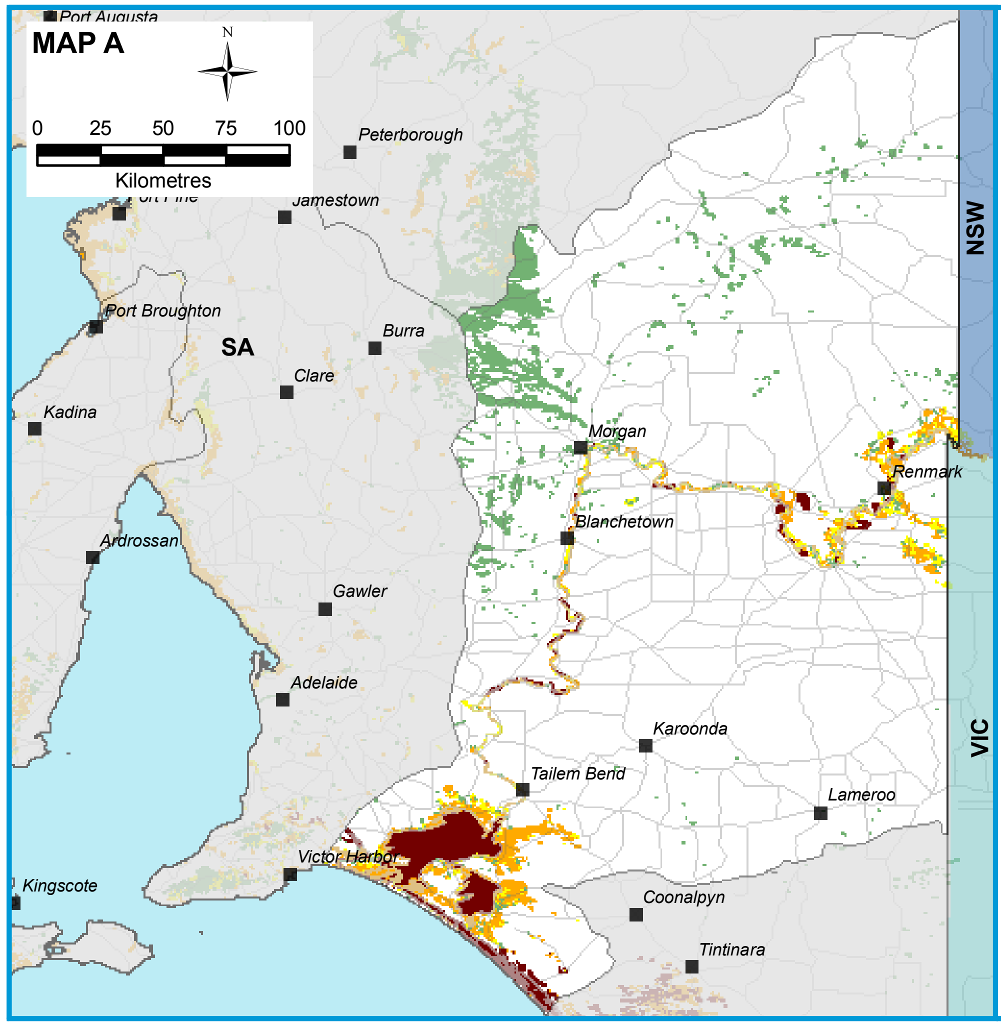
REPORT CARD: LOWER MURRAY ANALYSIS UNIT - Wetland Groundwater Dependent Ecosystems

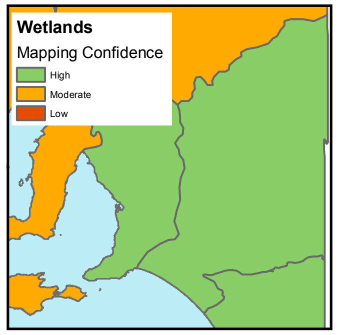


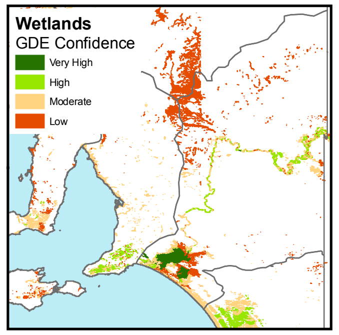
ASSET VULNERABILITY GROUNDWATER DEPENDENCE

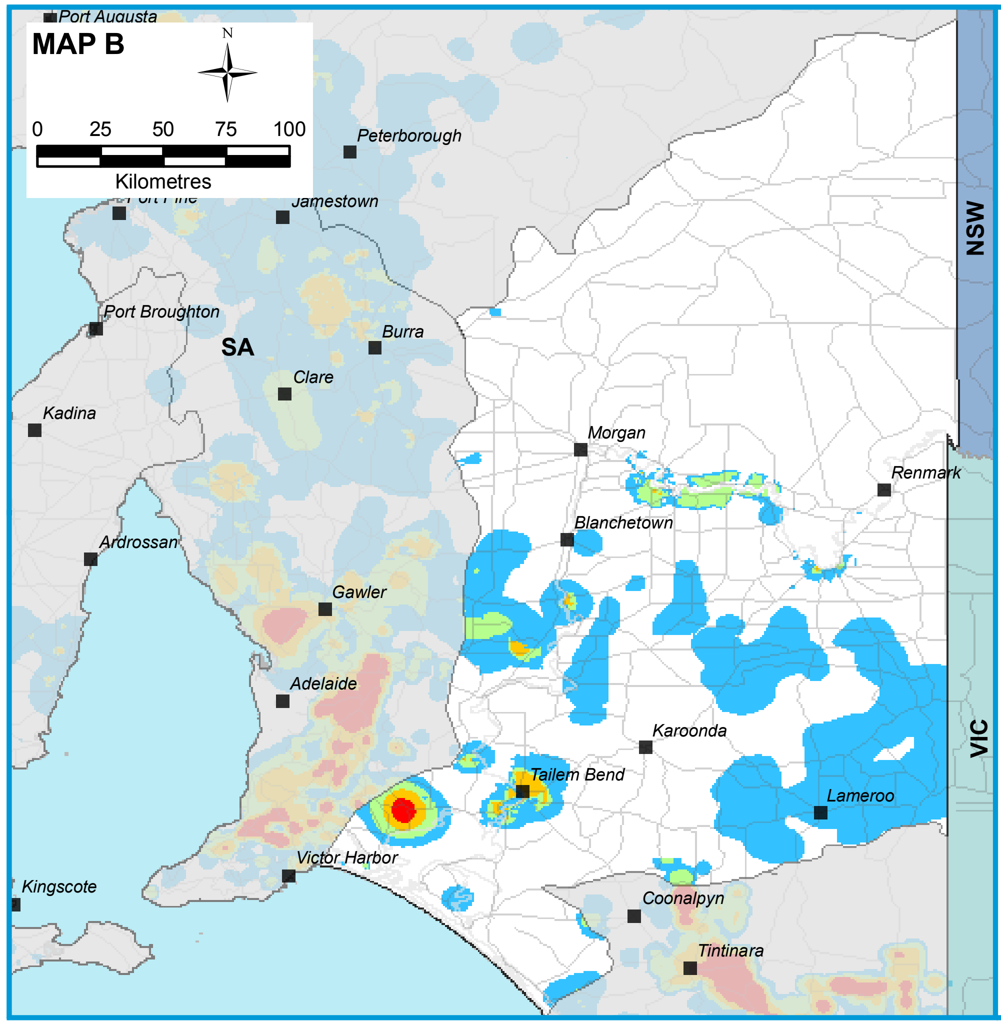
Water Dependent Assets

Likelihood of Groundwater Dependence

- 🟥 Very High
- 🟧 High
- 🟨 Moderate
- 🟩 Low (Surface Water Dependent)







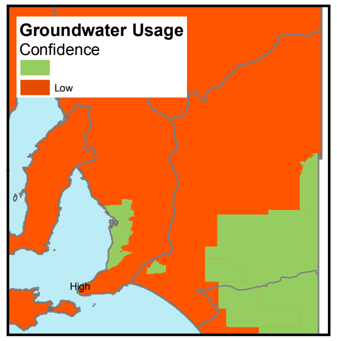
THREATS TO GDE PROCESSES - GROUNDWATER EXTRACTION

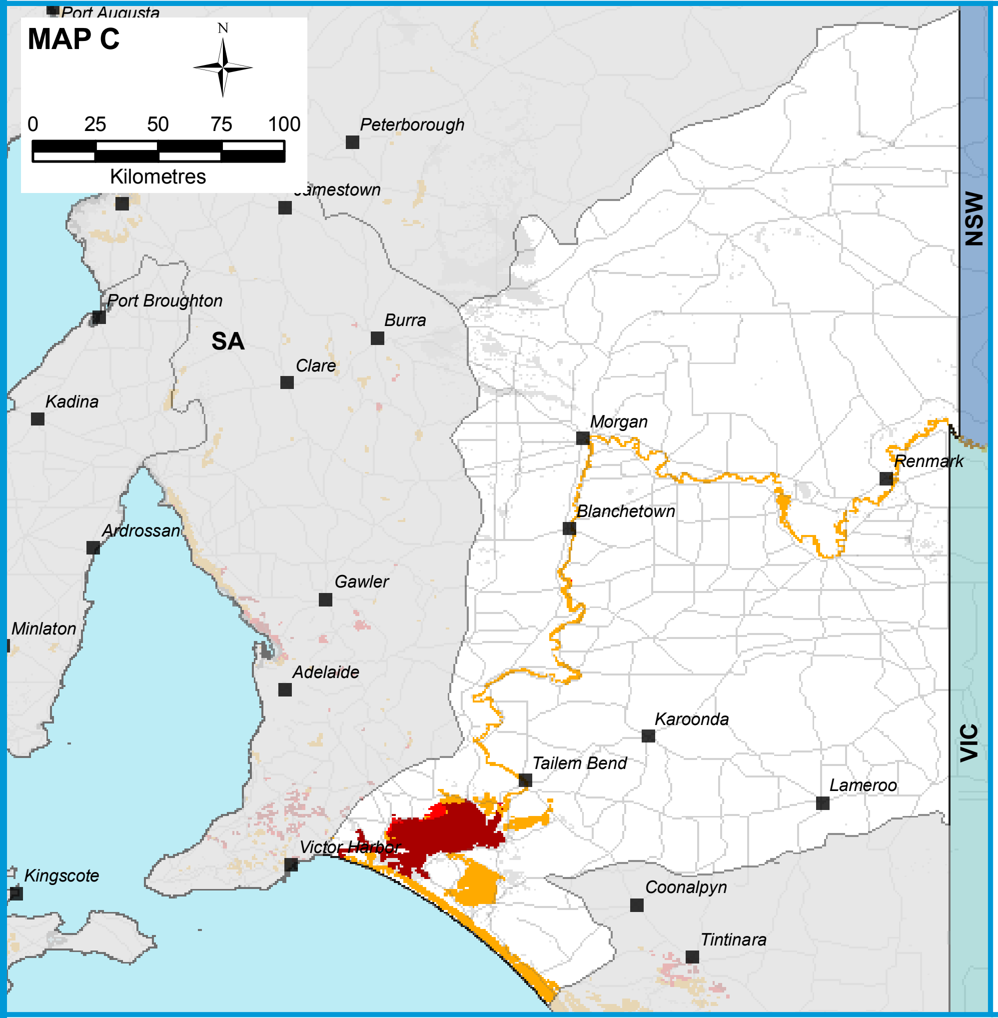
Groundwater Extraction (as at June 30th 2009)

Intensity

- ⬜ Low
- 🟦
- 🟩
- 🟧
- 🟥 Very High

⬜ Prescribed wells area



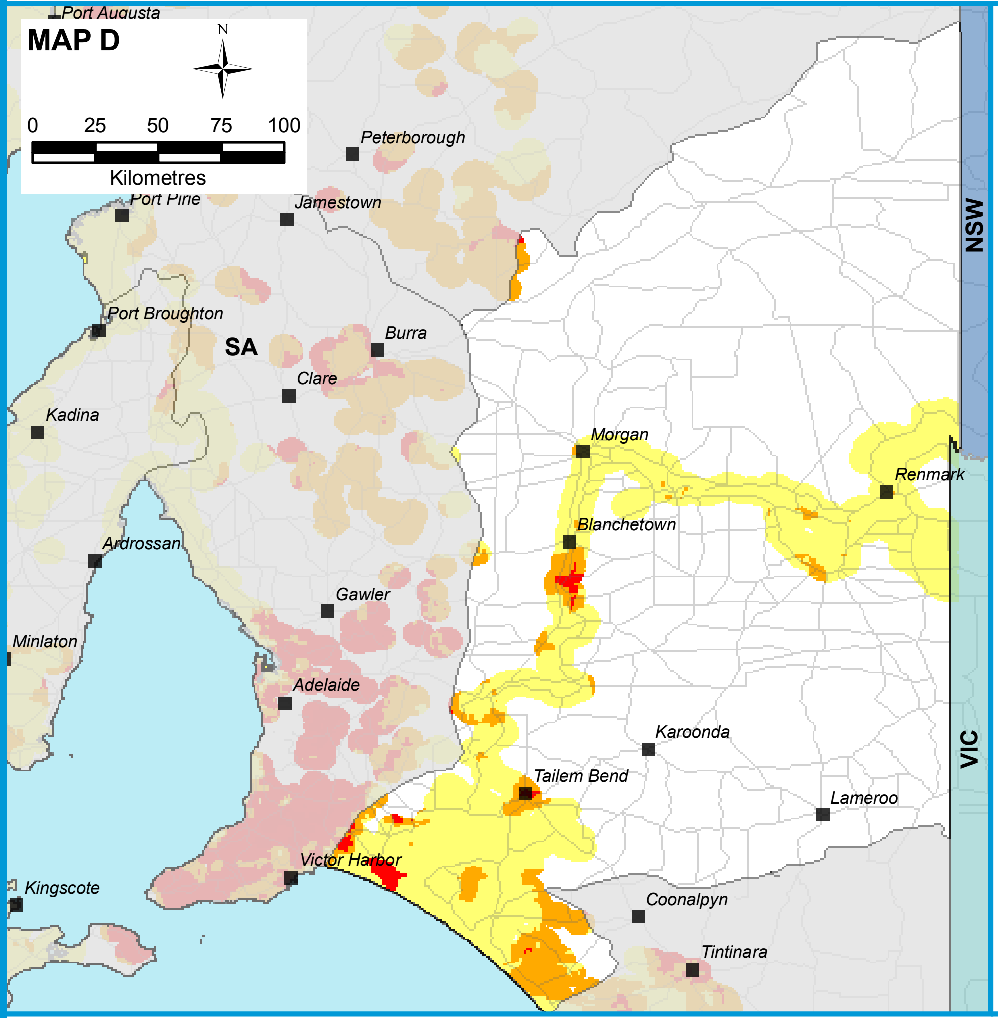


RISK TO WATER DEPENDENT ECOSYSTEMS FROM EXISTING GROUNDWATER EXTRACTION

Water Dependent Assets

Risk Level

- 🟥 Very High
- 🟥 High
- 🟧 Moderate
- ⬜ Low

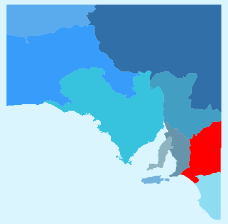


PRELIMINARY GROUNDWATER DEVELOPMENT RISK ZONES FOR GDEs

Potential Groundwater Development Risk Zones

- 🟥 High Risk - irrigation/stock & domestic/industrial (GDE proximity/Low Salinity Resource)
- 🟧 High Risk - stock & domestic/industrial (GDE proximity/Moderate Salinity Resource)
- 🟨 High Risk - industrial/mining (GDE proximity/High Salinity Resource)

LOWER MURRAY



Asset Summary

% State Assets	Layer Accuracy
Wetlands 9.17% (0 – 50%)	High
Rivers & Streams <1% (0 – 50%)	High
Karst features Not Applicable (0 – 50%)	N/A

Threat Summary

Extractive Use	Confidence
Groundwater (Low – High)	Mod

GDE Summary

% Assets GDE	Confidence
Wetlands 73.1% (0 – 100%)	Mod
Rivers & Streams Not Assessed (0 – 100%)	N/A
Karst features Not Applicable (0 – 100%)	N/A

Risk Summary

% Assets at Risk	Confidence
Wetlands 8.24% (0 – 100%)	Mod

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Department for Water
Date: March 2011

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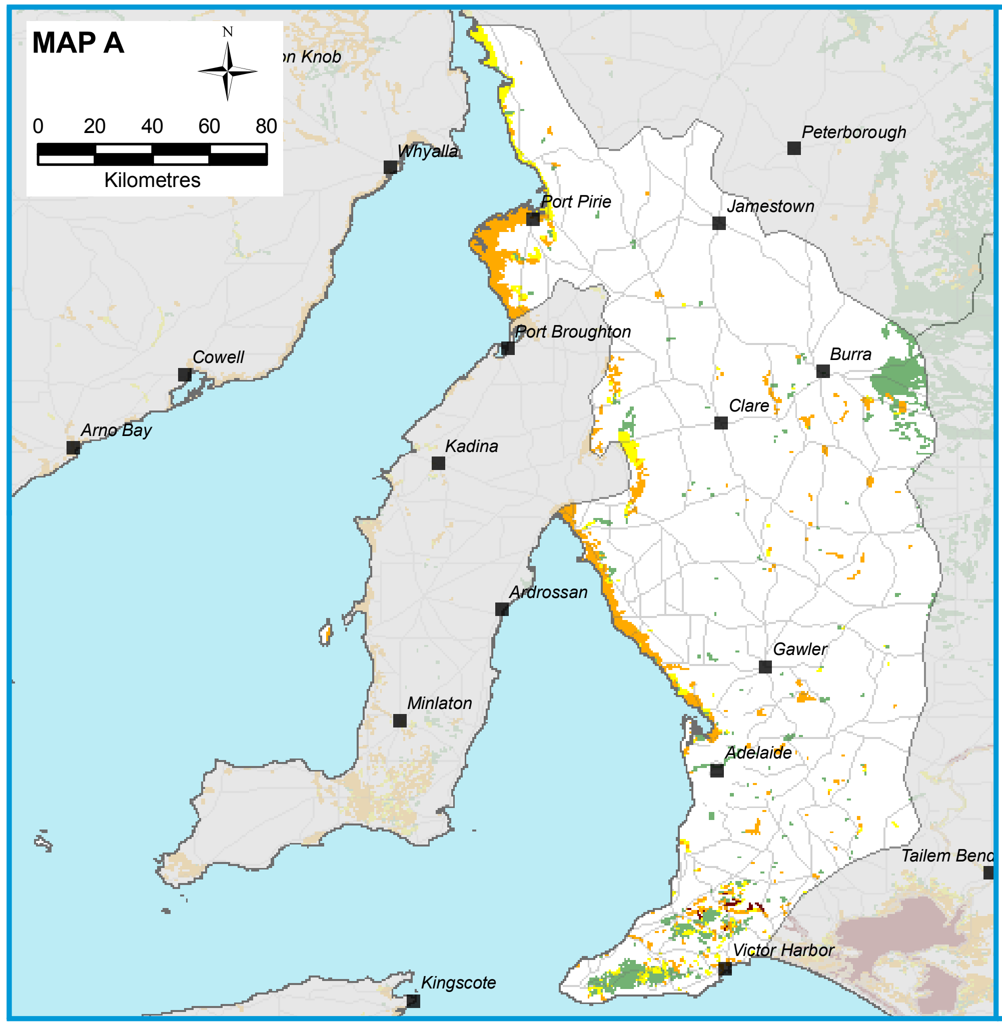
REPORT CARD: MOUNT LOFTY RANGES ANALYSIS UNIT - Wetland Groundwater Dependent Ecosystems



ASSET VULNERABILITY GROUNDWATER DEPENDENCE

Water Dependent Assets

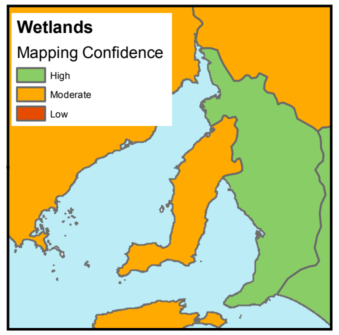
Likelihood of Groundwater Dependence

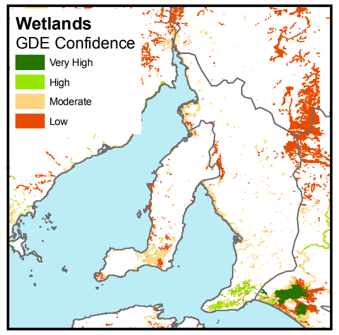
🟥 Very High

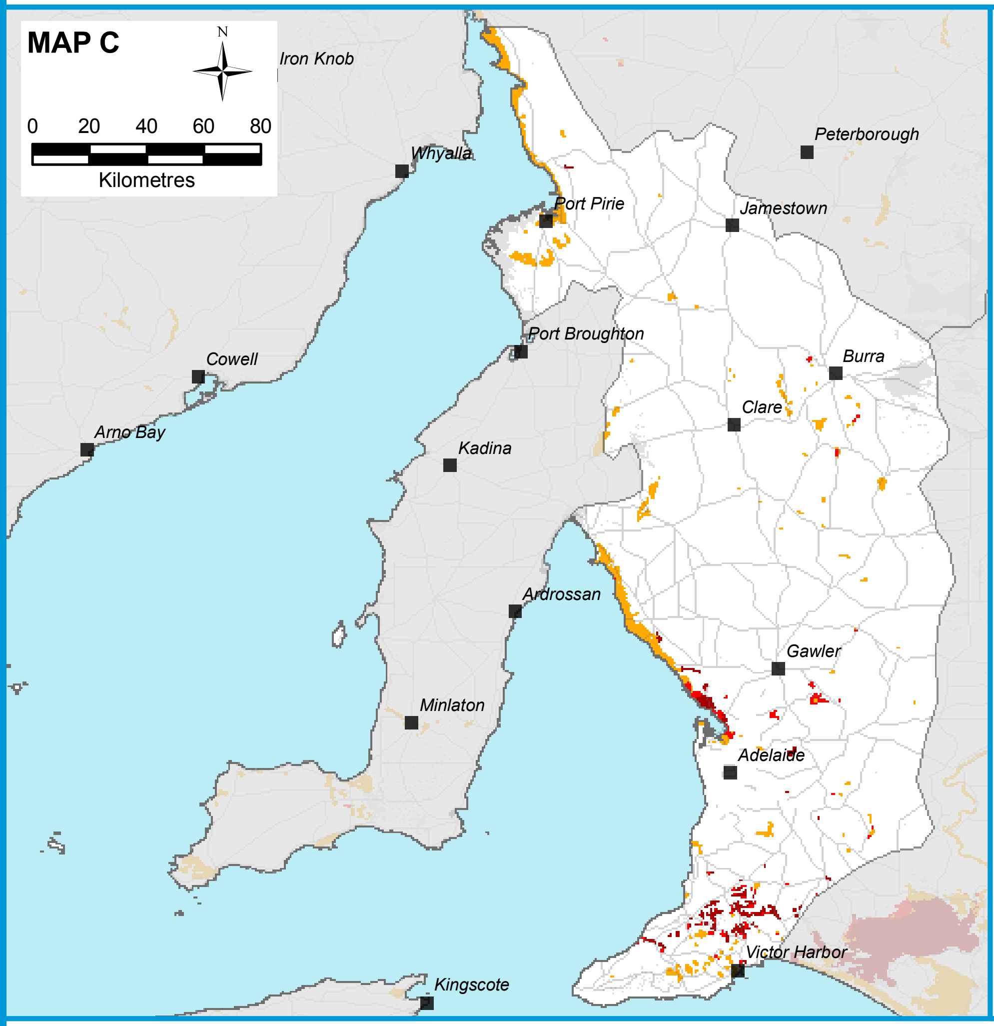
🟧 High

🟨 Moderate

🟩 Low (Surface Water Dependent)







RISK TO WATER DEPENDENT ECOSYSTEMS FROM EXISTING GROUNDWATER EXTRACTION

Water Dependent Assets

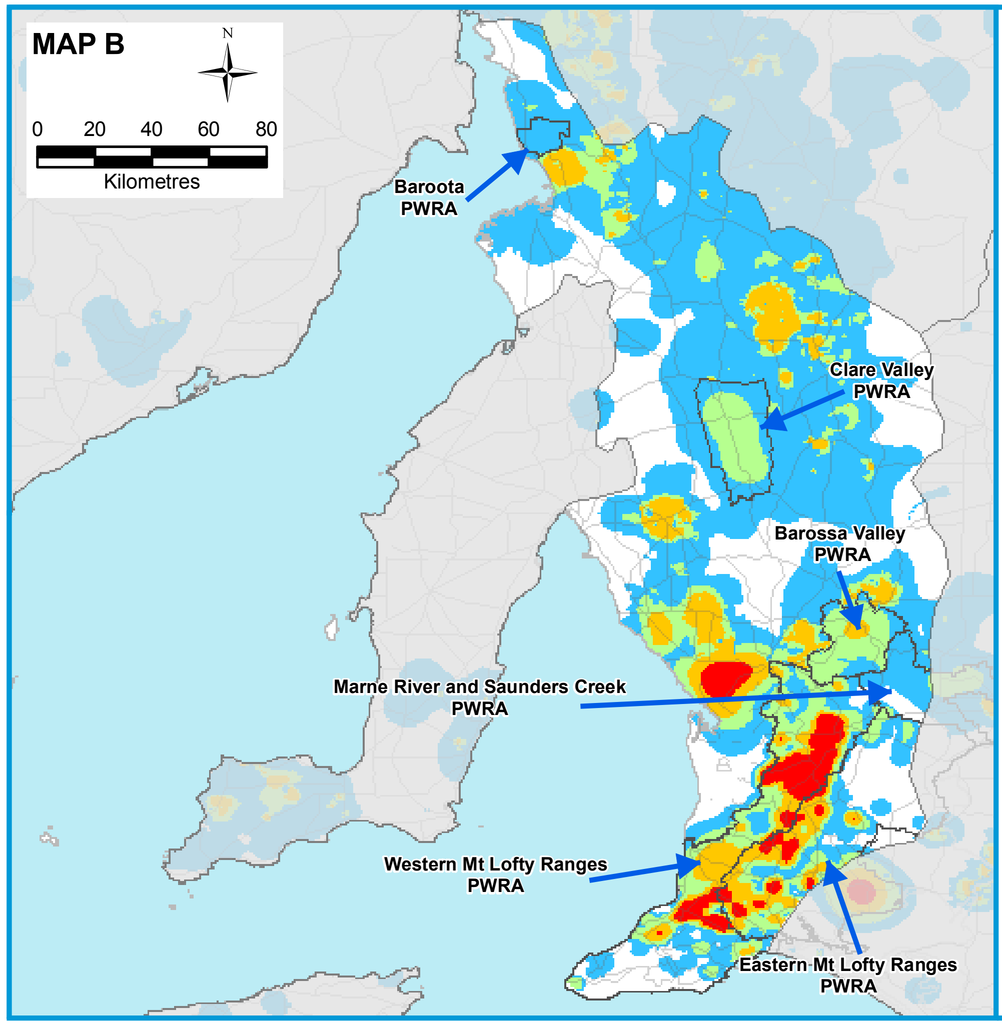
Risk Level

🟥 Very High

🟥 High

🟧 Moderate

⬜ Low



THREATS TO GDE PROCESSES - GROUNDWATER EXTRACTION

Groundwater Extraction (as at June 30th 2009)

Intensity

☐ Low

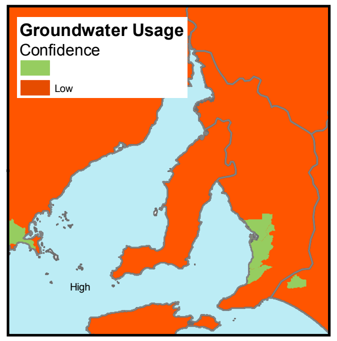
🟦

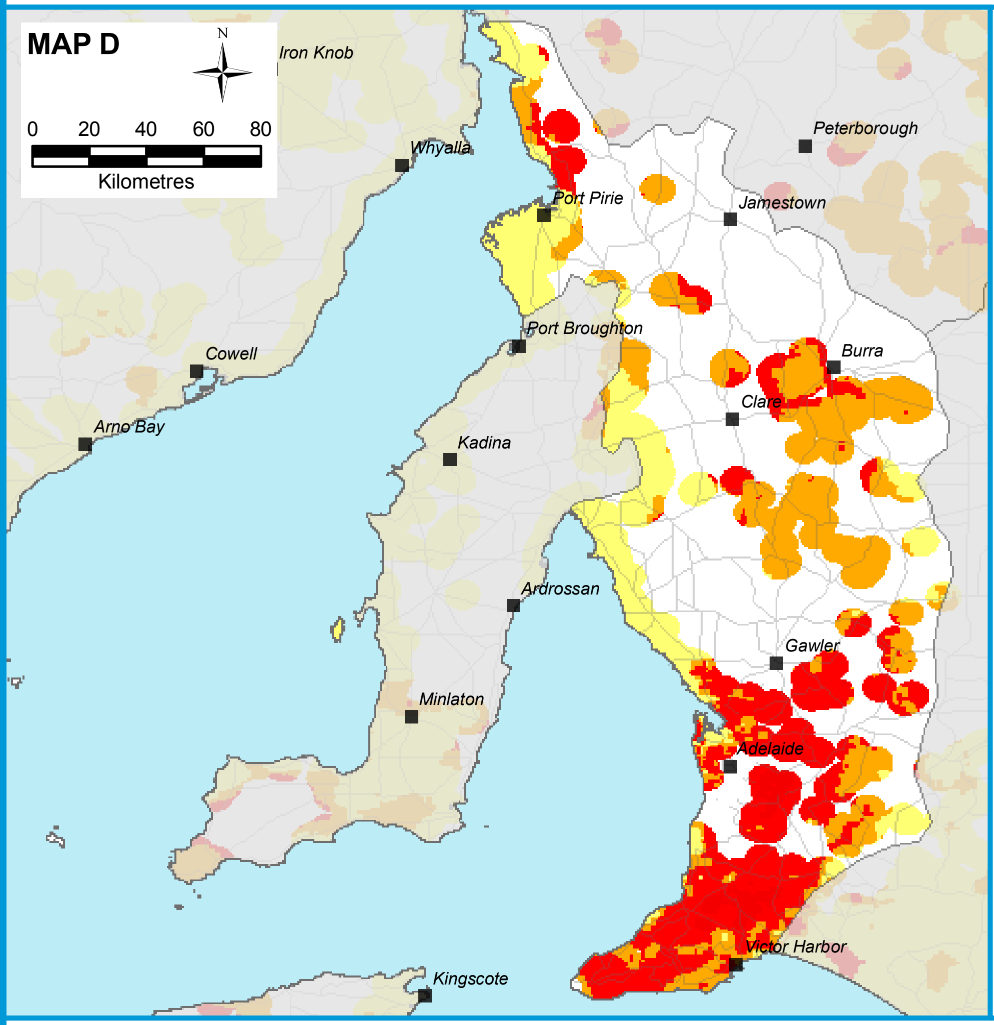
🟩

🟧

🟥 Very High

☐ Prescribed Water Resources Areas





PRELIMINARY GROUNDWATER DEVELOPMENT RISK ZONES FOR GDEs

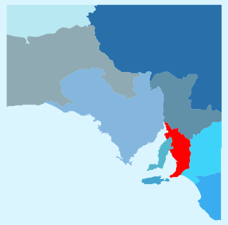
Potential Groundwater Development Risk Zones

🟥 High Risk - irrigation/stock & domestic/ industrial (GDE proximity/Low Salinity Resource)

🟧 High Risk - stock & domestic/industrial (GDE proximity/Moderate Salinity Resource)

🟨 High Risk - industrial/mining (GDE proximity/High Salinity Resource)

Mt LOFTY RANGES



Asset Summary

% State Assets		Layer Accuracy
Wetlands	4.27% (0 – 50%)	High
Rivers & Streams	3.62% (0 – 50%)	High
Karst features	Not Applicable (0 – 50%)	N/A

Threat Summary

Extractive Use		Confidence
Groundwater	Low – High	Mod

GDE Summary

% Assets GDE		Confidence
Wetlands	66.0% (0 – 100%)	Mod
Rivers & Streams	Not Assessed (0 – 100%)	N/A
Karst features	Not Applicable (0 – 100%)	N/A

Risk Summary

% Assets at Risk		Confidence
Wetlands	45.99% (0 – 100%)	Mod

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Produced By: Aquatic Ecosystems Group
Department for Water
Date: March 2011

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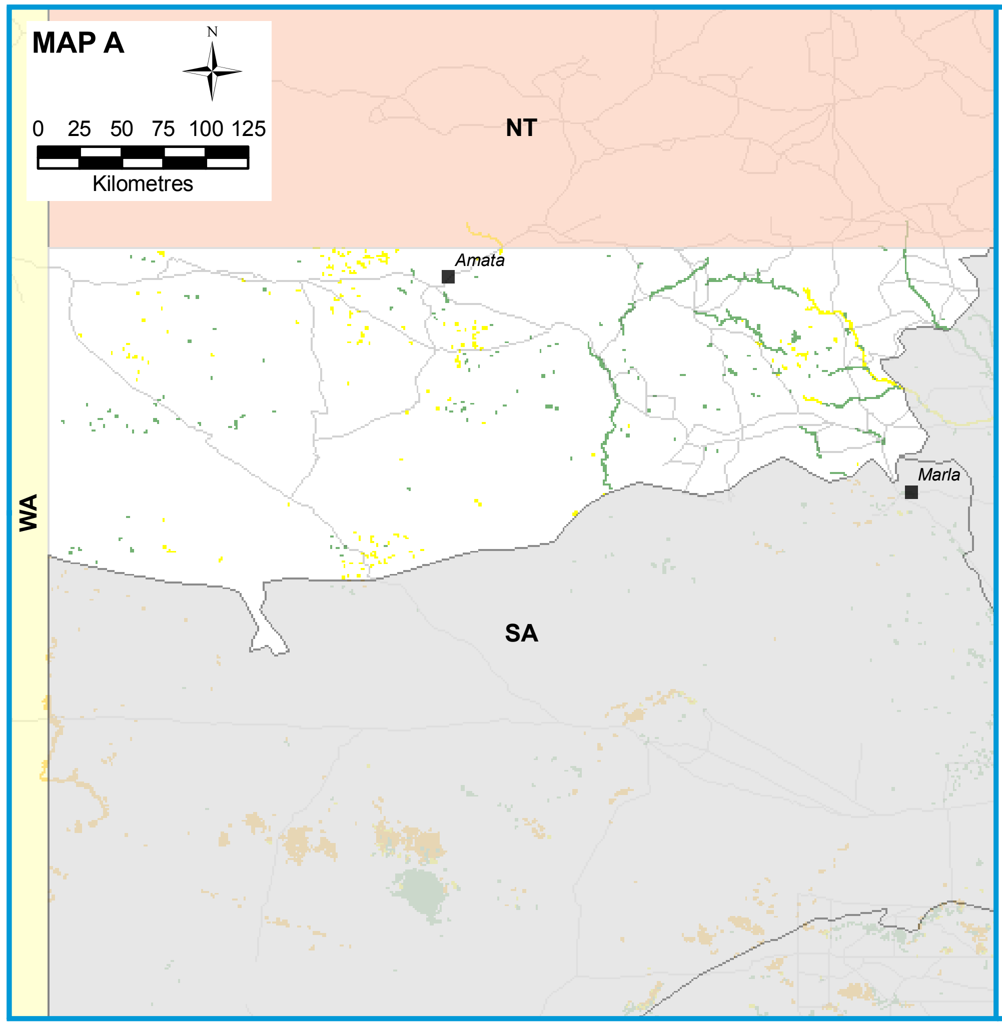
REPORT CARD: MUSGRAVE RANGES ANALYSIS UNIT - Wetland Groundwater Dependent Ecosystems

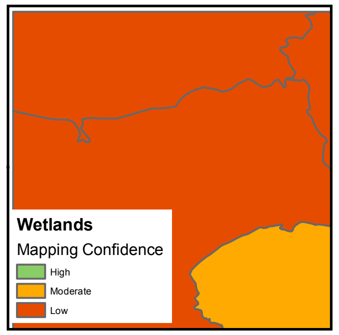


ASSET VULNERABILITY GROUNDWATER DEPENDENCE

Water Dependent Assets

Likelihood of Groundwater Dependence

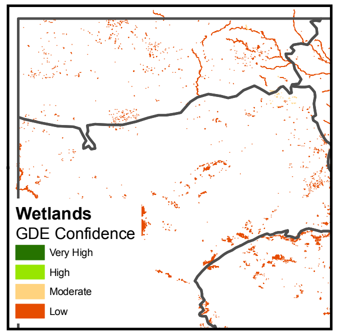
- 🟥 Very High
- 🟧 High
- 🟨 Moderate
- 🟩 Low (Surface Water Dependent)



Wetlands

Mapping Confidence

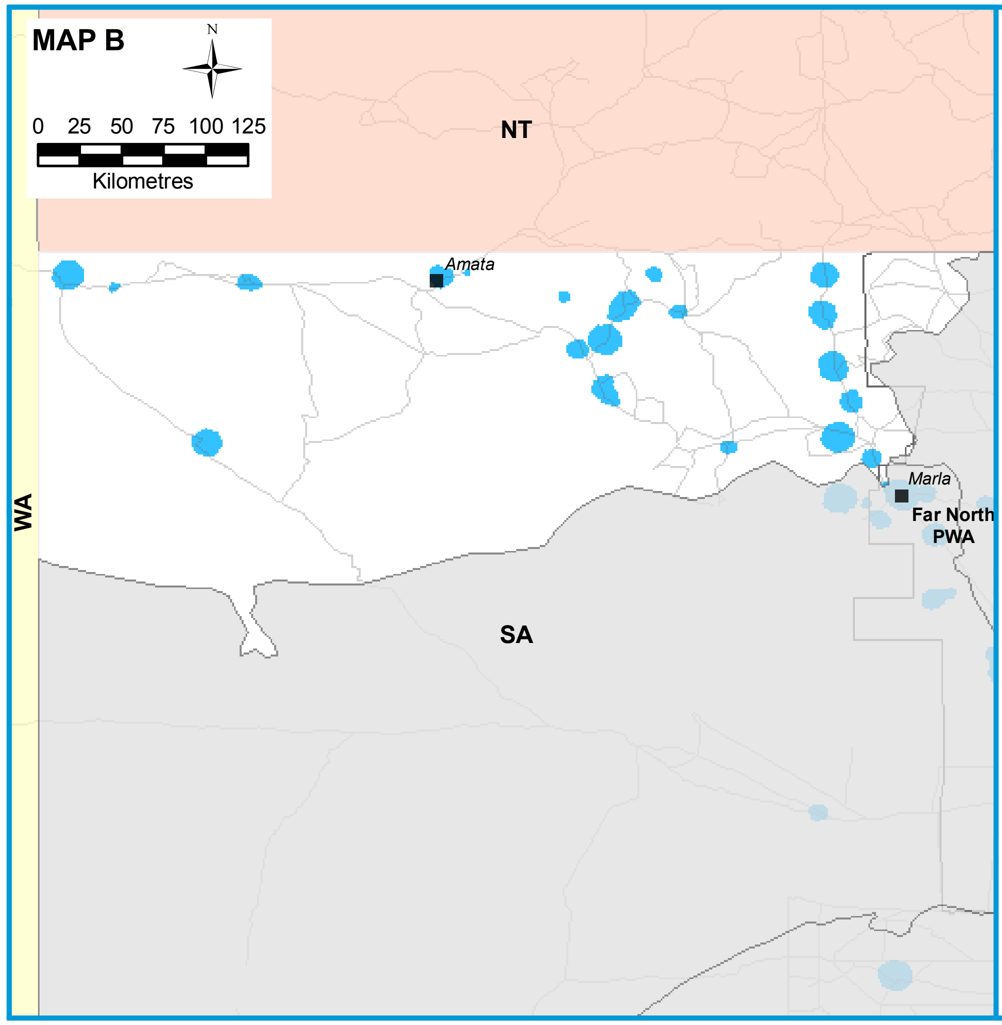
- 🟩 High
- 🟧 Moderate
- 🟥 Low



Wetlands

GDE Confidence

- 🟩 Very High
- 🟩 High
- 🟨 Moderate
- 🟥 Low



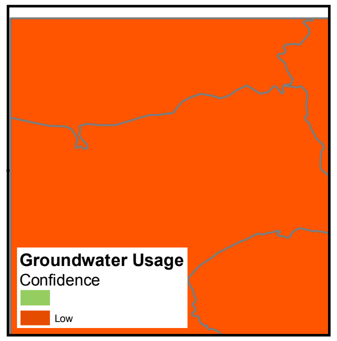
THREATS TO GDE PROCESSES - GROUNDWATER EXTRACTION

Groundwater Extraction (as at June 30th 2009)

Intensity

- ☐ Low
- 🟦
- 🟩
- 🟨
- 🟥 Very High

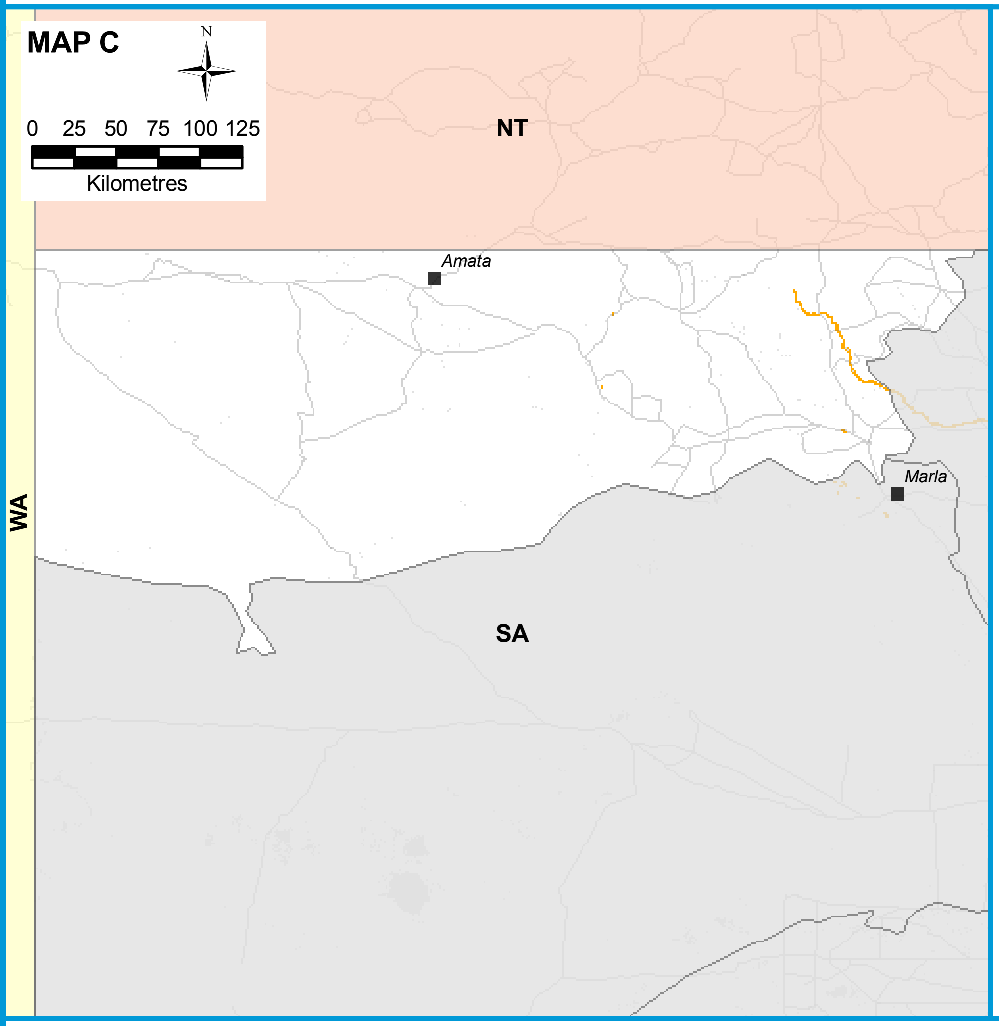
☐ Prescribed wells area



Groundwater Usage

Confidence

- 🟩
- 🟥 Low

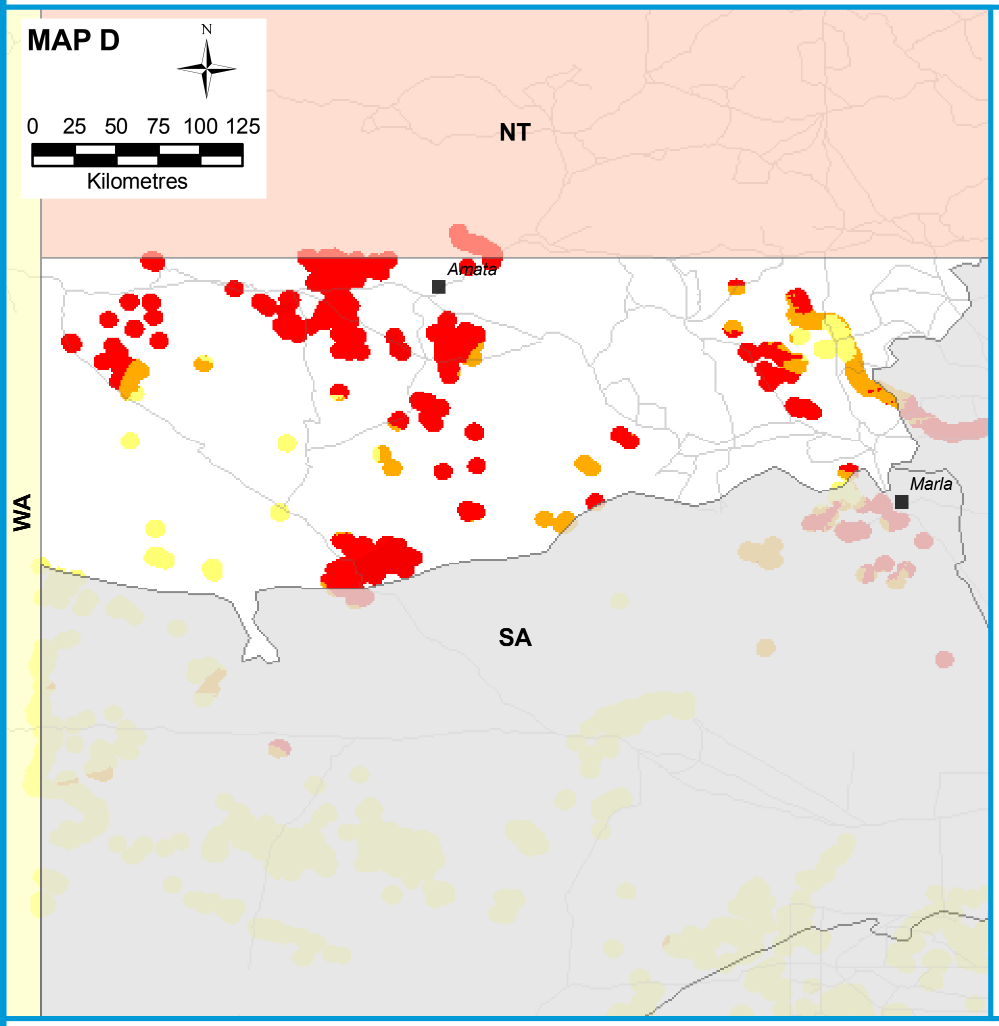


RISK TO WATER DEPENDENT ECOSYSTEMS FROM EXISTING GROUNDWATER EXTRACTION

Water Dependent Assets

Risk Level

- 🟥 Very High
- 🟥 High
- 🟧 Moderate
- ⬜ Low

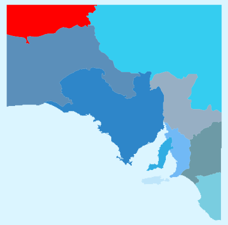


PRELIMINARY GROUNDWATER DEVELOPMENT RISK ZONES FOR GDEs

Potential Groundwater Development Risk Zones

- 🟥 High Risk - irrigation/stock & domestic/industrial (GDE proximity/Low Salinity Resource)
- 🟧 High Risk - stock & domestic/industrial (GDE proximity/Moderate Salinity Resource)
- 🟨 High Risk - industrial/mining (GDE proximity/High Salinity Resource)

MUSGRAVE RANGES



Asset Summary

% State Assets	Layer Accuracy
Wetlands 1.21% 0 50%	Low
Rivers & Streams 6.48% 0 50%	Low
Karst features Not Applicable 0 50%	N/A

Threat Summary

Extractive Use	Confidence
Groundwater Low High	Low

GDE Summary

% Assets GDE	Confidence
Wetlands 43.05% 0 100%	Low
Rivers & Streams Not Assessed 0 100%	N/A
Karst features Not Applicable 0 100%	N/A

Risk Summary

% Assets at Risk	Confidence
Wetlands 0.41% 0 100%	Low

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Department for Water
Date: March 2011

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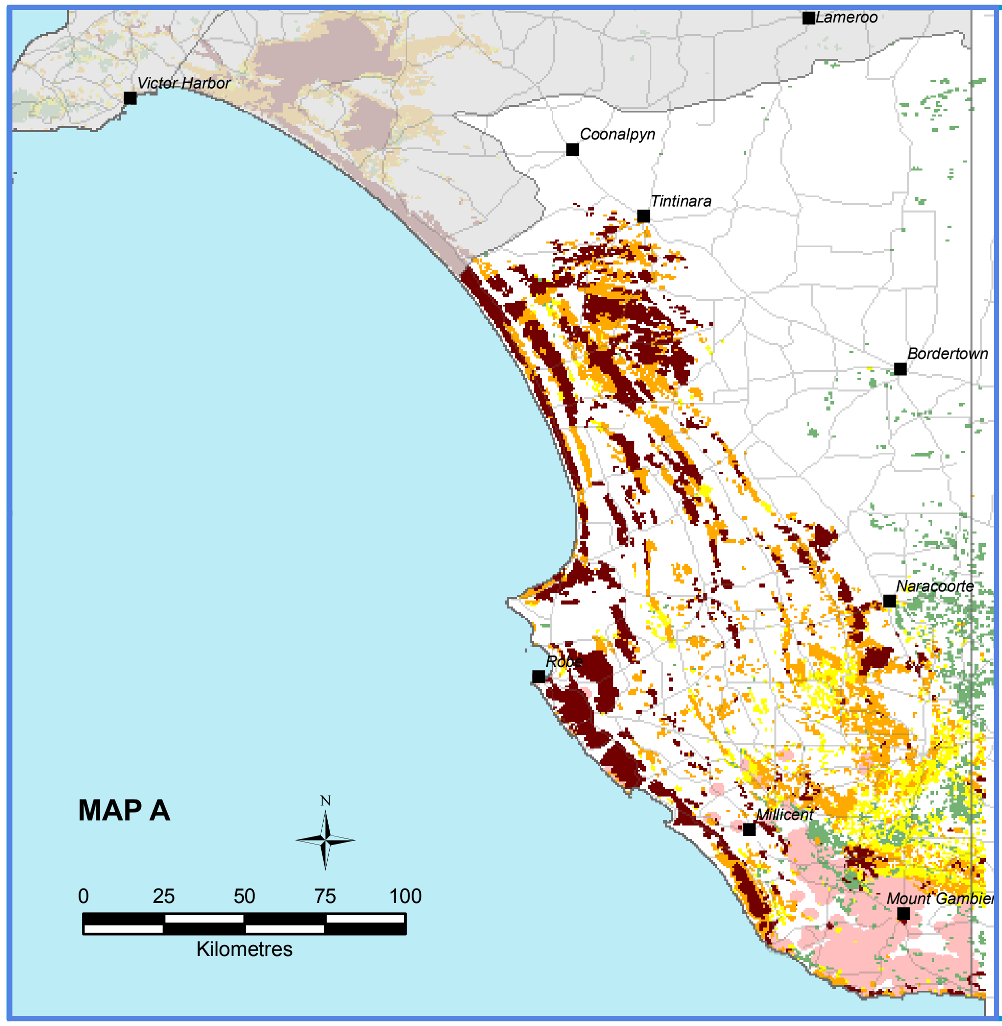
REPORT CARD: SOUTH EAST ANALYSIS UNIT - Wetland Groundwater Dependent Ecosystems

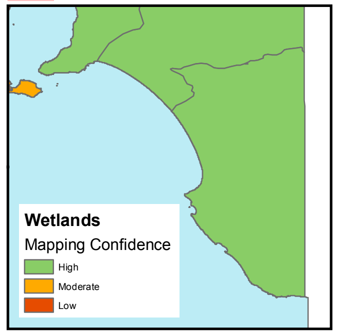


ASSET VULNERABILITY GROUNDWATER DEPENDENCE

Water Dependent Assets

Likelihood of Groundwater Dependence

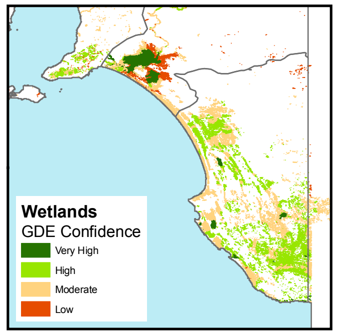
- 🟥 Very High
- 🟧 High
- 🟨 Moderate
- 🟩 Low (Surface Water Dependent)
- ▨ Karst GDE



Wetlands

Mapping Confidence

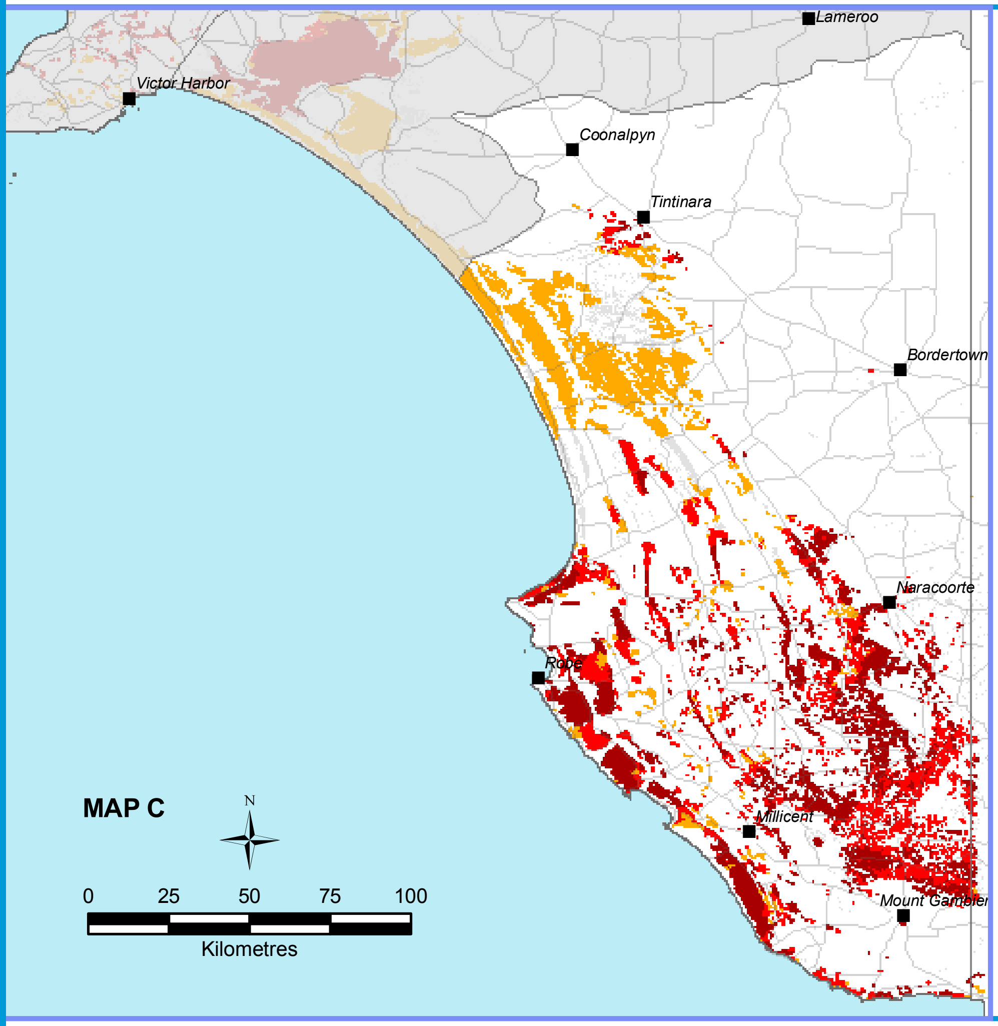
- 🟩 High
- 🟧 Moderate
- 🟥 Low



Wetlands

GDE Confidence

- 🟩 Very High
- 🟩 High
- ▨ Moderate
- 🟥 Low

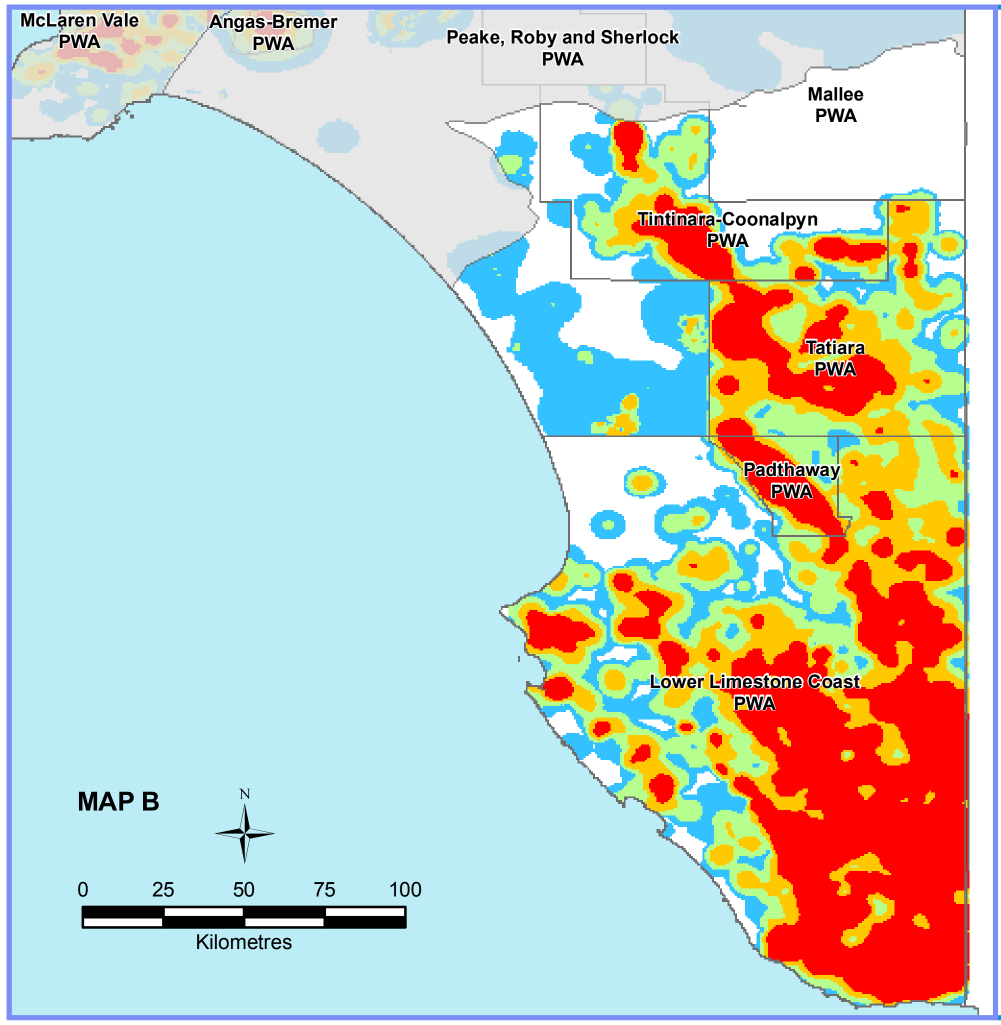


RISK TO WATER DEPENDENT ECOSYSTEMS FROM EXISTING GROUNDWATER EXTRACTION

Water Dependent Assets

Risk Level

- 🟥 Very High
- 🟥 High
- 🟧 Moderate
- ⬜ Low



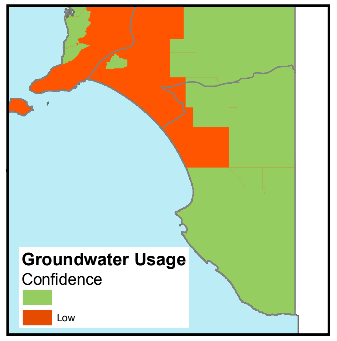
THREATS TO GDE PROCESSES - GROUNDWATER EXTRACTION

Groundwater Extraction (as at June 30th 2009)

Intensity

- ⬜ Low
- 🟦
- 🟩
- 🟧
- 🟥 Very High

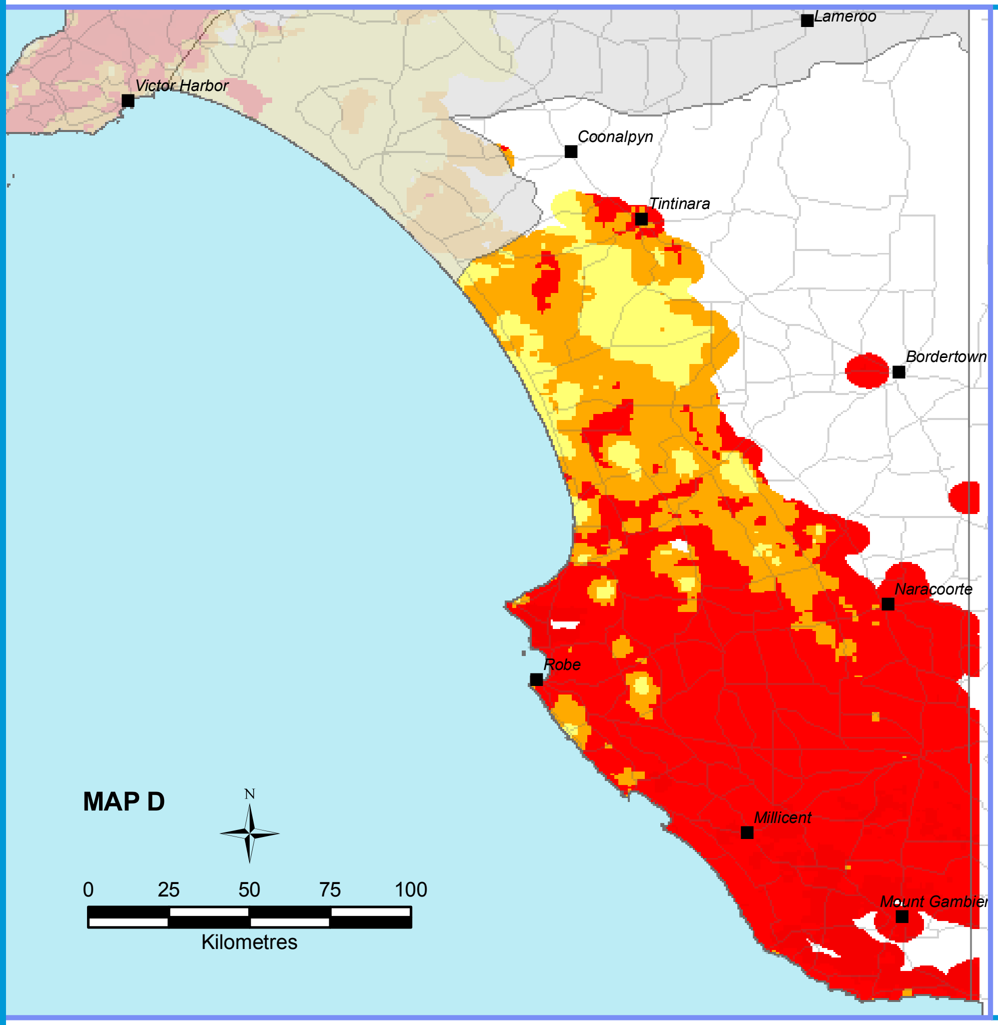
⬜ Prescribed wells area



Groundwater Usage

Confidence

- 🟩
- 🟧 Low

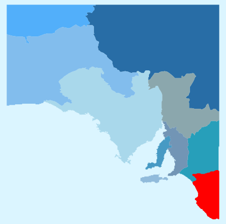


PRELIMINARY GROUNDWATER DEVELOPMENT RISK ZONES FOR GDEs

Potential Groundwater Development Risk Zones

- 🟥 High Risk - irrigation/stock & domestic/industrial (GDE proximity/Low Salinity Resource)
- 🟧 High Risk - stock & domestic/industrial (GDE proximity/Moderate Salinity Resource)
- 🟨 High Risk - industrial/mining (GDE proximity/High Salinity Resource)

SOUTH EAST



Asset Summary

% State Assets	**Layer Accuracy**
Wetlands 26.16% (0 – 50%)	High
Rivers & Streams <1% (0 – 50%)	Mod
Karst features >50% (0 – 50%)	Low

Threat Summary

Extractive Use	**Confidence**
Groundwater (Low – High)	High

GDE Summary

% Assets GDE	**Confidence**
Wetlands 76.7% (0 – 100%)	Mod
Rivers & Streams Not Assessed (0 – 100%)	N/A
Karst features (0 – 100%)	High

Risk Summary

% Assets at Risk	**Confidence**
Wetlands 66.96% (0 – 100%)	High

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Date: March 2011

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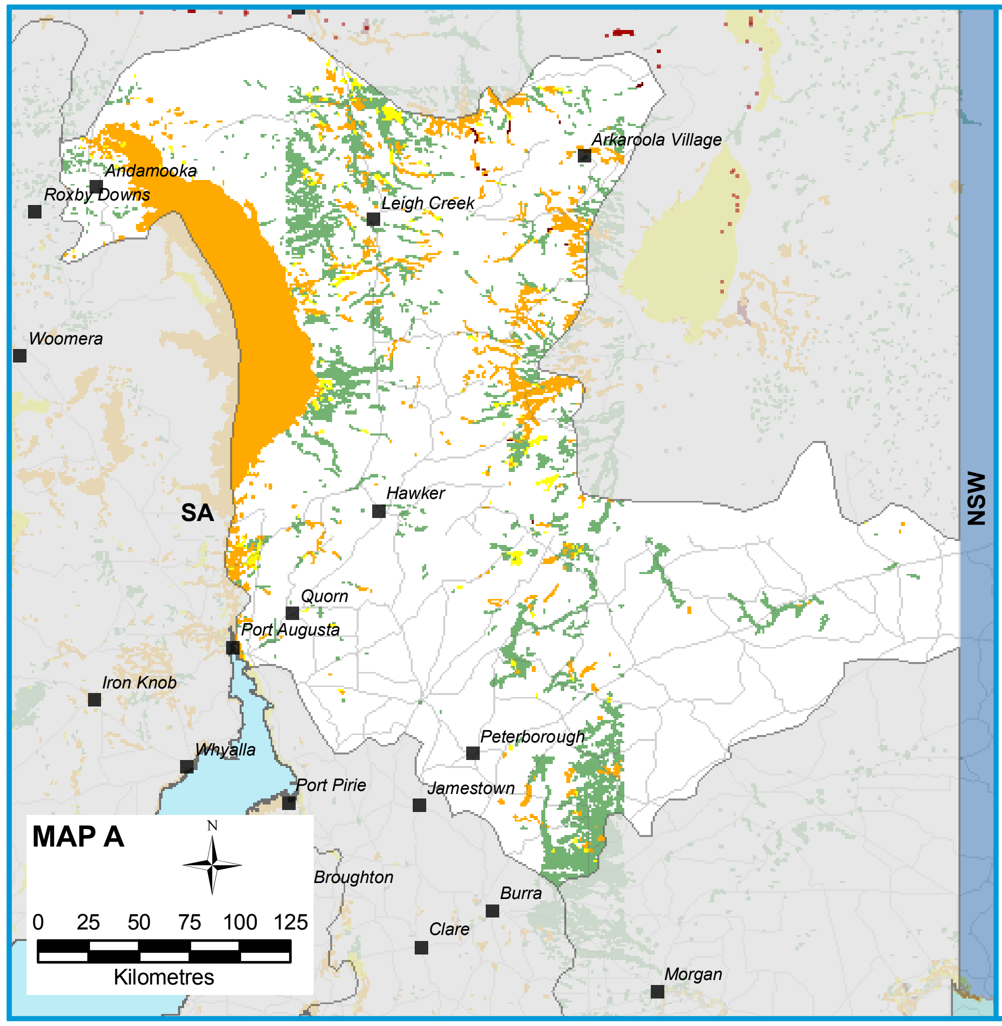
REPORT CARD: TORRENS ANALYSIS UNIT - Wetland Groundwater Dependent Ecosystems

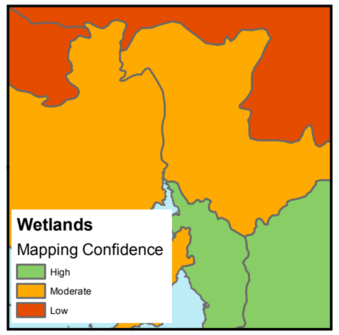


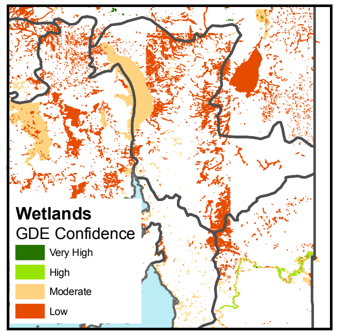
ASSET VULNERABILITY GROUNDWATER DEPENDENCE

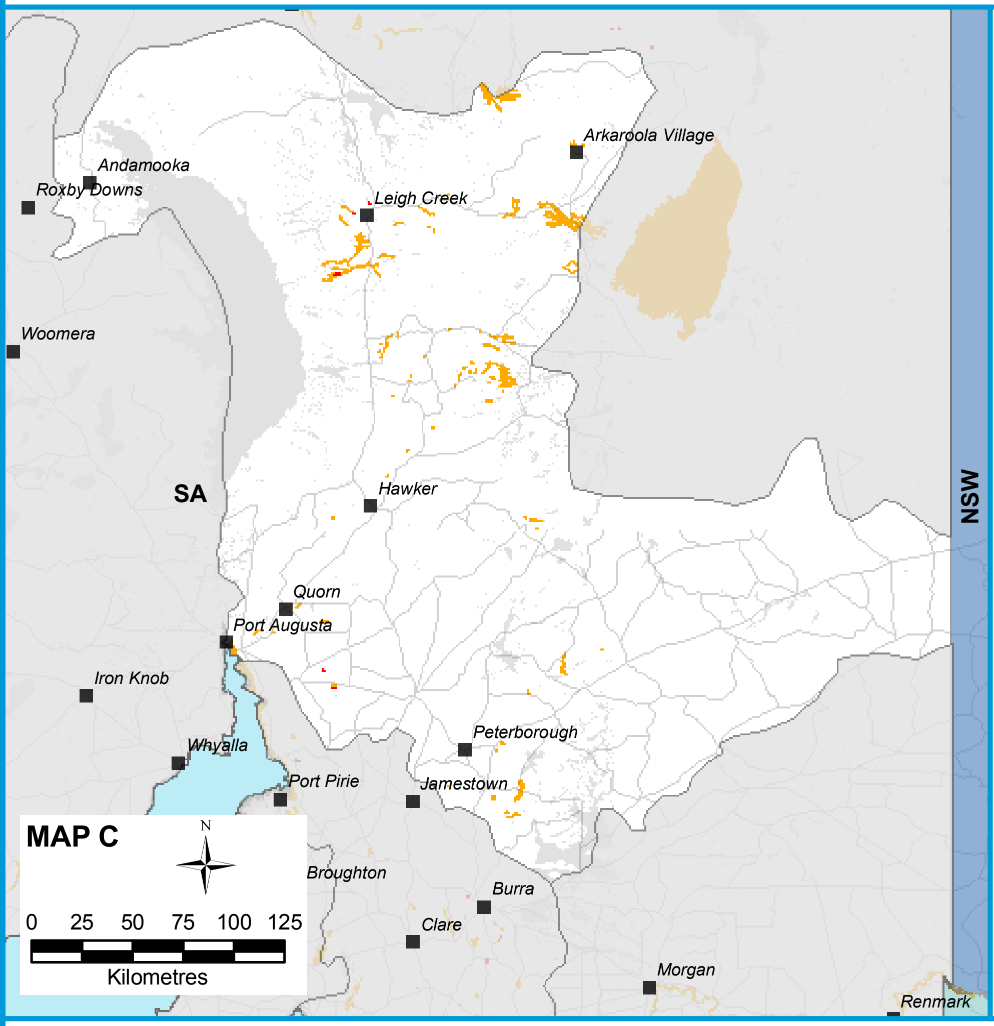
Water Dependent Assets

Likelihood of Groundwater Dependence

- 🟥 Very High
- 🟧 High
- 🟨 Moderate
- 🟩 Low (Surface Water Dependent)





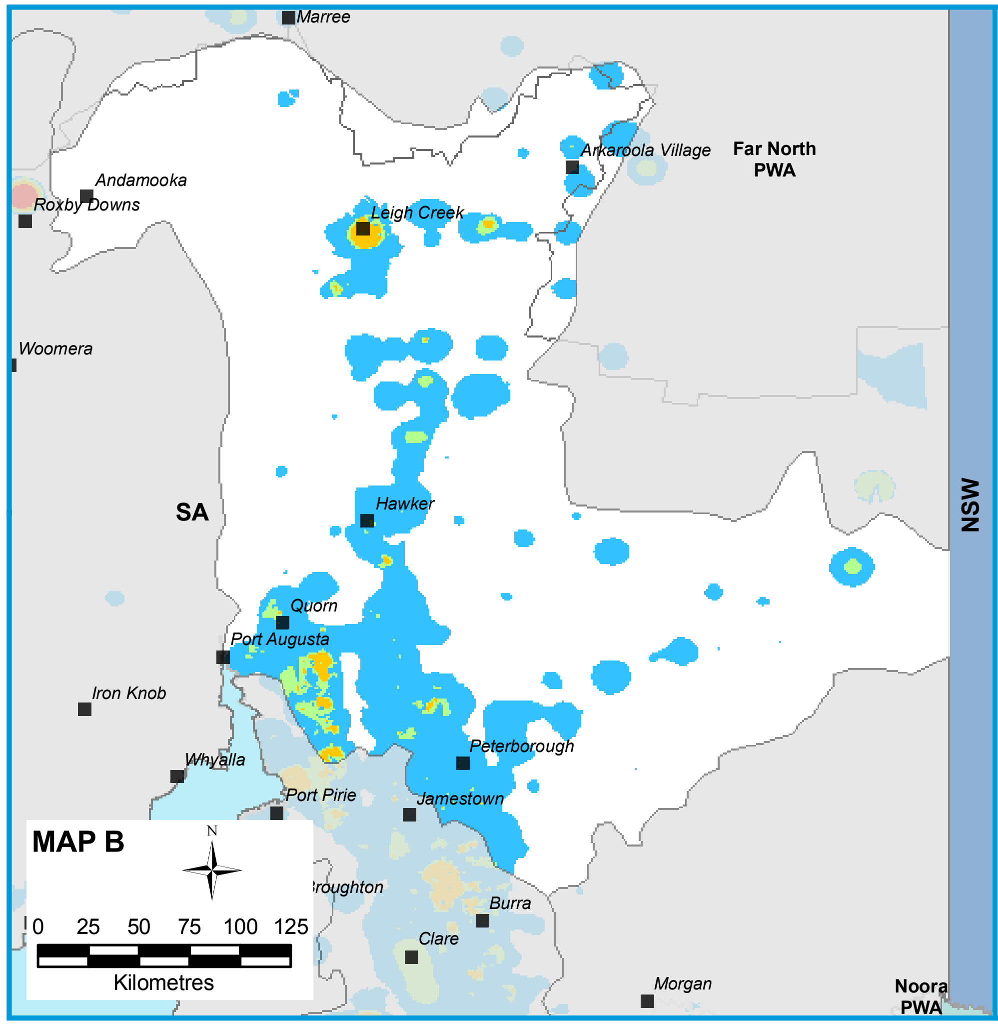


RISK TO WATER DEPENDENT ECOSYSTEMS FROM EXISTING GROUNDWATER EXTRACTION

Water Dependent Assets

Risk Level

- 🟥 Very High
- 🟥 High
- 🟧 Moderate
- ⬜ Low



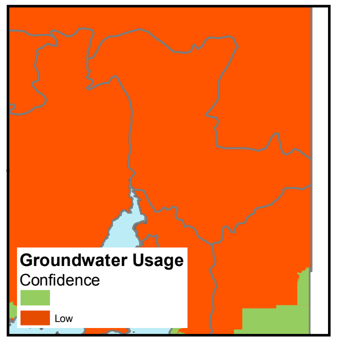
THREATS TO GDE PROCESSES - GROUNDWATER EXTRACTION

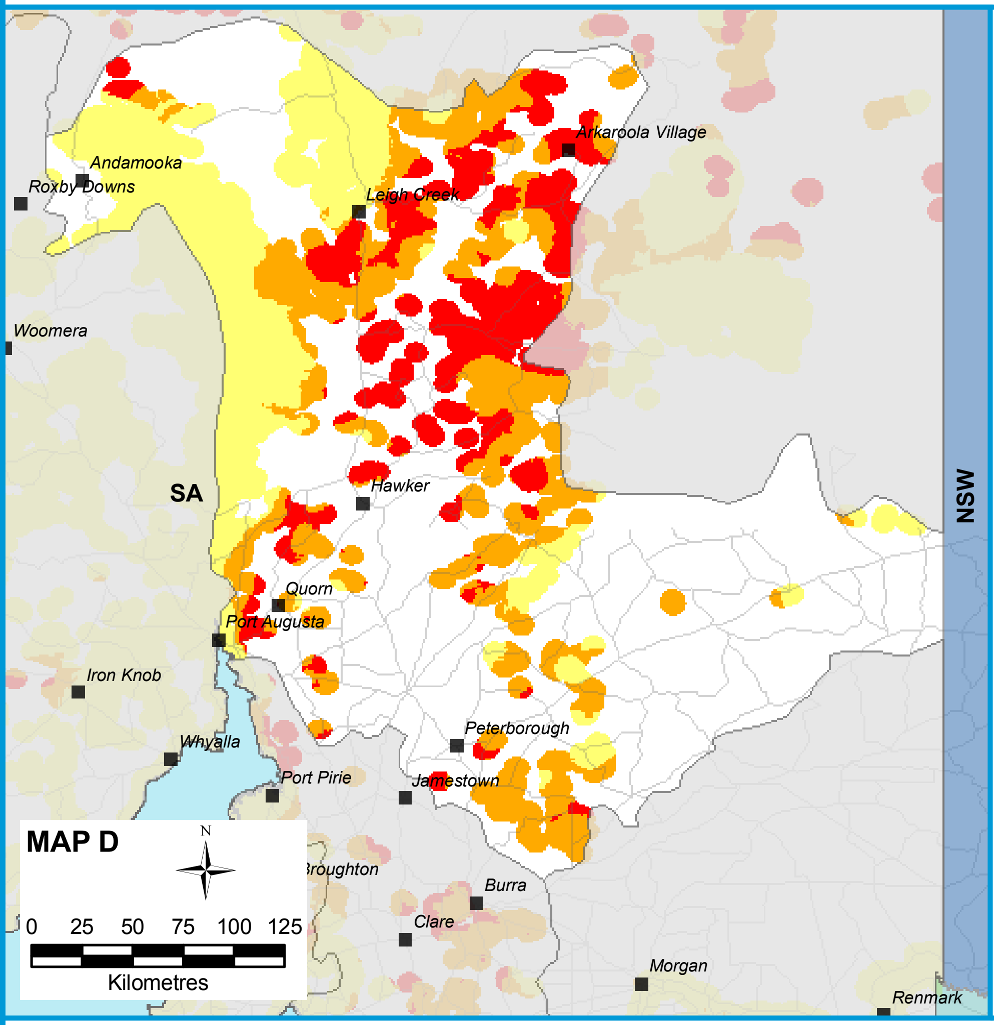
Groundwater Extraction (as at June 30th 2009)

Intensity

- ⬜ Low
- 🟦
- 🟩
- 🟨
- 🟥 Very High

⬜ Prescribed wells area





PRELIMINARY GROUNDWATER DEVELOPMENT RISK ZONES FOR GDEs

Potential Groundwater Development Risk Zones

- 🟥 High Risk - irrigation/stock & domestic/industrial (GDE proximity/Low Salinity Resource)
- 🟧 High Risk - stock & domestic/industrial (GDE proximity/Moderate Salinity Resource)
- 🟨 High Risk - industrial/mining (GDE proximity/High Salinity Resource)

TORRENS

Asset Summary

% State Assets	Layer Accuracy
Wetlands 9.3% (0 – 50%)	Mod
Rivers & Streams 12.0% (0 – 50%)	Mod
Karst features Not Applicable (0 – 50%)	N/A

Threat Summary

Extractive Use	Confidence
Groundwater Low – High	Low

GDE Summary

% Assets GDE	Confidence
Wetlands 42.05% (0 – 100%)	Low
Rivers & Streams Not Assessed (0 – 100%)	N/A
Karst features Not Applicable (0 – 100%)	N/A

Risk Summary

% Assets at Risk	Confidence
Wetlands 5.98% (0 – 100%)	Low

Datum: Australian Geodetic Datum 1984
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Department for Water
Date: March 2011

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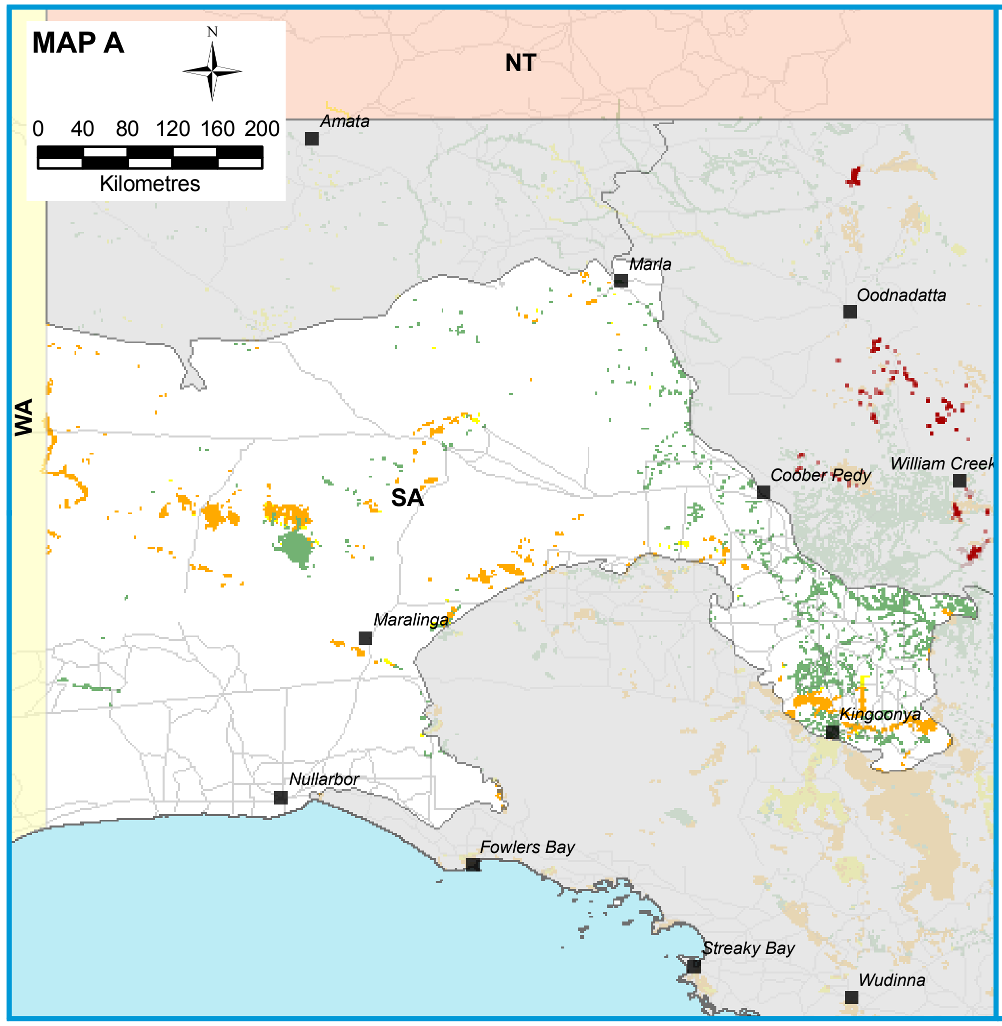
REPORT CARD: WARBURTON ANALYSIS UNIT - Wetland Groundwater Dependent Ecosystems

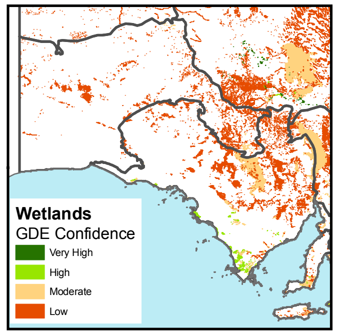


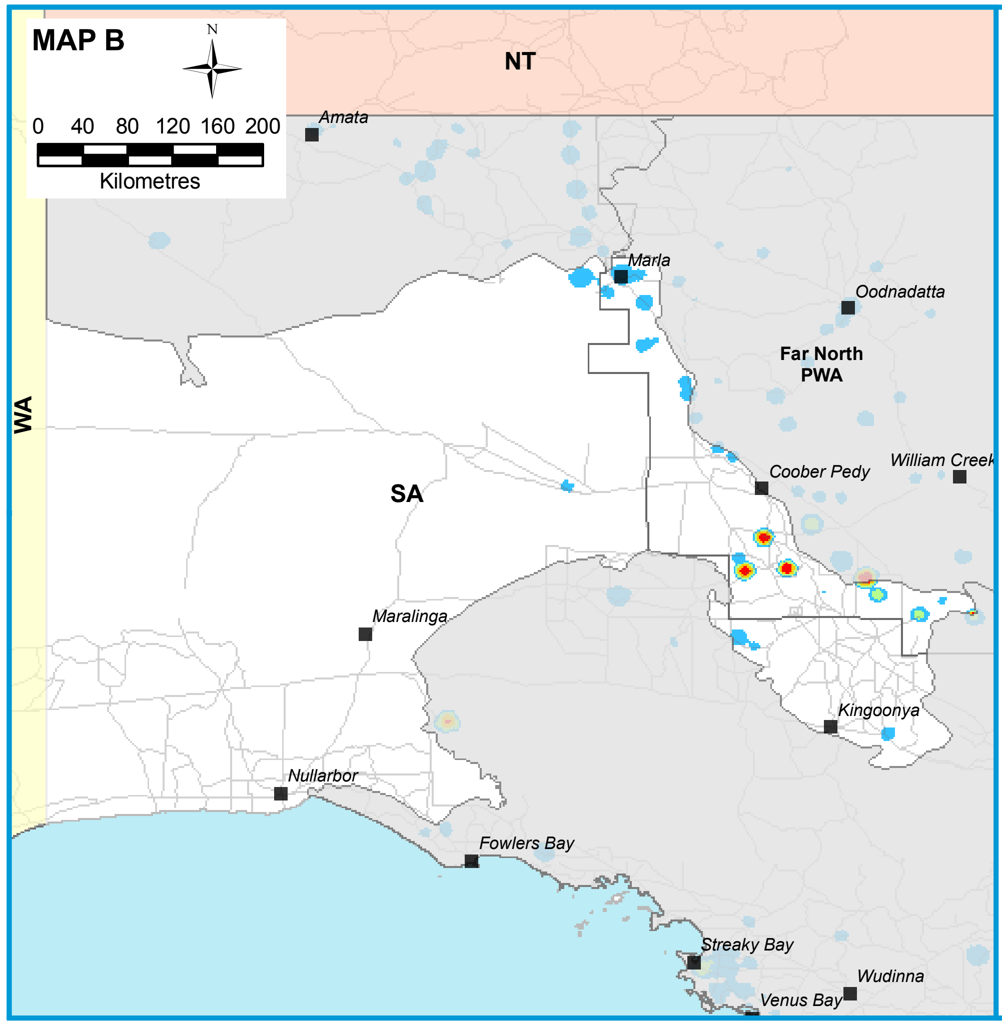
ASSET VULNERABILITY GROUNDWATER DEPENDENCE

Water Dependent Assets

Likelihood of Groundwater Dependence

- 🟥 Very High
- 🟧 High
- 🟨 Moderate
- 🟩 Low (Surface Water Dependent)





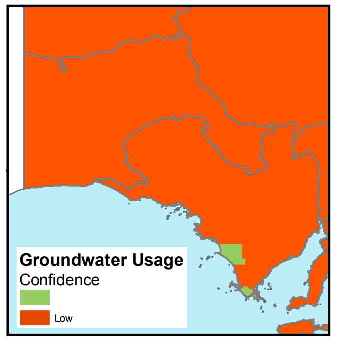
THREATS TO GDE PROCESSES - GROUNDWATER EXTRACTION

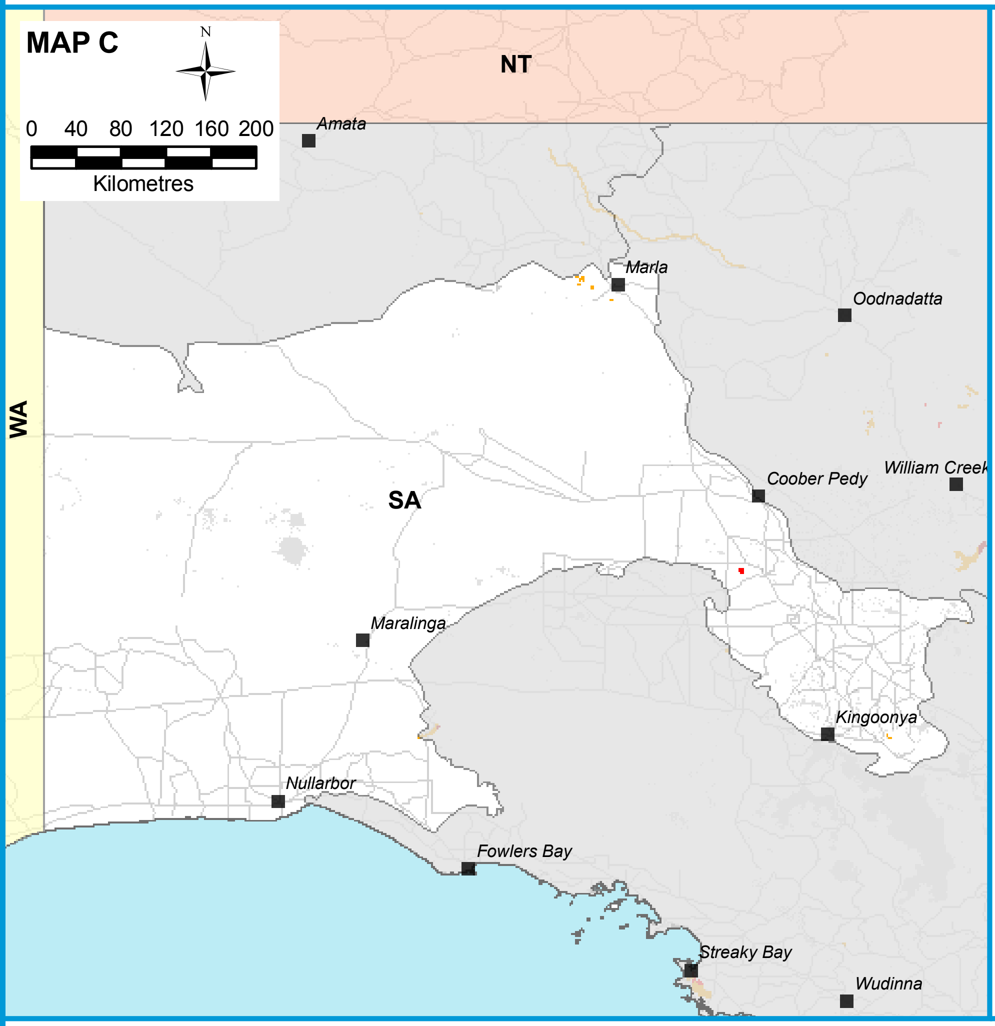
Groundwater Extraction (as at June 30th 2009)

Intensity

- ☐ Low
- 🟦
- 🟩
- 🟨
- 🟥 Very High

☐ Prescribed wells area



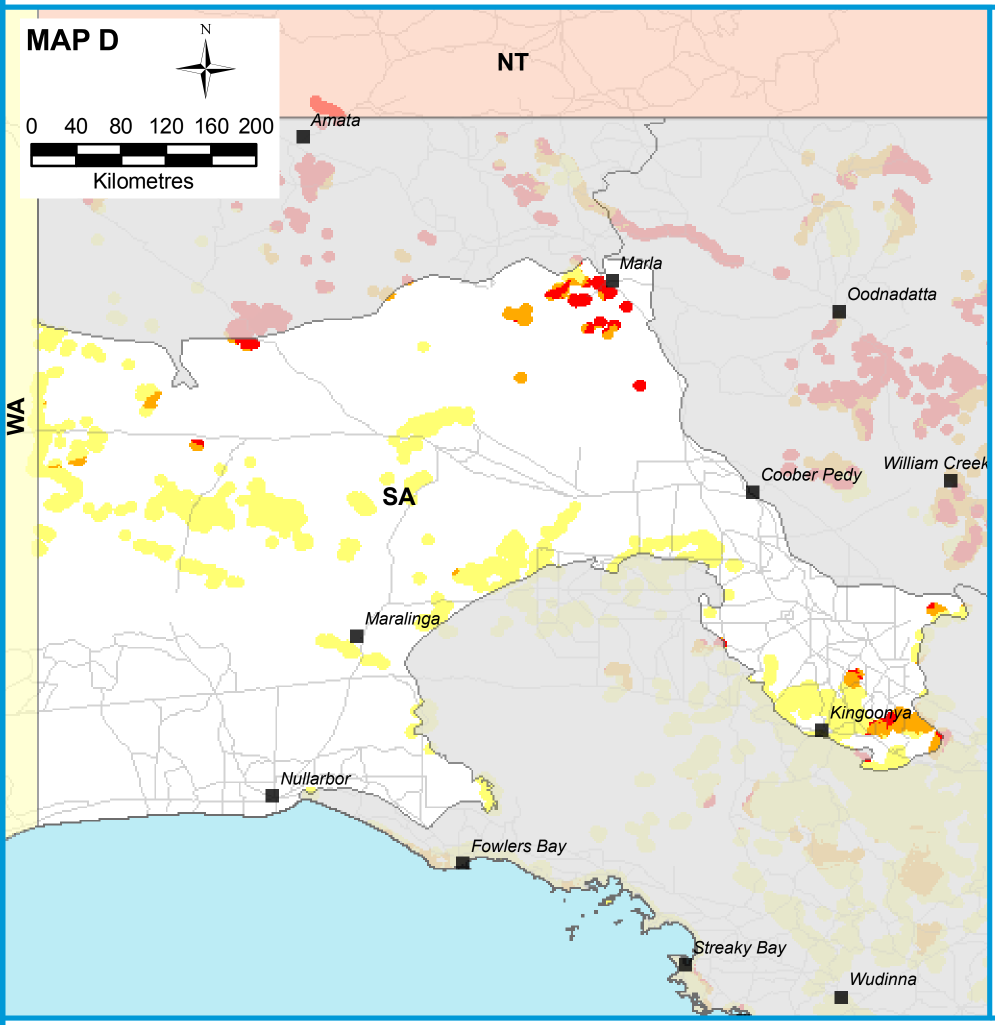


RISK TO WATER DEPENDENT ECOSYSTEMS FROM EXISTING GROUNDWATER EXTRACTION

Water Dependent Assets

Risk Level

- 🟥 Very High
- 🟥 High
- 🟧 Moderate
- ⬜ Low

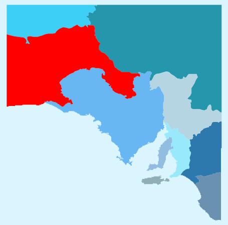


PRELIMINARY GROUNDWATER DEVELOPMENT RISK ZONES FOR GDEs

Potential Groundwater Development Risk Zones

- 🟥 High Risk - irrigation/stock & domestic/ industrial (GDE proximity/Low Salinity Resource)
- 🟧 High Risk - stock & domestic/industrial (GDE proximity/Moderate Salinity Resource)
- 🟨 High Risk - industrial/mining (GDE proximity/High Salinity Resource)

WARBURTON



Asset Summary

% State Assets	Layer Accuracy
Wetlands 5.15% (0 – 50%)	Low
Rivers & Streams 7.14% (0 – 50%)	Low
Karst features Not Assessed (0 – 50%)	N/A

Threat Summary

Extractive Use	Confidence
Groundwater (Low – High)	Low

GDE Summary

% Assets GDE	Confidence
Wetlands 46.59% (0 – 100%)	Low
Rivers & Streams Not Assessed (0 – 100%)	N/A
Karst features Not Assessed (0 – 100%)	N/A

Risk Summary

% Assets at Risk	Confidence
Wetlands 0.46% (0 – 100%)	Low

Datum: Australian Geodetic Datum 1984
Produced By: Aquatic Ecosystems Group
Department for Water
Date: March 2011

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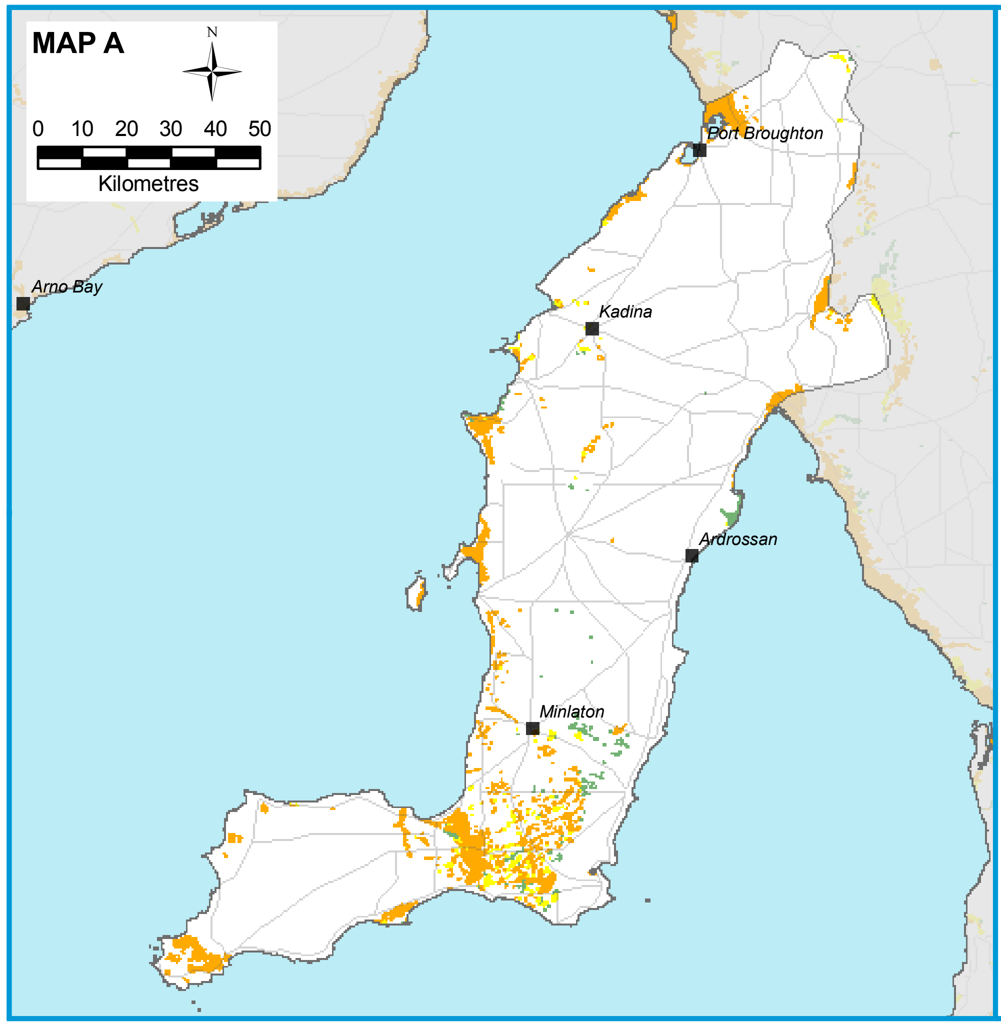
REPORT CARD: YORKE PENINSULA ANALYSIS UNIT - Wetland Groundwater Dependent Ecosystems

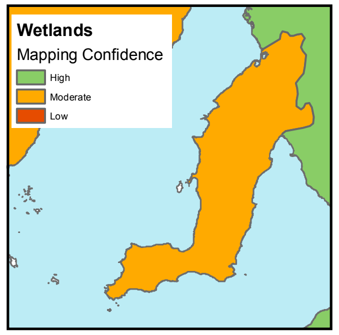


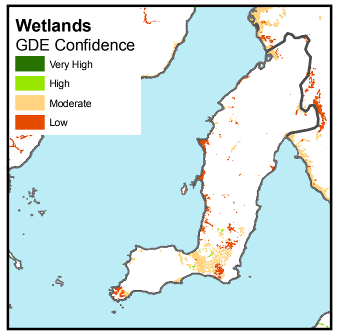
ASSET VULNERABILITY GROUNDWATER DEPENDENCE

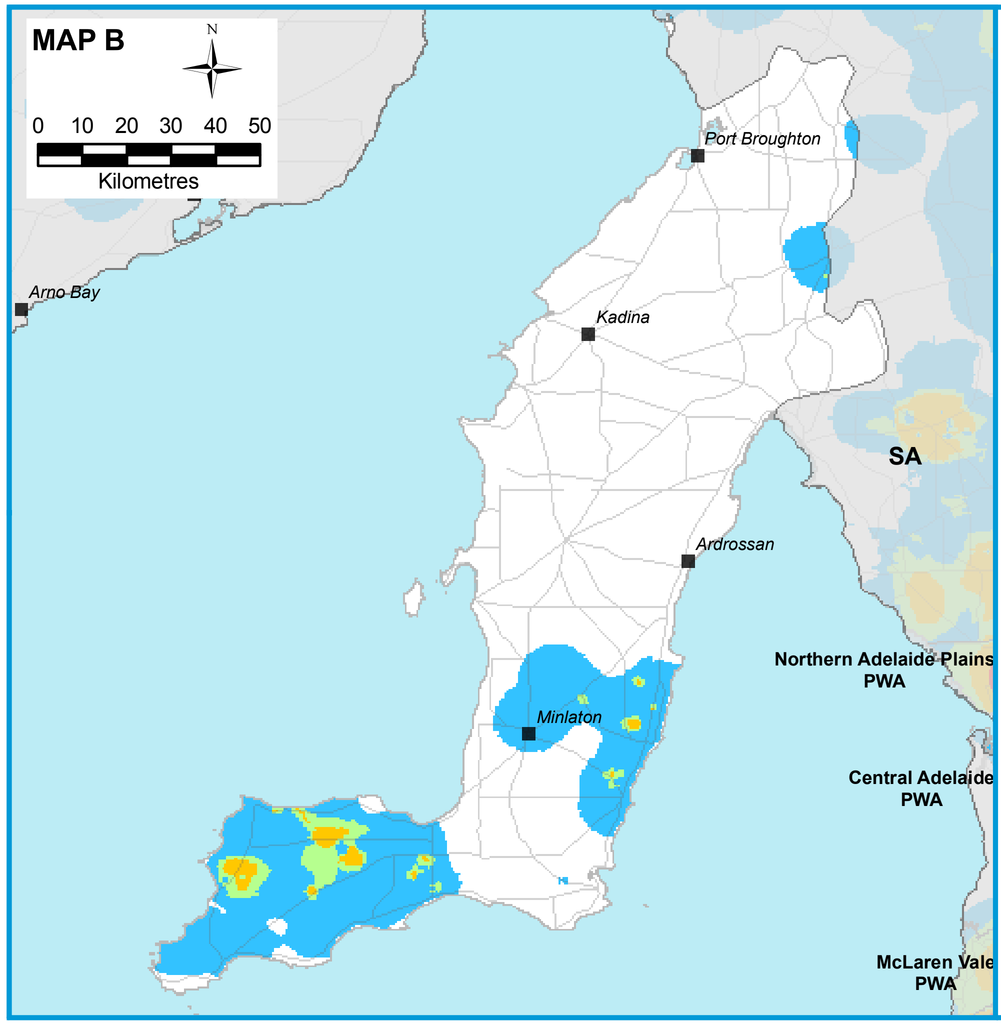
Water Dependent Assets

Likelihood of Groundwater Dependence

- 🟥 Very High
- 🟧 High
- 🟨 Moderate
- 🟩 Low (Surface Water Dependent)







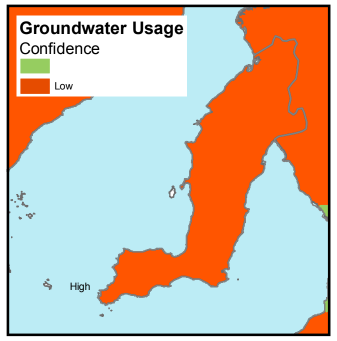
THREATS TO GDE PROCESSES - GROUNDWATER EXTRACTION

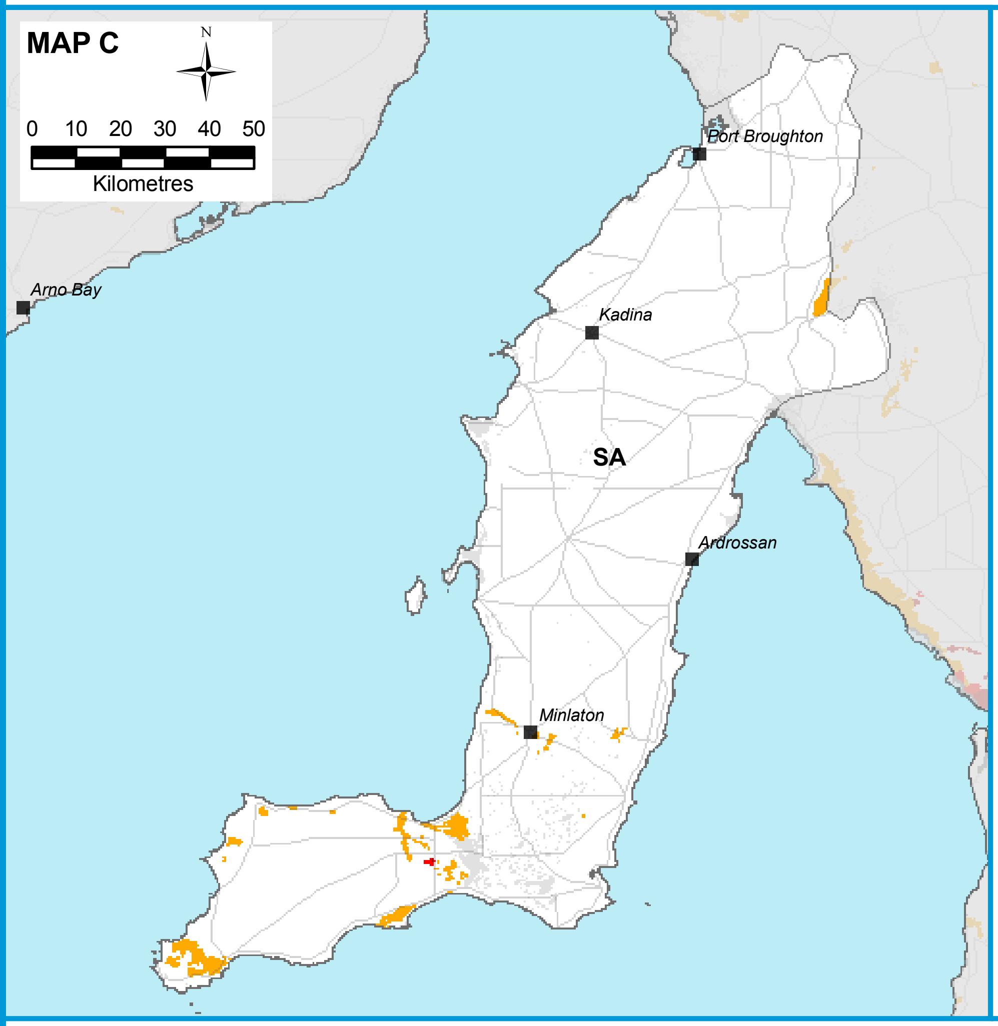
Groundwater Extraction (as at June 30th 2009)

Intensity

- ☐ Low
- 🟦
- 🟩
- 🟧
- 🟥 Very High

☐ Prescribed wells area



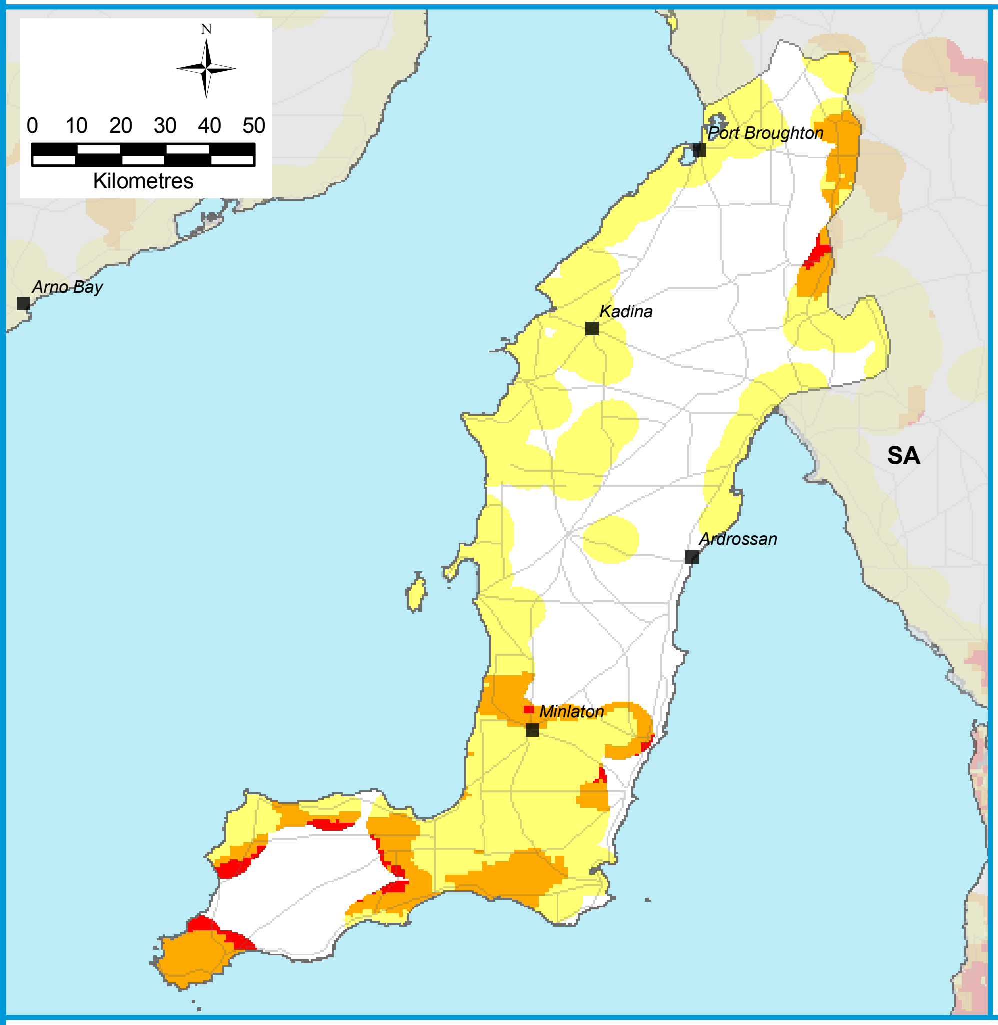


RISK TO WATER DEPENDENT ECOSYSTEMS FROM EXISTING GROUNDWATER EXTRACTION

Water Dependent Assets

Risk Level

- 🟥 Very High
- 🟥 High
- 🟧 Moderate
- ⬜ Low



PRELIMINARY GROUNDWATER DEVELOPMENT RISK ZONES FOR GDEs

Potential Groundwater Development Risk Zones

- 🟥 High Risk - irrigation/stock & domestic/industrial (GDE proximity/Low Salinity Resource)
- 🟧 High Risk - stock & domestic/industrial (GDE proximity/Moderate Salinity Resource)
- 🟨 High Risk - industrial/mining (GDE proximity/High Salinity Resource)

YORKE PENINSULA

Asset Summary

% State Assets		Layer Accuracy
Wetlands	2.4% (0–50%)	Mod
Rivers & Streams	<1% (0–50%)	Mod
Karst features	Not Applicable (0–50%)	N/A

Threat Summary

Extractive Use		Confidence
Groundwater	Low – High	Low

GDE Summary

% Assets GDE		Confidence
Wetlands	84.6% (0–100%)	Mod
Rivers & Streams	Not Assessed (0–100%)	N/A
Karst features	Not Applicable (0–100%)	N/A

Risk Summary

% Assets at Risk		Confidence
Wetlands	19.58% (0–100%)	Low

Datum: Australian Geodetic Datum 1984
Produced By: Aquatic Ecosystems Group
Department for Water
Date: March 2011

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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

Act (the) — In this document, refers to the *Natural Resources Management (SA) Act 2004,* which supersedes the *Water Resources (SA) Act 1997*

Adaptive management — A management approach often used in natural resource management where there is little information and/or a lot of complexity, and there is a need to implement some management changes sooner rather than later. The approach is to use the best available information for the first actions, implement the changes, monitor the outcomes, investigate the assumptions, and regularly evaluate and review the actions required. Consideration must be given to the temporal and spatial scale of monitoring and the evaluation processes appropriate to the ecosystem being managed.

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

Aquatic macrophytes — Any non-microscopic plant that requires the presence of water to grow and reproduce

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

Aquitard — A layer in the geological profile that separates two aquifers and restricts the flow between them

Arid lands — In South Australia, arid lands are usually considered to be areas with an average annual rainfall of less than 250 mm and support pastoral activities instead of broadacre cropping

Artesian — An aquifer in which the water surface is bounded by an impervious rock formation; the water surface is at greater than atmospheric pressure, and hence rises in any well which penetrates the overlying confining aquifer

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

Basin — The area drained by a major river and its tributaries

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

BoM — Bureau of Meteorology, Australia

Bore — See 'well'

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)

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

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)

DES — Drillhole Enquiry System; a database of groundwater wells in South Australia, compiled by the South Australian Department of Water, Land and Biodiversity Conservation (DWLBC)

DFW — Department for Water (Government of South Australia)

Diversity — The distribution and abundance of different kinds of plant and animal species and communities in a specified area

DO — Dissolved Oxygen

Domestic purpose — The taking of water for ordinary household purposes; includes the watering of land in conjunction with a dwelling not exceeding 0.4 hectares

Domestic wastewater — Water used in the disposal of human waste, for personal washing, washing clothes or dishes, and swimming pools

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 indicators — Plant or animal species, communities, or special habitats with a narrow range of ecological tolerance; for example, in forest areas, such indicators may be selected for emphasis and monitored during forest plan implementation because their presence and abundance serve as a barometer of ecological conditions within a management unit

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

Ecosystem services — All biological, physical or chemical processes that maintain ecosystems and biodiversity and provide inputs and waste treatment services that support human activities

EMLR — Eastern Mount Lofty Ranges

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

Endemic — A plant or animal restricted to a certain locality or region

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

EP — Eyre Peninsula

EPA — Environment Protection Authority (Government of South Australia)

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.

EPNRMB — Eyre Peninsula Natural Resources Management Board

Erosion — Natural breakdown and movement of soil and rock by water, wind or ice; the process may be accelerated by human activities

Evapotranspiration — The total loss of water as a result of transpiration from plants and evaporation from land, and surface water bodies

Floodplain — Of a watercourse means: (1) floodplain (if any) of the watercourse identified in a catchment water management plan or a local water management plan; adopted under the Act; or (2) where (1) does not apply — the floodplain (if any) of the watercourse identified in a development plan under the *Development (SA) Act 1993*; or (3) where neither (1) nor (2) applies — the land adjoining the watercourse that is periodically subject to flooding from the watercourse

Flow regime — The character of the timing and amount of flow in a stream

GAB — Great Artesian Basin

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

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

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

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’

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

KINRMB — Kangaroo Island Natural Resources Management Board

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.

Land — Whether under water or not, and includes an interest in land and any building or structure fixed to the land

Land capability — The ability of the land to accept a type and intensity of use without sustaining long-term damage

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

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

MLR — Mount Lofty Ranges

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

NRM — Natural Resources Management; all activities that involve the use or development of natural resources and/or that impact on the state and condition of natural resources, whether positively or negatively

NPWSA — National Parks and Wildlife, South Australia; a division of the Department for Environment and Heritage.

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

Obswell — Observation Well Network

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

PWCA — Prescribed Watercourse Area

PWRA — Prescribed Water Resources 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 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 DWLBC, respectively. DWLBC should be contacted for database extracts related to groundwater

SARDI — South Australian Research and Development Institute, a division within PIRSA

SA Water — South Australian Water Corporation (Government of South Australia)

Seasonal watercourses or wetlands — Those watercourses or wetlands that contain water on a seasonal basis, usually over the winter–spring period, although there may be some flow or standing water at other times

SEWPaC — The Department of Sustainability, Environment, Water, Population and Communities

Stock use — The taking of water to provide drinking water for stock other than stock subject to intensive farming (as defined by the Act)

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

Threatened species — Any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range

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

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 — 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 are all water-dependent ecosystems

WDE — Water dependent ecosystem

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.

REFERENCES

Aurecon Australia (2010). RESIC Infrastructure Demand Study. Resources & Energy Sector Infrastructure Council, Adelaide.

Beacon Ecological (2010). Groundwater Dependent Ecosystem Monitoring Program – vegetation monitoring. Report to the Department for Environment & Heritage. Beacon Ecological, Victoria.

Benyon, R.G. & Doody, T.M. (2004). Water Use by Tree Plantations in the South East, South Australia. CSIRO Forestry and Forest Products, Mount Gambier SA, Technical Report No. 148.

Brown, J.F., Bach, L., Aldous, A. & Wyers, A. (2007). Overcoming data shortfalls to locate groundwater-dependent ecosystems and assess threats to groundwater quantity and quality. The Nature Conservancy. IAH Conference Paper.

Cook, P., Simmons, C.T. & Brunner, P. (2008a). Regional Groundwater Dependent Ecosystems – our undiscovered assets at risk. Report to the Centre for Natural Resource Management, CSIRO Land & Water, Flinders University, Adelaide.

Cook, P.G., Wood, C., White, T., Simmons, C.T., Fass, T. & Brunner, P. (2008b). Groundwater inflow to a shallow, poorly-mixed wetland estimated from a mass balance of radon. Journal of Hydrology 354, 213-226.

Costelloe, J.F., Sheilds, A., Grayson, R.B. & McMahon, T. (2007). Determining loss characteristics of arid zone river waterbodies. River Research and Applications 23: 715-731.

Costelloe, J.F., Irvine, E.C., Western, A.W. & Herczeg, L. (2009). Groundwater recharge and discharge dynamics in an arid-zone ephemeral lake system, Australia. Limnol. Oceanogr., 54(1), 2009, 86-100.

Deane, D., Phipps, L. & Magarey, P.(2005). Ecological Condition Assessment: Streams of the Mambray Coast, Report 2005/36, Department of Water, Land & Biodiversity Conservation, South Australia

DENR (2010). South Australia Wetlands Inventory Database. GIS Geodatabase. Department for Environment & Natural Resources.

Ecological Associates (2010). Monitoring the Ecological Response of High Value Wetlands to Changes in Groundwater. Ecological Associates report CC017-2-C prepared for Department for Environment and Heritage, South Australia.

Fass, T. & Cook, P.G. (2004). Reconnaissance survey of groundwater dependence of wetlands, SE, SA, using a mass balance of radon and chloride. CSIRO Land & Water.

Fass, T. & Cook, P.G. (2005). Sources of groundwater discharging to Black Swamp, south-eastern Mount Lofty Ranges, South Australia. Report for River Murray Catchment Water Management Board. CSIRO Land & Water.

Favier, D., Scholz, G., Vanlaarhoven, J. & Bradley, J. (2004). A River Management Plan for the Broughton Catchment. Report 2004/16, Department of Water, Land & Biodiversity, Adelaide.

Haese, R.R, Gow, L., Wallace, L. & Brodie, R.S. (2008). Identifying groundwater discharge in the Coorong (South Australia). AUSGEO News 91.

Hale, J. Ed. (2010). Lake Eyre Basin High Conservation Value Aquatic Ecosystem Pilot Project. Report to the Australian Government Department of Environment, Water, Heritage and the Arts and the Aquatic Ecosystems Task Group.

Hammer, M., Wedderburn, S. & van Weenen, J. (2009). Action Plan for South Australian Freshwater Fishes. Native Fish Australia (SA) Inc., Department for Environment & Heritage, Adelaide.

REFERENCES

Harding, C. (2009). Extension of the Water Dependent Ecosystems Risk Assessment Framework to the South East NRM Region. Department for Water, Land & Biodiversity Conservation, Unpublished report, Mount Gambier.

Herpich, D. (2010) draft. Spatial extent of submarine groundwater discharge to estuarine and nearshore environments within a karst landscape. Interim report to EH Graham Centre. Department of Environment & Natural Resources.

Howard, J. & Merrifield, M. (2010). Mapping Groundwater Dependent Ecosystems in California. The Nature Conservancy. PLoS ONE, 5(6) e11249.

Howieson, P. (2003). Groundwater – Surface Water Interaction between Bonney's Camp North Wetland and the Northern Outlet Drain. Honours Thesis. Flinders University, Adelaide.

Jolly, I., Crosbie, R., McEwen, K., Holland, K., Lamontagne, S., Moe, K. & Simmons, C. (2008). Project 054121: Surface Water – Groundwater Interactions in River Murray Wetlands and Implications for Water Quality & Ecology. Final Report to the Centre for Natural Resource Management. CSIRO: Water for a Healthy Country National Research Flagship.

Jones, L. & Miles, M. (2009). River Murray Wetland Classification Project. Report to the Riverine Recovery Project, Department of Water, Land & Biodiversity Conservation. Department for Environment & Heritage, Adelaide.

Krause, S., Heathwaite, A.L., Miller, F., Hulme, P. & Crowe, A. (2007). Groundwater-Dependent Wetlands in the UK and Ireland: controls, functioning and assessing the likelihood of damage from human activities. Water Resource Management 21:2015-2025.

Land & Water Australia (2009). Ecohydrological Regionalisation of Australia – a tool for management & science. Australian Government Land & Water Australia, Griffith University.

Latcham, B. Carruthers, R. & Harrington, G. (2007). A New Understanding on the Level of Development of the Unconfined Tertiary Limestone Aquifer in the South East of South Australia. DWLBC Report 2007/11. Department of Water, Land & Biodiversity Conservation, Mount Gambier.

Lawson, J. & Stadter, F. (2004). Blue Lake Capture Zone Trail Field Survey. DWLBC Report 2004/27. Department of Water, Land & Biodiversity Conservation, Mount Gambier.

Mangelsdorf, T. & Kawalec, R. (2008). Stressed Water Resources Methodology. Department of Water, Land & Biodiversity unpublished report.

McEwan, K., Jolly, I. & Holland, K. (2006) Groundwater – surface water interactions in arid/semi-arid wetlands and the consequences of salinity for wetland ecology. CSIRO Land & Water Sciences Report 53/06McEvoy, P, & Goonan, P. (2003). Salinity is not necessarily bad for biodiversity: case studies of invertebrates from South Australian streams and River Murray wetlands. Records of the South Australian Museum 7:131-134.

Nielsen, D.L., Brock, M.A., Rees, G.N. and Baldwin, D.S. (2003). Effects of increasing salinity on freshwater ecosystems in Australia. Australian Journal of Botany 51: 655-665.

PIRSA (2000). Fact Sheet 66/00: Testing for Soil & Water Salinity. Primary Industries and Resources South Australia. www.pir.sa.gov.au/factsheets.

PIRSA (2009). PACE – Plan for accelerating exploration – Hot Prospects 2004-2009. Minerals and Energy Resources, Primary Industries and Resources South Australia.

REM (2005). A Review of the Environmental Water Requirments of the Groundwater Dependent Ecosystems of the South East Prescribed Wells Areas – Stage 1 Report. Report to South East Catchment Water Management Board. Resource & Environmental Management Pty Ltd & Ecological Associates Pty Ltd.

REFERENCES

REM (2006). A Review of the Environmental Water Requirements of the Groundwater Dependent Ecosystems of the South East Prescribed Wells Areas – Stage 2 Report. Report to South East Catchment Water Management Board. Resource & Environmental Management Pty Ltd & Ecological Associates Pty Ltd.

Risby, L., Scholz, G., Vanlaarhoven, J. & Deane, D. (2003). Willochra Catchment Hydrological and Ecological Assessment. Department of Water, Land & Biodiversity Conservation. Report, DWLBC 2003/20-21.

Roberts, S. (2007). Northern & Yorke Natural Resources Management Region water monitoring review. DWLBC Report 2006/15, Department of Water, Land & Biodiversity Conservation, Adelaide.

SAAL NRM Board (2009). Water Allocation Plan for the Far North Prescribed Wells Area. South Australian Arid Lands Natural Resources Management Board.

Scholz, G. (unpublished). Water Dependent Ecosystem Risk Assessment Tool (Water-RAT) for the Mount Lofty Ranges, South Australia. unpublished report, Department of Water, Land & Biodiversity Conservation.

Scholz, G. & Fee, B. (2008). A Framework for the Identification of Wetland Condition Indicators: A National Trial – South Australia. Department for Water, Land & Biodiversity Conservation.

SE NRM Board (2010 in draft). Draft Water Allocation Plan for the Lower Limestone Coast Prescribed Wells Area. South East Natural Resources Management Board, Mount Gambier.

Silcock, J. 2009. Identification of Permanent Refuge Waterbodies in the Cooper Creek & Georgina-Diamantina River Catchments for Queensland and South Australia. Final Report to South Australian Arid Lands Natural Resource Management Board. Queensland Herbarium. Department of Environment and Resource Management, Longreach.

Sheldon, R. (2007). Knowledge Review and Gap Analysis, Connecting the Catchment: the Integrated Management of Mosquito Creek. Report for the South East Natural Resources Management Board, Department for Environment & Heritage, Mount Gambier, SA.

SKM (2005). Hydrology of Lake Eyre Basin. Report to Department of Environment & Heritage, Sinclair Knight Merz Pty Ltd.

SKM (2006). Western Wimmera Wetland Classification – Groundwater-Surface Water Interaction. Report for Wimmera Catchment Management Authority, Sinclair Knight Merz Pty Ltd.

SKM (2009a). Classification of groundwater-surface water interactions for water dependent ecosystems in the South East, South Australia. Report to Department of Water, Land & Biodiversity Conservation. Sinclair Knight Merz Pty Ltd.

SKM (2009b). Eyre Peninsula Groundwater Dependent Ecosystem Scoping Study. Report to Eyre Peninsula Natural Resource Management Board. Sinclair Knight Merz Pty Ltd.

SKM (2010a). Atlas of Groundwater Dependent Ecosystems – Phase 1 Scoping Study. Report to National Water Commission. Sinclair Knight Merz Pty Ltd.

SKM (2010b). Conceptual Diagrams of Wetland Groundwater Dependent Ecosystems – GDE Monitoring Project South East, SA. Report to Department for Water, Sinclair Knight Merz Pty Ltd.

Vanlaarhoven, J. (2006a). Data Inventory: Water Dependent Ecosystems & Environmnetal Water Requirements of the Southern Fleurieu Peninsula. DWLBC Report 2009/03. Department of Water, Land & Biodiversity Conservation, Adelaide.

Vanlaarhoven, J. (2006b). Water Management Guidelines for the Protection of Water Dependent Ecosystems of the Southern Fleurieu Peninsula. DWLBC Report 2009/04. Department of Water, Land & Biodiversity Conservation, Adelaide.

REFERENCES

Waterhouse, J.D., Puhalovich, A. & Garnham, R. (2000). Hydrogeology of the Stuart Shelf in South Australia and Impacts of the Olympic Dam Mine. Golder Associates Pty Ltd. & EWL Sciences.

White, M. & Scholz, G. (2008). Prioritising Springs of Ecological Significance in the Flinders Ranges. Department for Water, Land & Biodiversity Conservation Report.

Wood, C. (2006). The combined use of seepage meters and radon-222 to quantify groundwater fluxes in a wetland. Honours Thesis, School of Chemistry, Physics and Earth Sciences, Flinders University, South Australia.

Wood, C. (2009). Measurement and evaluation of Key Groundwater Dependent Ecosystems in the Lower South East of SA. Department of Water, Land & Biodiversity Conservation, Mount Gambier.

Wood, C. & Green, G. (2011). Impacts of Climate Change on Water Resources – Phase 1: first order risk assessment and prioritisation. Department for Water Technical Report 2010/01. Government of South Australia, through Department for Water, Adelaide