Lake Eyre Basin Rivers Monitoring Project

South Australian Lake Eyre Basin aquatic ecosystem mapping and classification

DEWNR Technical report 2015/43

Government of South Australia
Department of Environment, Water and Natural Resources

Funding for these projects has been provided by the Australian Government through the Bioregional Assessment Programme.

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Foreword

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

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

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

Sandy Pitcher
CHIEF EXECUTIVE
DEPARTMENT OF ENVIRONMENT, WATER AND NATURAL RESOURCES

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The Lake Eyre Basin River Monitoring project was managed by Andy Harrison (DEWNR) with programme coordination provided by Tom Carrangis (DEWNR).

Funding for this project has been provided by the Australian Government through the Department of the Environment as part of the Bioregional Assessment Programme. See www.bioregionalassessments.gov.au for further information.

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Summary

This report is part of a series of studies forming part of the Lake Eyre Basin Rivers Monitoring (LEBRM). The LEBRM project is one of three water knowledge projects undertaken by the South Australian Department of Water, Environment and Natural Resources (DEWNR) to inform the Bioregional Assessment Programme in the Lake Eyre Basin. The aim of the work was to collate existing spatial knowledge about the attributes of aquatic ecosystems in the South Australian portion of the Lake Eyre Basin (LEB) and areas overlying the Arckaringa and Pedirka coal basins (the 'study region').

The SA LEB aquatic ecosystems mapping and classification (AEMC) project concentrated on the surface-water driven aquatic ecosystems in the catchments overlying the Arckaringa and Pedirka coal basins, namely the Neales, Macumba and Finke Catchments (the 'priority catchments'). Whilst Great Artesian Basin (GAB) springs were included in the aquatic ecosystems mapping and classification project, another project to inform the Bioregional Assessment Programme, the LEB Springs Assessment, is undertaking further work to map GAB springs and store these data. Therefore these ecosystems were not a priority for the AEMC project, however, it is anticipated that the AEMC dataset may be updated in future with data resulting from the LEB Springs Assessment project.

The AEMC project developed a hierarchical classification consistent with the interim Australian national aquatic ecosystem classification framework (AETG 2012), and broadly consistent with the draft South Australian aquatic ecosystems classification framework (Scholz and Fee 2010). The AEMC classification (Table 1-1) provides a systematic structure within which to describe basic hydrological, geomorphological and habitat attributes of aquatic ecosystems in a Geographic Information System (GIS) format. The GIS approach enables the individual attributes to be displayed and analysed spatially. The GIS also included a "methods" and "confidence" field for each of the Level 3 attributes.

Table 1-1 The LEBRM classification framework

<table>
<tr><th>Level</th><th></th><th colspan="10">Classification</th></tr>
<tr><td>1</td><td></td><td colspan="10">a) IBRA region b) Hydrological Basin</td></tr>
<tr><td>2</td><td></td><td colspan="10">a) IBRA subregion b) Catchment</td></tr>
<tr><td rowspan="5">3</td><td>Class</td><td colspan="10">Surfacewater</td></tr>
<tr><td>Group</td><td colspan="10">Inland</td></tr>
<tr><td>System</td><td colspan="10">Type (Palustrine / Lacustrine / Riverine / Floodplain)</td></tr>
<tr><td>Habitat</td><td rowspan="2">Landform transport zone</td><td rowspan="2">Size</td><td rowspan="2">Soil</td><td rowspan="2">Vegetation</td><td colspan="2">Water source</td><td rowspan="2">Salinity</td><td colspan="2">Water regime</td><td rowspan="2">Hydrological connectivity</td></tr>
<tr><td>Sub-categories</td><td>Groundwater source</td><td>Surface water source</td><td>Inflow frequency</td><td>Persistence</td></tr>
</table>

The AEMC project built on an earlier project, the regional Water Asset Database (WAD), which brought together existing spatial datasets for water assets (including aquatic ecosystems and water infrastructure) and attributed these for flow regime and water source (as well as other attributes), based on expert panel workshops and statewide datasets. The AEMC selected the aquatic ecosystems from the WAD for the study region and imported their asset name, unique identifier, type, flow regime and water source attributes.

In addition to the aquatic ecosystems features imported from the WAD, the following features were added to the GIS to address gaps in the spatial mapping in the priority catchments only:

- Preliminary floodplain mapping (based on vegetation mapping)
- Additional known waterholes (digitised from imagery)
- Potential and known bore-fed wetlands (digitised from imagery).

For features imported from the WAD, the water source and water regime attributes were classified based on the WAD. Other attributes were classified for the whole of study region based on existing state and national spatial datasets and 'mapping rules'. Attributes for aquatic ecosystems in the priority catchments were further refined based on project data sets, literature and local and expert knowledge.

One application of a hierarchical classification is the grouping of aquatic ecosystems with similar characteristics into 'types.' Attributes can be selected to determine types based on the purpose for which the typology is to be used. Another component of the LEBRM project identified broad aquatic ecosystem types for the purpose of conceptual modelling of their vulnerability to coal seam gas (CSG) and large coal mine (LCM) development activities. The LEBRM AEMC assigned the aquatic ecosystems in the region to these types where there was sufficient information.

The LEBRM AEMC successfully integrated project data, literature and expert knowledge to provide a more accurate mapping and description of aquatic ecosystems in the Neales, Macumba and Finke Catchments than has previously been available, particularly with regards to aquatic refuges. Further work is required to refine the attribution for aquatic ecosystems in other catchments, particularly the Cooper and Georgina-Diamantina Catchments, for which there is considerable additional information that could be used. Two related issues, overlapping polygons and multiple polygons representing a single feature, could not be resolved through this project, and further work is required to consistently delineate aquatic ecosystems in the LEB, however these issues were not considered significant for the priority catchments.

It is intended that the LEBRM AEMC be a 'living' product that can be updated as new information becomes available. In particular, new data generated from the LEB Springs Assessment project, Soil and Landscape Grid of Australia and the Water Observations from Space will be able to add considerable value to the AEMC.

1 Introduction

1.1 Aquatic ecosystems of the Lake Eyre Basin

The Lake Eyre Basin (LEB) is an internally-draining basin that takes up almost one sixth of Australia's land mass in the arid and semi-arid interior (Figure 1-1). It is unique in being one of the only unregulated dryland river systems in the world and having the most variable flows in the world (Puckridge et al. 1998). The first assessment of the health of LEB rivers found them to be in near-natural condition (LEBSAP 2008). The LEB contains wetlands of national and international importance for supporting Australia's waterbird populations (Reid et al. 2010) and nationally threatened and endemic species are found in the SA LEB (Morton et al. 2010). The ecology is driven by the flow regime and cycles from 'boom' periods following large floods through to 'bust' periods with little to no flow (Bunn et al. 2006).

The Basin gradient is very flat (less than 1% slope), except at the outer margins where it is fringed by low ranges (mostly around 300 to 400 m above sea level). Kati Thanda-Lake Eyre (North and South) is the terminus for most catchments in the Basin, however, under current climatic conditions, thirty-two percent of the Basin area does not contribute run-off to Kati Thanda-Lake Eyre (McMahon et al. 2005). Much of the Basin experiences long periods of little to no flow, punctuated by small to medium floods and the occasional large flood where entire floodplains of catchments are inundated.

Great Artesian Basin (GAB) springs are found along the eastern and southern boundary of the LEB in South Australia. These springs have flowed continuously for hundreds of thousands of years, providing the only refugia for obligate aquatic species with poor dispersal capabilities. The springs contain a high proportion of endemic species and populations of species that were once widespread (Davis et al. 2013; Gotch, 2013a). The community of species dependent on discharge from the GAB is listed as an endangered ecological community under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act) (Fensham et al. 2010).

The Neales Catchment is the major surface water drainage system of the western LEB and the catchment is highly ephemeral, with only one known potentially permanent freshwater waterhole, Algebuckina. Ten native fish species occur in the Neales Catchment and, during extended dry periods, Algebuckina waterhole has supported the entire diversity of obligate aquatic species in the catchment, although some saline waterholes and low-lying GAB springs provide refuge for a subset of the smaller and hardier species (McNeil et al. 2011).

1.2 The Lake Eyre Basin River Monitoring Project

The Lake Eyre Basin (LEB) presents unique challenges to assessing and managing the risks that may arise from coal seam gas (CSG) and coal mining developments. It is characterised by a high degree of hydro-climatic variability and unpredictability, with patterns of water availability occurring over annual and decadal scales. There are considerable knowledge gaps regarding the hydrology and ecology of surface water assets and their vulnerabilities during different phases of the hydro-climatic cycle.

The Lake Eyre Basin River Monitoring (LEBRM) project aims to address these knowledge gaps for areas potentially impacted by CSG or coal mining activities. The LEBRM project will form a key input into the Bioregional Assessment work for the LEB, and will, in turn, provide information and tools to assist the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC). The IESC is a statutory body under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) which provides scientific advice to Australian governments on the water-related impacts of coal seam gas and large coal mining development proposals.

Under the EPBC Act, the IESC has several legislative functions to:

- Provide scientific advice to the Commonwealth Environment Minister and relevant state ministers on the water-related impacts of proposed coal seam gas or large coal mining developments.
- Provide scientific advice to the Commonwealth Environment Minister on:
- bioregional assessments being undertaken by the Australian Government, and

- research priorities and projects commissioned by the Commonwealth Environment Minister.
- Publish and disseminate scientific information about the impacts of coal seam gas and large coal mining activities on water resources.

This report is part of a series of studies forming the Lake Eyre Basin Rivers Monitoring (LEBRM) project. The LEBRM project is one of three water knowledge projects undertaken by the South Australian Department of Water, Environment and Natural Resources (DEWNR) to inform the Bioregional Assessment Programme in the Lake Eyre Basin region. The three projects are:

- Lake Eyre Basin Rivers Monitoring
- Arckaringa and Pedirka Groundwater Assessment
- Lake Eyre Basin Springs Assessment.

The Bioregional Assessment Programme is a transparent and accessible programme of baseline assessments that increase the available science for decision making associated on potential water-related impacts of coal seam gas (CSG) and large coal mining (LCM) developments. The coal-bearing Arckaringa, Pedirka, Cooper and Galilee Basins (Figure 1-1) have been identified as regions where CSG and LCM developments are likely to occur or increase in the future. Bioregional assessments are being prepared in the LEB for the four coal regions to strengthen the science underpinning future decisions about CSG and LCM activities and their impacts on groundwater quality, surface water resources and aquatic ecosystems.

The overarching goal of the LEBRM project was to collate a baseline of scientific knowledge around the hydrology and ecology of aquatic ecosystems in the LEB, thus providing an advanced and up-to-date knowledge platform that can support the detailed modelling, impact and risk analysis needs of LEB bioregional assessments. The LEBRM project background, purpose, approach and links to the bioregional assessment are described in more detail in DEWNR (2014).

Figure 1-1 The Lake Eyre Basin, showing the major waterbodies and location of the coal-bearing basins

1.3 The LEBRM aquatic ecosystem classification and mapping project

Within the SA LEB, there are numerous aquatic ecosystems occupying a large proportion of the region. These aquatic ecosystems range from seasonal rocky streams of the Flinders Ranges, to the massive salt lakes such as Kati Thanda-Lake Eyre to the Great Artesian Basin Springs to the waterholes and floodplains of the major watercourses. The hydrological, geomorphological and climatic conditions vary across the region, leading to variation in the characteristics and biotic assemblages of aquatic ecosystems in space and time. However, there is limited information in spatial datasets to describe the differences in aquatic ecosystems across the region. Some aquatic ecosystems are poorly defined while others are not mapped in SA government corporate datasets.

In each of the signatory states to the National Partnership Agreement on Coal Seam Gas and Large Coal Mining Development, NRM bodies in regions containing large coal or CSG deposits with potential for development have compiled a database of water assets, including aquatic ecosystems for the Bioregional Assessment Programme. In South Australia, the Water Asset Database (WAD) work completed by DEWNR was linked to a GIS database (Berens et al. 2014, Denny & Berens 2013). This project resulted in a significant compilation of water asset information, with some attribution of aquatic ecosystem. Particularly informative attributes for this project were attributes of type (after Cowardin et al. 1979) water source and water regime.

1.3.1 Aims, objectives and applications

The aims of the LEBRM aquatic ecosystem mapping and classification (AEMC) project were to provide up-to-date mapping and classification of aquatic ecosystems in the SA LEB.

The specific project objectives were to:

- Improve the spatial mapping of aquatic ecosystems
- Build on the work undertaken for the WAD project (Denny & Berens 2013)
- Align with the Interim Australian National Aquatic Ecosystems (ANAE) classification framework (AETG 2012a)
- Identify where aquatic ecosystems are dependent on groundwater (both subsurface and surface expression).

Due to resource and timeframe constraints it was necessary to utilise existing datasets and knowledge in attributing aquatic ecosystems.

Applications of the classification of aquatic ecosystems include:

- Linking different types to conceptual and other models of ecosystem function (e.g. Imgraben and McNeil 2013)
- Understanding the drivers of aquatic ecosystems to enable assessments of vulnerability and risk
- Inform identification and description of High Ecological Value Aquatic Ecosystems (AETG 2012b)
- Identification of priority areas for data collection by including confidence rankings and 'unknown' categories for each attribute
- Mapping of specific attributes of aquatic ecosystems (e.g. salinity, persistence)
- Consistency in describing aquatic ecosystems
- Grouping aquatic ecosystems with common attribute values into types.

1.3.2 Study area

The study area included all the LEB in South Australia and the areas to the west of the LEB that are underlain by the Arckaringa and Pedirka Basins (Figure 1-2).

The majority of the study area was mapped and classified based on existing data and automated classification, however, in line with the broader objectives of the LEBRM project (DEWNR 2014), the mapping and attribution was refined based on expert opinion, project datasets and literature for priority catchments, assets and attributes as follows:

1. Priority catchments: Neales and Macumba (see discussion below)
2. Priority aquatic ecosystems: the location and attribution of aquatic refuges

3. Priority attributes: water source, water regime (inflows and persistence) and hydrological connectivity.

The Neales and Macumba Catchments were prioritised on the basis that they partially overlie the Pedirka and Arckaringa Basins and have been the subject of sufficient research and monitoring to undertake some attribution of aquatic ecosystems within them.

1.3.3 Links to other projects

The LEBRM mapping and classification project built on the WAD developed for the SA Arid Lands NRM region (Denny & Berens 2013) to classify and map aquatic ecosystems consistently with the Australian National Aquatic Ecosystem (AETG 2012a) and South Australian Aquatic Ecosystems (SAAE) (Fee and Scholz 2010) classification frameworks. Information gathered through the Aridflo (Costelloe et al. 2004), Critical Refugia (McNeil et al. 2011; Costelloe 2010) and Lake Eyre Basin Rivers Assessment (McNeil 2008; Cockayne et al. 2012, 2013) projects was used to classify the habitat attributes in the framework. The classification has been used to identify which aquatic ecosystems fit the types identified in the LEBRM conceptual models (Imgraben and McNeil 2013). Data-sets developed as part of the LEBRM hydroecological modelling (Hooper and Miles 2015) were used in the mapping and classification. The attribute table for the classification includes a field for unique codes used to identify GAB spring groups (Gotch 2013b) so it can be linked to a database being developed for the LEB Springs Assessment (an aligned bioregional assessment project currently underway) and to be potentially updated in future with outputs from that project.

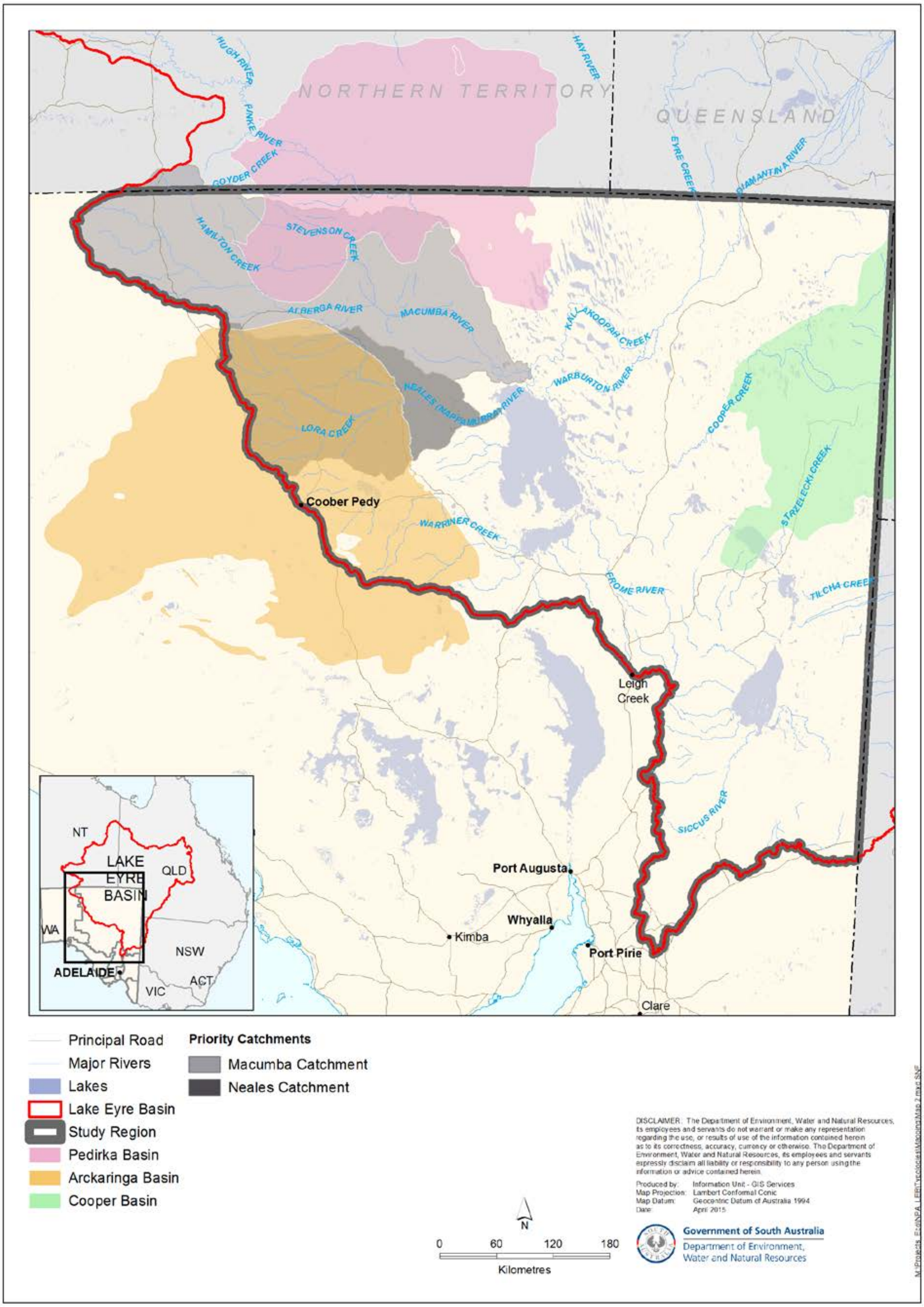


Figure 1-2 Showing the LEBRM AEMC study region (the LEB and coal basins) and priority catchments

1.4 The LEBRM Aquatic Ecosystem Classification Framework

Aquatic ecosystem classification provides a systematic framework to describe attributes of aquatic ecosystems (AETG 2012a). The application of a classification in a spatial (GIS) format enables spatial datasets relating to the hydrological, physical and biological environment to be used to define the attributes. This approach is referred to as 'top down' (broad scale) by the AETG (2012a) and was the approach taken for the LEBRM classification. The top down approach has the advantage of enabling the individual attributes to be displayed and analysed spatially, but assumes that the chosen attributes and the categories of those attributes are meaningful for ecological functions (AETG 2012a). A potential limitation of the top down approach is that the scale of the source data is too coarse for confident attribution of small aquatic ecosystems.

An Interim ANAE Classification Framework was developed to promote consistency in classification of aquatic ecosystems across Australia while allowing flexibility in the data sets used to describe the attributes within the framework (AETG 2012a). The framework is 'a broadscale, semi-hierarchical, attribute-based, biogeophysical framework' (AETG 2012a p. 4) based on a top-down approach. The ANAE has the following tiered structure:

- Level 1 – large scale national-level regionalisations that provide context for the aquatic ecosystems setting. The ANAE classification framework is flexible in the choice of datasets used in Level 1
- Level 2 – subset of the Level 1 classification (i.e. if Level 1 is hydrological basins, Level 2 is catchments), providing more specific but still broadscale context for the aquatic ecosystem setting
- Level 3 – classifies the class of aquatic ecosystem (surface or subterranean), major types (derived from Cowardin et al. 1979) and a pool of habitat level attributes chosen to reflect ecological functioning of the systems (AETG 2012a).

Prior to the development of the ANAE, a South Australian Aquatic Ecosystem (SAAE) classification was drafted (Fee and Scholz 2010). The SAAE is broadly consistent with the ANAE but differs in two key areas, by:

- Specifying the higher level (landscape setting) attributes
- Specifying the resulting types of aquatic ecosystems.

The ANAE classification was adopted for the LEBRM classification framework, however an additional attributes (size and connectivity) were included from the SAAE and the flow regime was split into two attributes (inflow frequency and persistence, Table 1-1) consistent with the SAAE. The water source attribute was also split into two levels to enable differentiation of whether aquatic ecosystems are dependent on surface water, groundwater or a combination, as well as greater differentiation of groundwater sources (Table 1-1). The river confinement attribute from the ANAE was not included as this was not considered to have as strong relevance to the study region.

The LEBRM classification framework is presented in Table 1-1.

Table 1-1 The LEBRM classification framework

<table>
<tr><th>Level*</th><th></th><th colspan="10">Classification</th></tr>
<tr><td>1</td><td></td><td colspan="10">a) IBRA region b) Hydrological basin</td></tr>
<tr><td>2</td><td></td><td colspan="10">a) IBRA subregion b) Catchment</td></tr>
<tr><td rowspan="5">3</td><td>Class</td><td colspan="10">Surface water</td></tr>
<tr><td>Group</td><td colspan="10">Inland</td></tr>
<tr><td>System</td><td colspan="10">Type (Palustrine / Lacustrine / Riverine / Floodplain)</td></tr>
<tr><td>Habitat</td><td rowspan="2">Landform transport zone</td><td rowspan="2">Size</td><td rowspan="2">Soil</td><td rowspan="2">Vegetation</td><td colspan="2">Water source</td><td rowspan="2">Salinity</td><td colspan="2">Water regime</td><td rowspan="2">Hydrological connectivity</td></tr>
<tr><td>Sub-categories</td><td>Groundwater source</td><td>Surface water source</td><td>Inflow frequency</td><td>Persistence</td></tr>
</table>

* The a/b represent options that may be selected at Level 1 and 2, the LEBRM classification applied both options however the IBRA regions and subregions were found to be difficult to apply and therefore the hydrological basins and catchments are recommended for Level 1 and 2 classification (see section 2.2.1)

1.4.1 Level 3 habitat attributes

As discussed above, the level three habitat attributes were drawn from the ANAE (AETG 2012a) and SAAE (Fee & Scholz 2010) frameworks. The thresholds and metrics to differentiate habitats within the attributes were also largely drawn from the ANAE and SAAE (Table 1-2). Further detail on valid options for attributes is included in Section 2.2.

In addition to the habitat attributes presented in Table 1-2, an additional attributes was included, GAB spring code, to enable linkage to a spring database under development for another bioregional assessment project, the *LEB Springs Assessment*.

Table 1-2 Level 3 habitat attribute metrics and thresholds (see Sect. 2.2.3)

<table>
<tr><th>Level 3 Habitat Attributes</th><th colspan="2">Metrics / Thresholds</th></tr>
<tr><td>Landform transport zone (riverine only)</td><td colspan="2">High Energy - Upland
High Energy - Slope
Low Energy - Upland (plateau)
Low Energy - Lowland</td></tr>
<tr><td>Size (palustrine & lacustrine only)</td><td colspan="2">Mega (> 10 000 ha)
Macro (100 - 10,000 ha)
Meso (25 - 100 ha)
Micro (1 - 25 ha)
Lepto (0.01 - 1 ha)
Nano (< 0.01 ha)</td></tr>
<tr><td>Soil</td><td colspan="2">Non-porous - Rock (non-soil)
Porous - Mineral (soil)
Porous - Peat (organic)
Porous - Sand (non-soil)</td></tr>
<tr><td>Vegetation (/fringing vegetation)</td><td colspan="2">Woodland
Shrubland >1 m
Shrubland <1 m
Grassland
Sedgeland
Forbland
No vegetation
Unknown</td></tr>
<tr><td rowspan="2">Water source</td><td colspan="2">Surface Water
Groundwater
Combined: Surface water dominant
Combined: Groundwater dominant
Combined: Unknown</td></tr>
<tr><td>Groundwater source:
Alluvial
Fractured Rock
Confined Artesian
Confined Non-artesian
Unconfined (e.g. unconfined GAB)</td><td>Surface water source:
In-stream
Overbank
Rainfall</td></tr>
<tr><td>Salinity</td><td colspan="2">Fresh (< 1000 mg/L)
Brackish (1000 - 3000 mg/L)
Saline (3000 – 10 000 mg/L)
Hypersaline (>10 000 mg/L)</td></tr>
<tr><td>Water regime</td><td>Inflow frequency:
Permanent
Seasonal (≥ 1 in 1 years)
Ephemeral (<1 in 1 to ≥ 1 in 5 years)
Highly ephemeral (< 1 in 5 years)</td><td>Persistence:
Permanent
Mid-term (≥ 1 year but not permanent)
Annual (< = 1 year)</td></tr>
<tr><td>Hydrological connectivity</td><td>Palustrine, lacustrine & floodplain
Overbank Flow
Retained
Terminal Branch
Through Flow
Unconnected</td><td>Riverine
Always connected
Sometimes connected</td></tr>
</table>

2 Methods and results

A LEBRM AEMC geodatabase was created to house polygon geometry for the LEBRM AEMC. This included an attribute table with fields matching the requirements of the LEBRM classification framework (Table 1-1 and Table 1-2). The components of the geodatabase are hereafter referred to as the AEMC polygon layer and the AEMC schema respectively.

2.1 Source geometries and pre-processing

2.1.1 Wetlands

The WAD was selected as the primary source geometry for the project as this database represented a significant recent collation of known aquatic ecosystem spatial datasets with attributes that could be used to populate some attributes of the LEBRM Classification. The WAD was developed on a region by region basis and there were slight differences in the approach used in each region. The project boundary included most of the SA Arid Lands NRM region and parts of the Alinitjara Wilurara and Northern and Yorke NRM regions. Original data sources are listed in the regional reports and it is recommended that this report be read in conjunction with Denny and Berens (2013) and Berens et al. (2014).

The following 'major water asset type' polygons were selected from the WAD:

- Wetlands
- Waterholes
- Springs
- Dams
- Gilgais.

All polygons for these features from the statewide WAD were imported into the AEMC polygon layer and then those entirely outside of the project boundary were deleted. Multi-part polygons with parts outside the project boundary were 'exploded' and the parts outside the boundary deleted.

The *Geometry Source* for all polygon features imported from the WAD was attributed as WAD. The following WAD fields were imported into temporary fields in the AEMC to inform final attributes:

- PKUID (a unique identifier for each WAD feature)
- Wetland_ID
- Asset_Name
- Description
- Water_Regime and WR_Confidence (water regime confidence)
- Water_Source and WS_Confidence (water source confidence)
- Waterbody_Type.

The PKUID allows for a table join or relate between the LEBRM wetlands layer and the Asset table (from the WAD). The Asset table contains most of the detail attributed to the spatial features. The Water Regime, Waterbody_Type and Water_Source fields in the LEBRM wetlands layer were all populated from the joined Asset table.

Gilgai ecosystems were 'trimmed' to remove overlap with other aquatic ecosystem types.

All features imported from the WAD except GAB springs and gilgais were assigned medium confidence indicating they are highly likely to represent a feature that exists but the geometry may not be accurate at a fine scale. GAB springs and gilgais were assigned low confidence for geometry, except for Dalhousie and Francis Swamp Springs which were assigned high confidence.

2.1.2 Watercourses

Watercourses were not imported from the WAD because all watercourses within the WAD were merged into a single polyline for each catchment or subcatchment. All watercourses from the Australian Hydrological Geospatial Fabric (AHGF, version 1.2) within the project boundary were selected. Due to the vast number of minor watercourses and gullies included in the AHGF this dataset was divided into named watercourses and unnamed watercourses. This effectively separated most major watercourses (e.g. 3rd order and above) into the former group and minor watercourses and gullies (e.g. 1st and 2nd order) into the latter.

An alternative option for delineating major and minor watercourses would have been to use the 'Hierarchy' attribute in the AHGF. This contains a distinction between 'major' and 'minor' streams, however, where there are multi-channel watercourses (such as commonly occur in the LEB), the AHGF only classifies a single channel as 'major' and all other channels are classified as 'minor.' Otherwise the range of watercourses that were selected using this method was similar to those selected using the naming method. Therefore the naming method was used.

Of the named watercourse group, all polylines with the same name were merged into a single feature. The named watercourse polylines were then transformed into polygons by buffering the lines by 5 metres on either side. The resulting polygons were imported into the LEBRM schema.

Watercourses without names were all buffered by 1 metre either side. These watercourses were imported into the AEMC polygon layer or classified but were included in the AEMC geodatabase for display purposes where required.

All watercourse features were assigned medium confidence for geometry based on it being considered likely to represent a feature that exists but with a geometry that may not be accurate at a fine scale.

2.1.1 Floodplains

As noted in Denny and Berens (2013), the SA_Wetlands_All_Polygons which was used as the source dataset for the South Australian Arid Lands (SAAL) region includes a classification for lacustrine or palustrine, but does not include a classification for floodplains. Therefore, where floodplains had been included with the source dataset they would have been misclassified as either lacustrine or palustrine. However, for the priority study catchments there was no mapping of floodplains for the Neales Catchment, a small proportion of floodplains were mapped as lacustrine system types for the Macumba and larger proportion for the Margaret – Warriner Creek Catchment (these were re-classified as part of the attribution stage). A landform element map was developed as part of the LEBRM project (Hooper and Miles 2015) for the Finke, Macumba, Neales and Stuart-Warriner Catchments based on vegetation associations, biological surveys and Landsat image analysis.

The floodplain landform element polygons from Hooper and Miles (2014) were imported for the Finke, Macumba and Neales Catchments into the AEMC polygon layer.

The Hooper and Miles (2015) floodplain mapping should be considered a preliminary floodplain extent and further work is required to accurately define the floodplain for the priority catchments. Remote sensing has been used to map extent of inundation for the eastern catchments (Tunn and Cameron 2008, Wainwright et al. 2006); these polygons were included in the WAD and hence are incorporated in AEMC but are misclassified as lacustrine types. Further work is required to re-classify these floodplains. Floodplains in other parts of the study region are poorly defined.

All floodplain polygons imported from Hooper and Miles (2015) landform element mapping were attributed as medium, denoting where 'there is a high likelihood that floodplains exist within the floodplain polygons but the geometry may be incorrect'.

2.1.2 Digitisation of new features

Based on inspection of the above source datasets it was determined that certain aquatic ecosystems were not included, namely bore-fed wetlands, some known waterholes and dams in the SAAL NRM region. Based on available information and expert knowledge, these features were manually digitized from the available imagery for *the priority catchments only*.

It should be noted that, for most of the region, only Landsat 7 Enhanced Thematic Mapper imagery was available and due to the large pixel size (12.5 m) the accuracy of the digitised features was limited and all features were assigned medium confidence.

2.1.2.1 Waterholes

Waterholes that have been surveyed as part of the Aridflo (Costelloe et al. 2004), Lake Eyre Basin Rivers Assessment (LEBRA) (McNeil et al. 2008; Cockayne et al. 2012, 2013), Critical Refugia projects (McNeil et al. 2011) or LEBRM (e.g. Wakelin-King 2015) that were not in the WAD were manually digitised based on GPS locations and the recommendation of D. Schmarr (SARDI, pers. com. July 2014). Some waterholes that were included in the WAD that were found to have very inaccurate geometries, were manually re-digitised during this process.

2.1.2.2 Bore-fed wetlands

Nearly all GAB bores within the study region have been controlled, however some bores (including controlled bores) still support small to medium-sized wetlands, some of which are connected with the surface water network (i.e. are located on floodplains and/or close to watercourses). Bore-fed wetlands were included in the AEMC polygon layer where they are considered likely to interact with the surface-water network, as they can provide refuges for native and introduced aquatic species. It is possible that flows from some of the bores supporting bore wetlands may be reduced in future, and the mapping and classification would need to be updated accordingly.

There was no spatial layer identifying bore-fed wetlands, therefore new polygons needed to be created. In 2003 and 2004 a project to identify the values and water requirements of GAB bore-fed wetlands, surveyed and mapped 16 bore-fed wetlands (Phipps 2008). Of these, only one, (Coward Springs) was within the priority study areas and a map is not included in the report. For the priority study areas, potential bore-fed wetlands were identified using the following method by R. Hooper (DEWNR):

> Bores were queried from Obswell: non-artesian; controlled, artesian; and uncontrolled, artesian bore flows based on data from the Great Artesian Basin Sustainability Initiative (GABSI) program for ground-truthing and maintenance of Great Artesian Basin bores (L. Sampson, DEWNR, pers. comm. 2014). Historical time-series data on bore flow rates were also compiled from 1880–2002 for selected bores in the Neales-Peake Catchment. From these data, two indices were calculated including: maximum flow rate (ML/day) and number of years flow (where flow rate > 1 ML/day) and overlaid onto spatial data. Data were then converted to KML file format in ESRI ArcToobox and plotted onto aerial imagery in Google Earth, to examine wetland characteristics including: presence/absence of a waterbody, permanence of flow and evidence of connectivity with rivers.

New features were then digitised where there appeared to be a wetland with some connectivity to the surface water network. The delineation of bore-fed wetlands should be considered preliminary and further work is required to comprehensively determine the location and features of all bore-fed wetlands in the project region.

A further development of the LEBRM mapping and classification would be to incorporate the bore wetlands occurring outside the priority study catchments from Phipps (2008).

2.1.2.3 Dams

Dams on or near floodplains that have been surveyed as part of the Critical Refugia project (McNeil et al. 2011) were manually digitised based on GPS locations and recommendations of D. Schmarr (SARDI, pers. com., 2014).

2.2 Attribution

Attribution was firstly undertaken at the whole of study-region scale where national, statewide or regional data (including the WAD) were available. For the priority study catchments and major large lakes, local-scale attribution was undertaken to improve the first level attribution. Major data sources are listed in Table 2-1.

The Neales Catchment has been the subject of several hydroecological investigations, including the Aridflo project (Costelloe et al. 2004), the LEBRA (Costelloe 2008; McNeil et al. 2008, Cockayne et al. 2012, 2013), Critical Refugia project (McNeil et al. 2011; Costelloe 2011; Scholz and Deane 2011) as well as the current LEBRM project (Ryu et al. 2014; Montazeri and Osti 2015; Hooper and Miles 2015, Schmarr et al. 2014; Wakelin-King 2015). Excepting the latter, these studies have focused predominantly on waterholes, however information for some springs and dams in close connectivity to the floodplain has been collected. Information from these studies was used to inform the attribution of the aquatic ecosystems in the Neales Catchment. These attributes were manually entered for the sites for which information was available, and a reference to the report (author, date) included as method. Confidence ratings were applied as follows:

- Low- based on expert opinion
- Medium- some data to support the classification but further data required to confirm
- High- sufficient data to confidently assign a classification.

Attribution of the Neales Catchment waterholes is shown in Appendix B.

The Macumba Catchment has recently been included as part of the LEBRA sampling regime (Cockayne et al. 2012, 2013) and some field surveys have been undertaken as part of the LEBRM project (Schmarr et al. 2014, Ryu et al. 2014). Both projects have only sampled a very small number of sites in the Macumba Catchment. Information on depth was used to attribute persistence (after Costelloe 2011) and water quality data used to attribute salinity for these sites. Prior to this, a survey of arid rivers in 2005 collected information on biota, water quality and geomorphological features with photographs of each site as well as some anecdotal comments on the water regime.

The SA Environment Protection Authority (EPA) assessed the aquatic ecosystem health of 54 sites in the SAAL NRM region in 2012 (EPA 2012). The results of this monitoring in the priority catchments were included.

Note, for display purposes, gilgai wetlands are not shown on the maps.

Table 2-1 Overview of attribution

Level	Attribute	Data source: whole region	Data source: priority catchments
1	Basin	AHGF Basins	
1	IBRA Region	IBRA Regions v.7	
2	Catchments	Catchments shapefile developed for this purpose	
2	IBRA subregions	IBRA Subregions v.7	
3	System type	Water asset database	Identification of water assets intersected by watercourses, naming of watercourses
3	Landform Transport Zone (riverine only)	May be derived from 3-sec DEM available through CSIRO	
3	Size (palustrine & lacustrine only)	Calculated in ArcGIS	
3	Soil	May be derived from CSIRO soils mapping	
3	Vegetation (/fringing vegetation)	SA vegetation structure	
3	Water source	Water asset database	Costelloe 2010; expert panel workshop
3	Salinity	None available	Costelloe 2010, Cockayne et al. 2012, 2013, EPA (2012), Brandle/arid rivers survey, expert panel workshop
3	Water regime	Water asset database	Costelloe 2010, Montazeri and Osti 2014; Kingsford et al. 1999, Hooper and Miles 2015, Schmarr pers. com. (SARDI, July 2014)

Level	Attribute	Data source: whole region	Data source: priority catchments
3	Hydrological connectivity	None available	Mapping rules

2.2.1 Level 1

The ANAE classification (AETG 2012a) suggests a number of options for Level 1 classification. For the LEBRM Classification, surface-water drainage basins and interim biogeographical regions of Australia (IBRA) were selected for level 1 classification (and their subcategories selected for Level 2). These are presented below.

2.2.1.1 Basins

Description: The Basin boundaries provide a very high level grouping for aquatic ecosystem classification. Many areas within the Basins are hydrologically connected during major flooding events or have been under past, wetter climates.

Data Source: AHGF Drainages

Valid Options: Lake Eyre Basin

South Western Plateau

Method: The Aquatic Ecosystems polygons were spatial joined to the AHGF Level 1 drainages and the attribute populated with the Basin name.

Discussion: The classification of Basins provided a clear delineation of aquatic ecosystems and no further work is required to classify this attribute (see Figure 2-1). However, whilst Basins define major hydrological boundaries, it should be noted that not all aquatic ecosystems within the Basins are hydraulically connected. For example:

- Endorheic[1] basins draining into terminal lakes (e.g. Lake Cadibarrawirracanna)
- Some catchments flood out before reaching Kati Thanda-Lake Eyre (e.g. Finke)
- Other areas are so flat there is effectively no surface run-off (e.g. Simpson Desert dunefields and Gilgai systems).

Data confidence: Data confidence is high for this feature and was not included as an attribute in the schema.

[1] Basins or catchments draining into a lake with no outflow

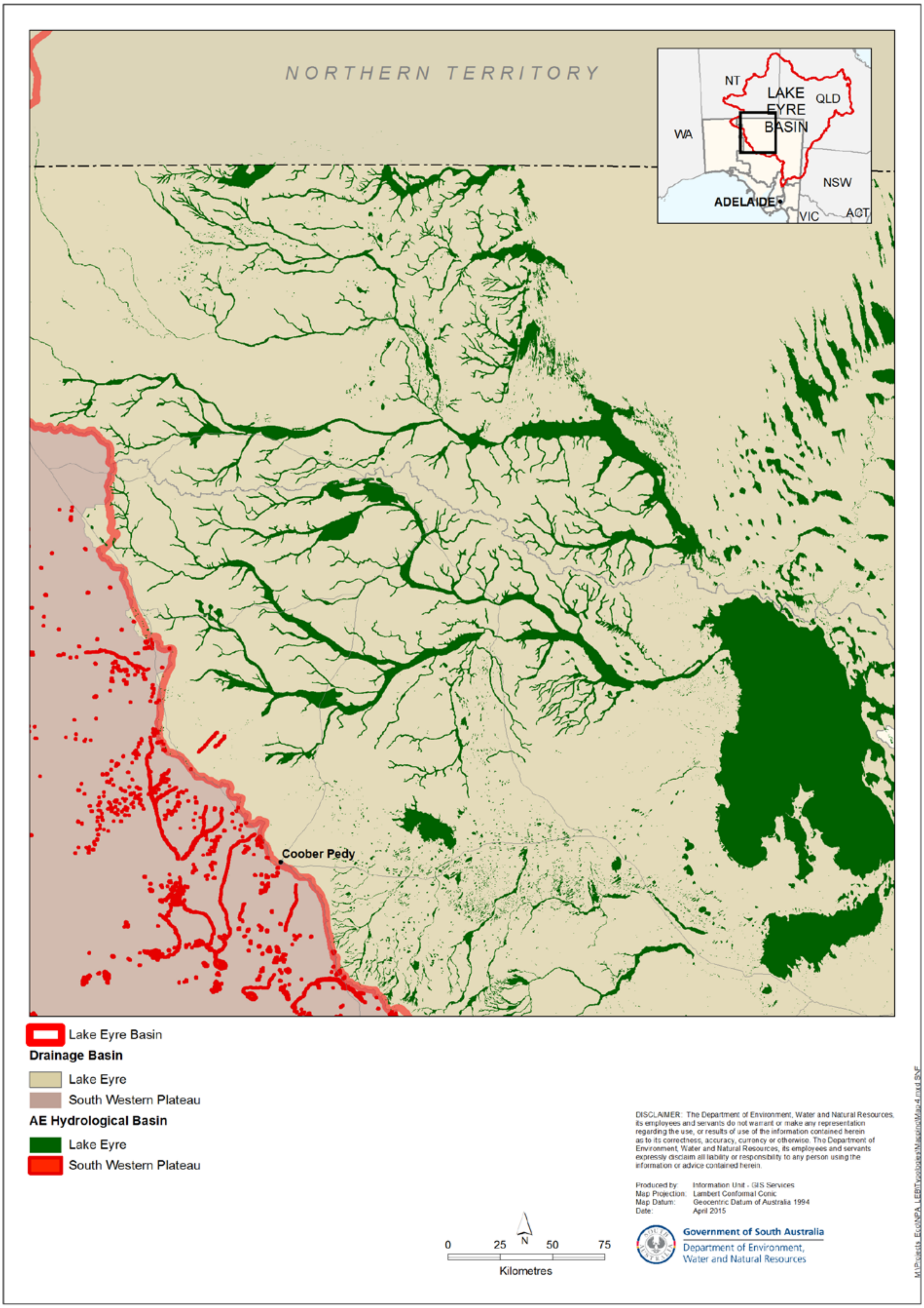


Figure 2-1 Aquatic ecosystems classified by AHGF Basins

2.2.1.2 *IBRA region*

Description: The Interim Biogeographic Regionalisation for Australia (IBRA) identifies high level bioregions based on common climate, geology, landform, native vegetation and species information.

Data Source: Landscapes IBRA Regions (version 7)

Valid Options:

Murray-Darling Depression	Flinders Lofty Block
Broken Hill Complex	Gawler
Central Ranges	Great Victoria Desert
Channel Country	Simpson-Strzelecki Dunefields
Finke	Stony Plains

Method: Overlaying AEMC with IBRA regions was complicated by the fact that many aquatic-ecosystem polygon features intersect two or more IBRA regions, and many are also situated on the boundary of two IBRA regions (Figure 2-2). For aquatic-ecosystem polygons with relatively rounded forms (e.g. lakes and wetlands), using spatial joins by centroids provided an acceptable classification. However, for linear features such as watercourses, this method often resulted in unreliable classification, as either the centroids were situated outside the polygon (particularly where the watercourse segment was curved), or the segment had significant lengths crossing separate bioregions. Using the intersect tool was not acceptable because this method splits polygons along the boundary with the join feature and it was considered that polygons should not be excessively split (e.g. where a small section of anabranching or braided watercourse crossed back and forth across an IBRA boundary). Therefore watercourse polygons were visually inspected and watercourses that intersected IBRA regions were manually cut where a major section of watercourse crossed an IBRA boundary. All polygons were then spatially joined by centroids to IBRA regions, and the IBRA-region name used to attribute polygons.

Discussion: The classification of IBRA regions may provide broad context for the floodplain and terrestrial ecological functions of the LEB aquatic ecosystems, however the classification should be considered less reliable for aquatic ecosystems close to or overlapping IBRA region boundaries, particularly where watercourses run along the boundary of two IBRA regions. The IBRA regions are therefore not recommended for inclusion in the final classification of aquatic-ecosystem types. Some of the features that are used to define IBRA regions (e.g. soils and vegetation) are included in the Level 3 classification, and therefore the IBRA features may be more accurately delineated at that level. An alternative Level 1 classification would be to use the broadscale definition of geomorphological regions described by Nanson (2010), or a climate classification.

Data confidence: A confidence field was not applied for this attribute (noted above). The attribute is likely to be more accurate for features in the centre of an IBRA region than close to a boundary.

Figure 2-2 Position of aquatic ecosystems in relation to IBRA regions

(note watercourses along the boundary of IBRA regions, particularly the Finke IBRA region)

2.2.2 Level 2

2.2.2.1 Catchment

Description: Catchment boundaries enable grouping of aquatic ecosystems with some level of hydrological connectivity.

Data Source: There is no 'official' spatial layer delineating the surface water catchments of the LEB. A catchments shapefile was created for the purposes of the LEBRM classification as follows:

- Catchment boundaries for the Finke, Macumba, Neales, and Margaret-Warriner Catchments were created for other LEBRM project components using ESRI ArcHydro to amalgamate the AHGF_Catchments (see Hooper and Miles 2015; Montazeri & Osti 2014; Osti 2015)
- A surface water catchments shapefile created by Gotch & Dunk (DEWNR 2012, in Denny & Berens 2013) for the WAD was used to split and name the AHGF_NCB DrainageBasinGp as follows:
    - Remaining small catchments adjoining the western side of Kati Thanda-Lake Eyre were labelled 'Western LEB' and small catchments to the south were labelled 'Southern LEB.'
    - Lake Cadibarrawirracanna was defined as the area within the LEB Drainage Basin to the west of the Neales and Margaret-Warriner Catchments
    - All other areas to the west were named Lake Gairdner Catchment
    - Cooper Drainage was split along the WAD catchments to separate the Cooper Catchment from the Frome Catchment
    - The Georgina-Diamantina Drainage was re-shaped along the northern boundary to separate the Simpson Desert
- Lake Gairdner Drainage Basin was named Lake Gairdner Catchment and Lake Torrens-Mambray Coast was named Lake Torrens Catchment.

Valid Options:

Cooper Creek	Neales
Georgina-Diamantina	Finke
Simpson Desert	Macumba
Frome (including Lakes Gregory, Blanche and Callabonna)	Lake Cadibarrawirracanna
Western LEB	Warriner-Margaret
Gairdner	Kati Thanda-Lake Eyre (the lake and aquatic ecosystems therein)

Method: The AEMC polygons were spatially joined to LEBRM Catchments and the attribute populated with the catchment name.

Discussion: The catchment shapefile used for this work is a combination of catchment shapefiles assembled for this project. Further work is required to develop a verified catchment shapefile for the LEB in SA. For most aquatic ecosystems the classification was considered satisfactory (Figure 2-3). For aquatic ecosystems that are not connected with the surface water system (e.g. GAB springs above the floodplain and isolated interdunal lakes), this attribute is less meaningful. Additionally, some aquatic ecosystems lying close to the catchment boundaries may be misclassified, particularly between the boundary of the Georgina-Diamantina Catchment and Simpson Desert. This boundary is particularly poorly defined. The flatness of the region makes accurate catchment definition difficult and many areas exhibit complex hydrology, with different catchments becoming connected under different flow thresholds. Some particular areas of difficulty include:

- The Macumba Catchment does not discharge directly into Kati Thanda-Lake Eyre but into an anabranch of the lower Georgina-Diamantina, and therefore could be classed as a sub-catchment of the Georgina-Diamantina
- The lower Neales River can overflow into the lower Umbum Creek Catchment under high flow conditions, therefore the Umbum could be considered as part of the Neales Catchment
- There are complex inter-relationships between the Cooper and Frome Catchments.

Data confidence: This attribute was not given a confidence rating in the AEMC polygon layer, however the results are considered reliable for most of the major catchments, excepting those areas highlighted above.

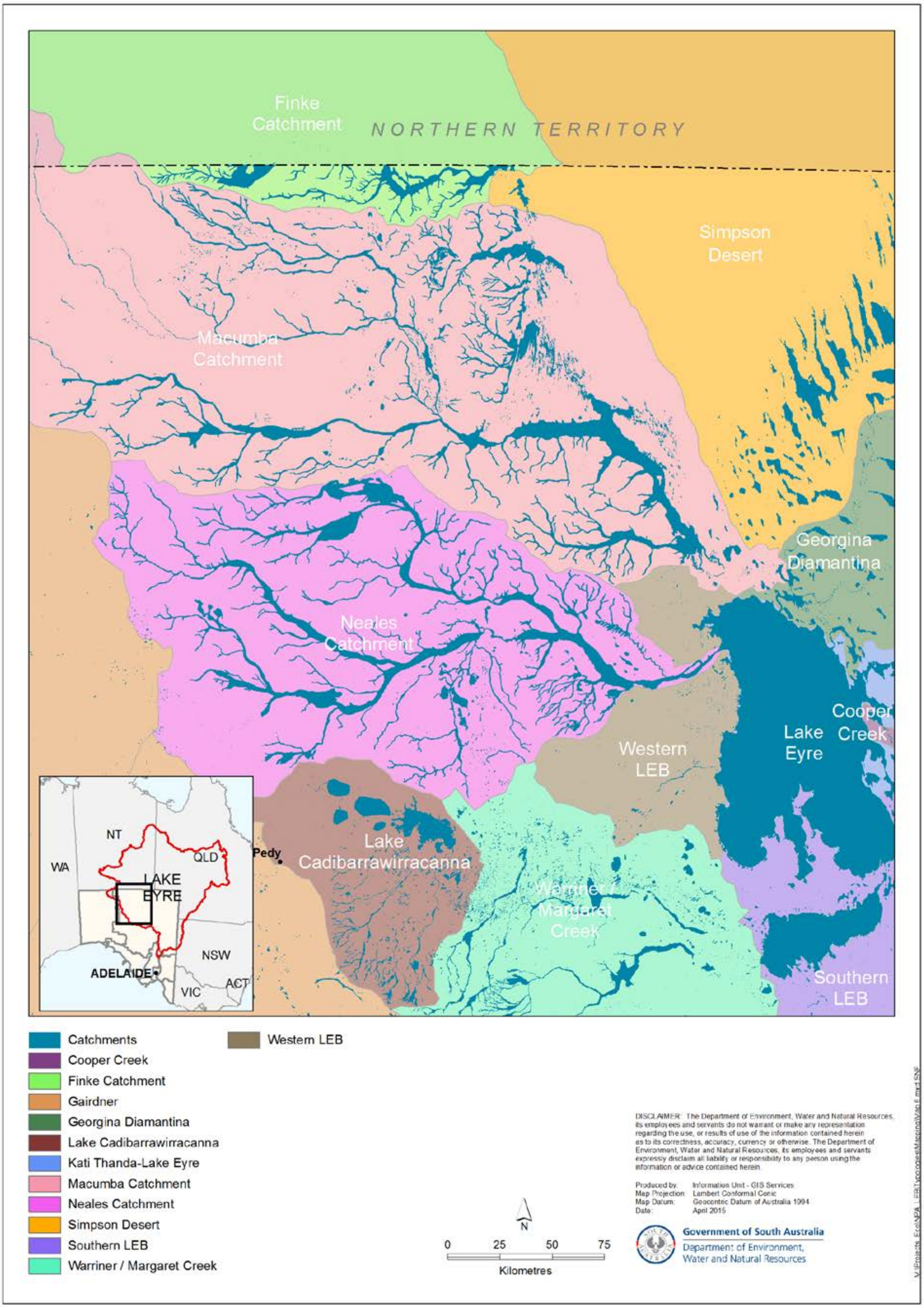


Figure 2-3 Aquatic ecosystems and catchment boundaries

2.2.2.2 IBRA subregion

Description: IBRA subregions provide more detailed classification of bioregions within IBRA regions.

Data Source: Landscapes IBRA Subregions (version 7)

Valid Options:

Arcoona Plateau	Macumba
Baltana	Mann-Musgrave Block
Barrier Range	Maralinga
Barrier Range Outwash	Murnpeowie
Bimbowrie	Northern Flinders
Braemer	Olary Spur
Breakaways	Oodnadatta
Broughton	Peake-Dennison Inlier
Central Flinders	Pedirka
Commonwealth Hill	Roxby
Coongie	Simpson Desert
Cooper-Diamantina Plains	Southern Flinders
Core Ranges	Strzelecki Desert
Curnamona	Sturt Stony Desert
Diamantina-Eyre	Tallaringa
Dieri	Tieyon
Everard Block	Torrens
Kingoonya	Warriner
Kintore	Witjira
Lake Pure	Yellabinna

Method: As for IBRA regions above

Discussion: As for IBRA regions above, however the problems of intersecting boundaries were exacerbated under the Level 2 classification due to the greater number of subregions (Figure 2-4). The IBRA subregions were therefore not selected for inclusion in the final classification of aquatic ecosystem types, and future work incorporating climatic or geomorphological zones may be more useful.

Data confidence: As for IBRA regions above, this attribute is likely to be of greater reliability for aquatic ecosystems that are situated in the middle of IBRA subregions than on the edges.

Figure 2-4 Position of aquatic ecosystems in relation to IBRA subregions

(note the proximity of watercourses to IBRA subregion boundaries)

2.2.3 Level 3

2.2.3.1 Class Type

"Surfacewater" was the only valid class type for the aquatic ecosystems included in this project. All polygons were assigned this value.

2.2.3.2 Group Type

"Inland" was the only valid system type for the aquatic ecosystems included in this project. All polygons were assigned this value.

2.2.3.3 System Type

Description:	The definitions for System Type (AQ_3WSYSTEM_TYPE) follow those outlined in ANAE (AETG 2012a) which are based on Cowardin et al. (1979). This classification provides a high-level grouping for aquatic ecosystems, however it should be noted that many sections of watercourse in the western LEB do not clearly meet the Cowardin (1979) definition of riverine systems as aquatic ecosystems contained within a channel and its associated streamside vegetation. In many areas, there is not a clear channel (individual or multiple) lined with riparian vegetation, rather broad, shallow depressions where flows spread out across. Riparian vegetation exists from one side of the depression to the other (Figure 2-5).
Data Source:	WAD features were classified for system type [Waterbody_Type]. The process by which system type was assigned for the SAAL WAD was: *"For all assets imported from SA_Wetlands_All_Polygons, the attributes 'Palustrine', 'Lacustrine', and 'Marine' were applied to wetland assets according to the existing classification in the source data (SA_Wetlands_All_Polygons layer …). Because the SA_Wetlands_All_Polygons does not include 'Floodplain' in its classification scheme, it is possible that some 'Palustrine' wetlands would be more accurately classified as 'Floodplain' wetlands…* *"The 18061 features imported from SAAL_LEB_Wetlands_June2010 were classified in their source layer as floodplain features …* *"Waterholes imported from SAAL_Waterholes_CooperDiamantina … were attributed as 'Riverine' (Denny & Berens 2013)."*
Valid Options and definitions	Lacustrine (usually less than 30 percent vegetation cover and greater than 8 hectares, however habitats less than 8 ha may be lacustrine if they have wave-formed or bedrock shoreline-features or are greater than 2 metres deep. Dams are commonly lacustrine.) Palustrine (usually more than 30 percent vegetation cover and always less than 8 hectares, however habitats with less than 30 percent vegetation may be palustrine if they lack wave formed or bedrock features and are less than 2 metres deep.) Riverine (habitats contained within the channel and its associated vegetation.) Floodplains (areas inundated by overbank flow from riverine systems and flood-out areas of lacustrine and palustrine systems). Unknown
Method (whole of region):	All watercourses sourced from the AHGF were classified as 'riverine'. All polygons imported from the floodplain mapping of Hooper and Miles (2015) were attributed as 'floodplain' For features imported from the WAD, the values from the Waterbody Type field were copied to the

System Type, however, as Denny and Berens (2013) noted, there was potential that features sourced from SA_Wetlands_All_Polygons contained floodplain systems classified as palustrine or lacustrine. On examination of the WAD classification that riverine waterholes were classified as either palustrine or lacustrine when riverine would be more appropriate. Therefore the following mapping rules were applied to improve the classification of system type:

- Waterholes were identified – if containing the word 'waterhole' in the name field, these were classified as 'riverine'
- Dams were classified as lacustrine (many were previously palustrine or man-made/artificial)
- All features classified as "Man-made/artificial" type in the WAD were farm dams located in the NY NRM region and were re-classified as lacustrine
- Two features classified as "Fractured Rock Aquifer" in the WAD were re-classified as 'palustrine' as these are Tarlton and Edith Springs.

All watercourses (as identified by their source geometry) were classified as riverine. All waterholes were identified by containing 'waterhole' in the name field and classified as riverine.

Method (priority catchments): All lacustrine and palustrine polygons intersected by a watercourse in the priority catchments were selected. If a lacustrine or palustrine polygon had the same name as the overlapping watercourse it was re-classified as 'floodplain.' Polygons not sharing a name with the watercourse were visually inspected and re-classified as floodplain if they appeared likely to be a floodplain (based on having a shape that followed a watercourse feature). Small, unnamed polygons intersected by a watercourse in the Neales Catchment were manually re-classified as 'riverine' by the author. All features imported from the Hooper and Miles (2015) mapping were classified as floodplain.

All new features digitised for the project were assigned their system type classification based on the definitions outlined above. Bore wetlands were classified as 'palustrine.'

Discussion: The results of the System Type classification are shown in Figure 2-6.

Any waterholes that were unnamed features in the WAD would not have been identified as waterholes based on name searching, and therefore would have retained their original classification from the WAD. Some waterholes are named as waterholes but may in fact more accurately fit the classification of palustrine or lacustrine system types (i.e. are not on the main channel of a watercourse; particularly likely in the Cooper and Georgina-Diamantina Catchments) and may have been misclassified.

Palustrine wetlands with an area greater than 8 ha were selected to determine if any were misclassified; this resulted in only GAB springs being selected which had been correctly classified. Lacustrine wetlands with an area less than 8 ha were selected to determine if these were likely to be misclassified palustrine wetlands. This selection identified small polygons association with Kati Thanda-Lake Eyre, the Lakes Gregory to Frome sequence and farm dams; these polygons were considered to have been correctly classified.

The greatest potential for erroneous system-type classification are areas of floodplain on the Cooper and Georgina-Diamantina that were classified as lacustrine in the WAD but could be more accurately described as floodplain. Examination of original data sources for these areas would assist to accurately classify the system types. More reliable vegetation mapping could also assist to distinguish lacustrine from floodplain system types (i.e. polygons with little vegetation are more likely to be lacustrine while vegetated polygons are likely to be floodplains).

Data confidence: Source data and associated confidences were classified as follows:

- Data sourced from the WAD (non-waterholes):
    - Palustrine wetlands = medium confidence

    - Lacustrine systems = low confidence

- NPA Line: high confidence
- Waterholes: medium confidence except for known waterholes (i.e. sampled through major projects) which were given high confidence
- Floodplains: medium confidence.

Figure 2-5 Example watercourse in the Macumba Catchment that exhibits characteristics of both floodplain and riverine system types

Figure 2-6 Aquatic ecosystems classified by system type

2.2.3.4 Landform transport zone

Description: The landform transport zone (LTZ) is used to describe the broad processes of erosion and deposition, as well as water velocity. AETG (2012a) suggest that this attribute is most relevant to riverine ecosystems.

Hale (2010) derived a landform attribute for the LEB based on the 9-sec DEM using a roughness index classified into three groups based on natural breaks, however Hale (2010) noted that the application of this system resulted in a number of anomalies that required manual resolution. In addition, this method does not differentiate upland areas that are plateaus, as per the ANAE metrics, although these are not considered predominant in the SA LEB.

Brooks et al. (2014) applied a combination of the Valley Bottom Flatness Index (Stein 2006) and Ridge Top Flatness Index (Gallant and Dowling 2003) in the Murray-Darling Basin (MDB) as it was felt to provide the best option for uniform application across the MDB.

Data Source: The CSIRO Soil and Landscape Grid of Australia products became available in November and December 2014 following the development of the draft AEMC. This data was sourced for inclusion in post project analysis, with the Slope Relief Classification used to attribute the Landform Transport Zone (Appendix C, Table C-1, see Landform energy).

Valid Options:

- High energy
- Intermediate energy
- Low energy
- Unknown
- NA – for non-relevant ecosystem types

Method & Discussion: See Appendix C, Table C-1, Landform energy

2.2.3.5 Scale

Description: The scale attribute is not included in the ANAE but is included in the SAAE to provide differentiation amongst aquatic ecosystems of different size classes.

Data Source: Shapefiles in the LEBRM AEMC polygon layer

Valid Options and Definitions:

- Mega (> 10 000 ha)
- Macro (100 – 10 000 ha)
- Meso (25 - 100 ha)
- Micro (1 - 25 ha)
- Lepto (0.01 - 1 ha)
- Nano (< 0.01 ha)
- Unknown
- NA (for rivers and floodplains)

Method: Only palustrine and lacustrine aquatic ecosystems were classified for scale (AQ_3INLAND_SIZESCALE_SA). The size of these aquatic ecosystems was calculated in ArcGIS and grouped by the above size categories.

Discussion: Due to some aquatic ecosystems being represented by multiple polygons and/or having poor geometrical delineation, the classification of size may be misrepresentative. However, it is likely that larger aquatic ecosystems are more accurately represented. This classification could be improved by refining the delineation of aquatic ecosystems (AETG 2012b).

Data confidence: Due to the above limitations, this attribute was considered to have low confidence for all except those aquatic ecosystems classified as Mega and Macro.

2.2.3.6 Soil Type

Description: The AETG (2012) recommend the use of soil to classify aquatic ecosystems as it is considered a powerful indicator of aquatic ecosystem dynamics due to its influence on other system characteristics (e.g. water quality, fauna and vegetation). Soils may also be a reflection of the physical processes occurring within the system (e.g. water inflows and chemistry) (AETG 2012) and may be indicative of, or a determinant of, surface water–groundwater interactions.

Data Source: When the AEMC project was undertaken, there were no soils data of sufficient resolution to classify soil types for aquatic ecosystems in the study region. A national soil mapping program is currently underway to develop a Soil and Landscape Grid of Australia (TERN 2014) and some data became available in October 2014 after the draft AEMC was prepared. The Clay Content and Depth to Regolith data-set were sourced for this attribute (see Appendix C, Table C-1).

Valid Options:

Clay (> 30 % clay)	Rock (depth to regolith ≤ 1 m)
Non-clay (<30% clay)	Unknown

Method and Discussion: Once available, soil-grid data were interpreted to classify aquatic ecosystems as described in Appendix C, Table C-1.

2.2.3.7 Vegetation

Description: The AETG (2012a) recommend the inclusion of dominant or fringing vegetation in the ANAE Classification Framework as it is useful for distinguishing aquatic-ecosystem types and contributes to the habitat and biodiversity of sites. Vegetation can also be considered to be determined by other factors included in the classification (e.g. water regime, soil type and salinity) and therefore may assist to differentiate between aquatic ecosystems where data for these other factors are poor.

Data Source: The statewide SA_Veg_Structure was used to define vegetation.

Valid Options:

Woodland	Sedgeland
Shrubland >1 m	Forbland
Shrubland <1 m	No vegetation (e.g. lacustrine system types)
Grassland	Unknown

Method: The attribution of vegetation structure required a combination of methods because, whilst the aquatic ecosystem polygons and vegetation polygons generally had a similar geometry, linear and curved features were difficult to classify using ArcGIS tools. Splitting polygons was not considered a satisfactory option. Therefore the following methods were used:

- All watercourses ('in-channel habitats' in LEBRM Type) were classified as woodland and the results were then visually inspected. Any watercourses lying predominantly outside a woodland vegetation structure were manually classified as the appropriate vegetation structure
- All floodplains imported from Hooper and Miles (2015) were assigned vegetation structure based on their original source data (this shapefile was derived from vegetation mapping and therefore the geometry was consistent with vegetation mapping geometry)
- All other polygons were classified using spatial joins by centroids.

Due to the requirement to manually inspect watercourse and floodplain polygons, Vegetation was only applied in the Neales, Macumba and Finke catchments.

Discussion: The classification of vegetation structure was limited by a number of factors:

1. The coverage and accuracy of the source dataset – whilst most of the priority catchments have vegetation mapping, this was largely based on mapping from satellite imagery with sparse on-ground surveys. Visually comparing the vegetation mapping with Landsat imagery, and where available, higher resolution imagery, indicated smaller and/or narrower areas of discrete vegetation types are less likely to have been detected. The occurrence of small or narrow vegetation types is common in aquatic ecosystems. The geometry of the vegetation types also did not align with the geometry of the aquatic ecosystems.
2. Where aquatic-ecosystem polygons overlapped two or more vegetation-structure polygons, they may not have been classified by the predominant or central vegetation structure.
3. Depending on the scale at which aquatic ecosystems have been delineated they may include areas of two or more vegetation types, however the LEBRM AEMC framework only allowed for the attribution of one vegetation structure.
4. It is questionable whether, in a 'top-down' classification approach such as the one used for the LEBRM AEMC, classification of vegetation structure should be included as an attribute, as vegetation is largely determined by other Level 3 attributes. Vegetation mapping may however be useful to infer or verify the classification of other attributes where other data are unavailable or unreliable, such as system type, flow regime and salinity. The SAAE classification (Fee & Scholz 2010) only includes presence or absence of vegetation as the valid options.

Data confidence: Low for all polygons

2.2.3.8 Water Source

Description: For the purposes of the LEBRM project, the classification of water source was one of the priority attributes as this is one of the major pathways by which impacts from coal mining and CSG may occur. The AETG (2012a) recommend a single tier water source classification, however, for the purpose of the LEBRM AEMC it was determined that a greater level of detail should be included to describe the multiple sources of groundwater (e.g. Great Artesian Basin, alluvial and unconfined fractured rock aquifers).

Data Source: The WAD included a water source field (Water_Source) and also included information on the groundwater source in the water regime field (Water_Regime) for some features.

Valid Options: The water source attribute was split into a two tier classification, where the first tier was of was a basic description of Water Source (AQ_3INLAND_SOURCE) consistent with the ANAE:

- Surface Water (e.g. negligible groundwater inputs)
- Groundwater (e.g. negligible surface water inputs)
- Combined: Surface water dominant
- Combined: Groundwater dominant
- Combined: Unknown
- Unknown

The second tier of the water source provides a greater level of detail about the source of ground and surface water. The Groundwater Source (AQ_3INLAND_GW_SOURCE) options are a combination of aquifer type and confinement, with mutually exclusive combinations known to occur in the region selected:

- Alluvial
- Fractured Rock
- Confined Artesian

- Confined Non-artesian
- Unconfined (e.g. regional unconfined aquifer, non-alluvial and non-fractured rock)
- Unknown
- NA (if source is surface water only)

For Surface Water (AQ_3INLAND_SW_SOURCE), valid options were:

- In-stream
- Overbank
- Rainfall
- Unknown
- NA (if source is groundwater only)

Method: The water source attributes were derived from the WAD as shown in Appendix A. The method was classified as NPADB[2] for all attributes derived from the WAD and the confidence values from the WAD were assigned.

For the priority catchments, information on the water source was derived from cited papers and reports listed in the methods and the expert panel workshop (Appendix B).

Discussion: The GAB springs are the only aquatic ecosystems in the priority catchments for which there is reliable information on the water source. Shallow alluvial groundwater is thought to exist along many watercourses but there is little data to verify if and where this does occur.

Data confidence: Where the water source was classified based on the WAD, the confidences assigned in the WAD were brought across to the LEBRM AEMC. Where attributes were derived from papers, reports and expert panel, confidence was accordingly assigned (Appendix B).

[2] NPADB: an earlier acronym for Water Asset Database

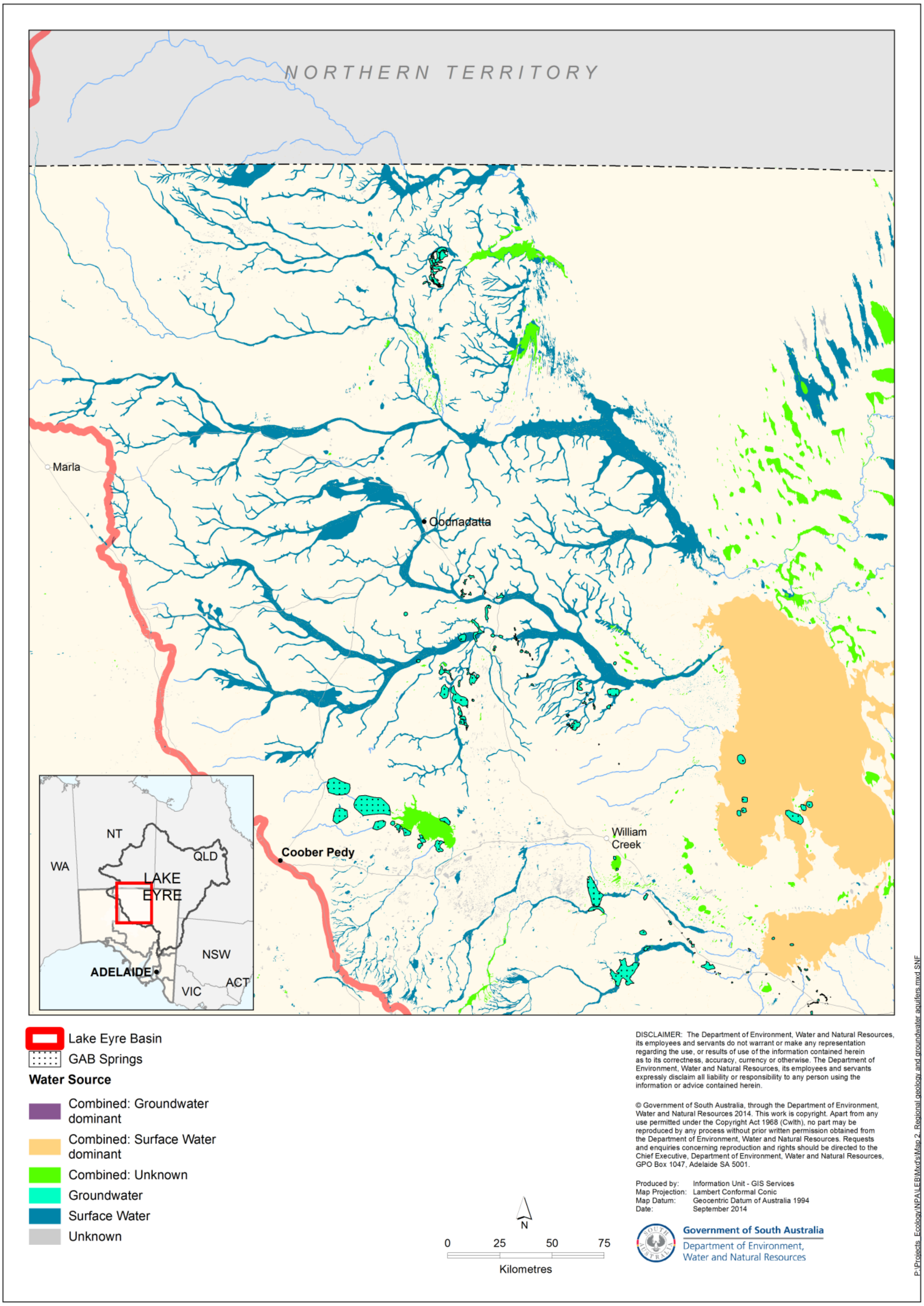


Figure 2-7 Aquatic ecosystems classified by water source

(note: due to the scale, the classification of some polygons is not visible)

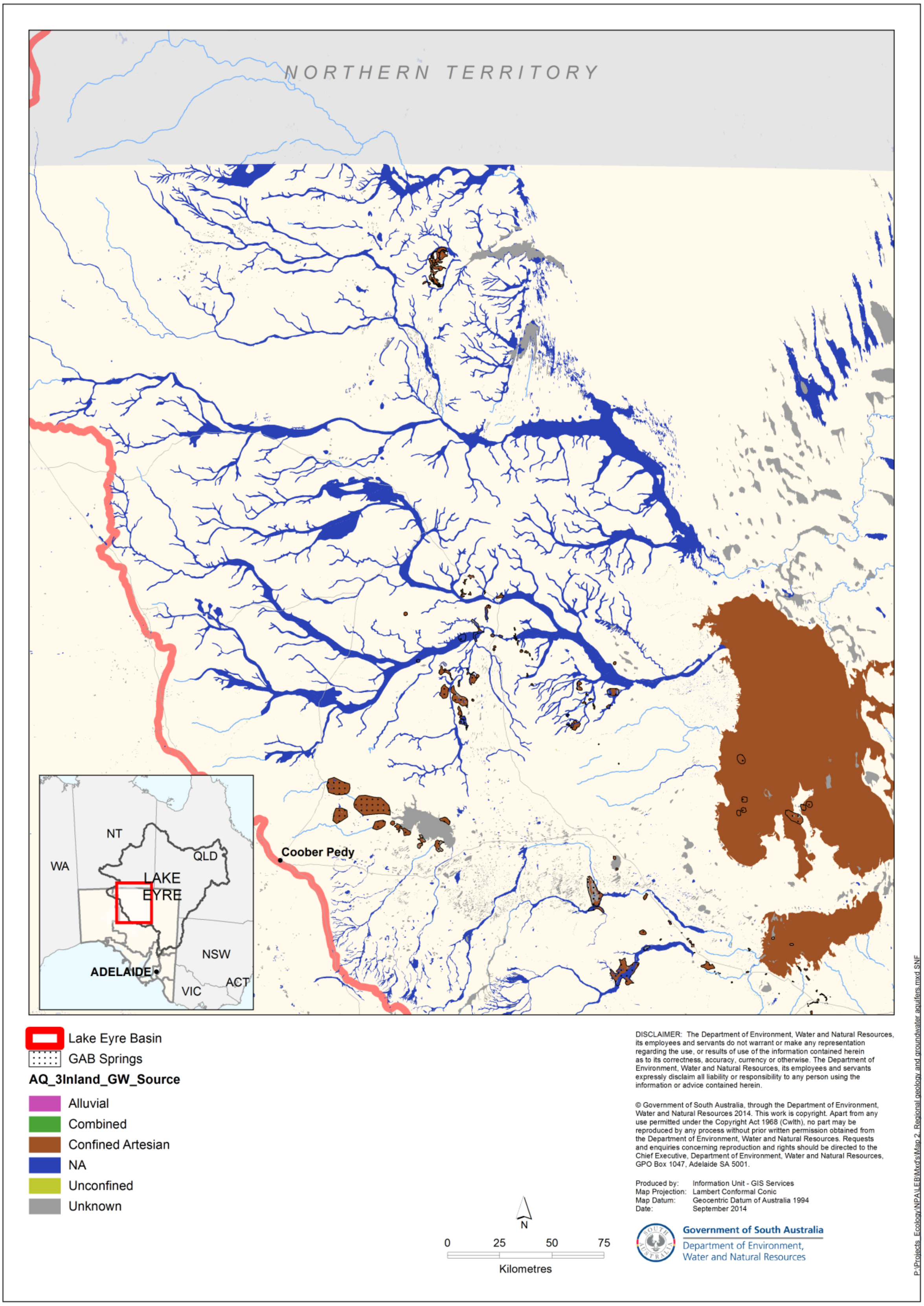


Figure 2-8 Aquatic ecosystems classified by groundwater source

(note: due to the scale, the classification of some polygons is not visible)

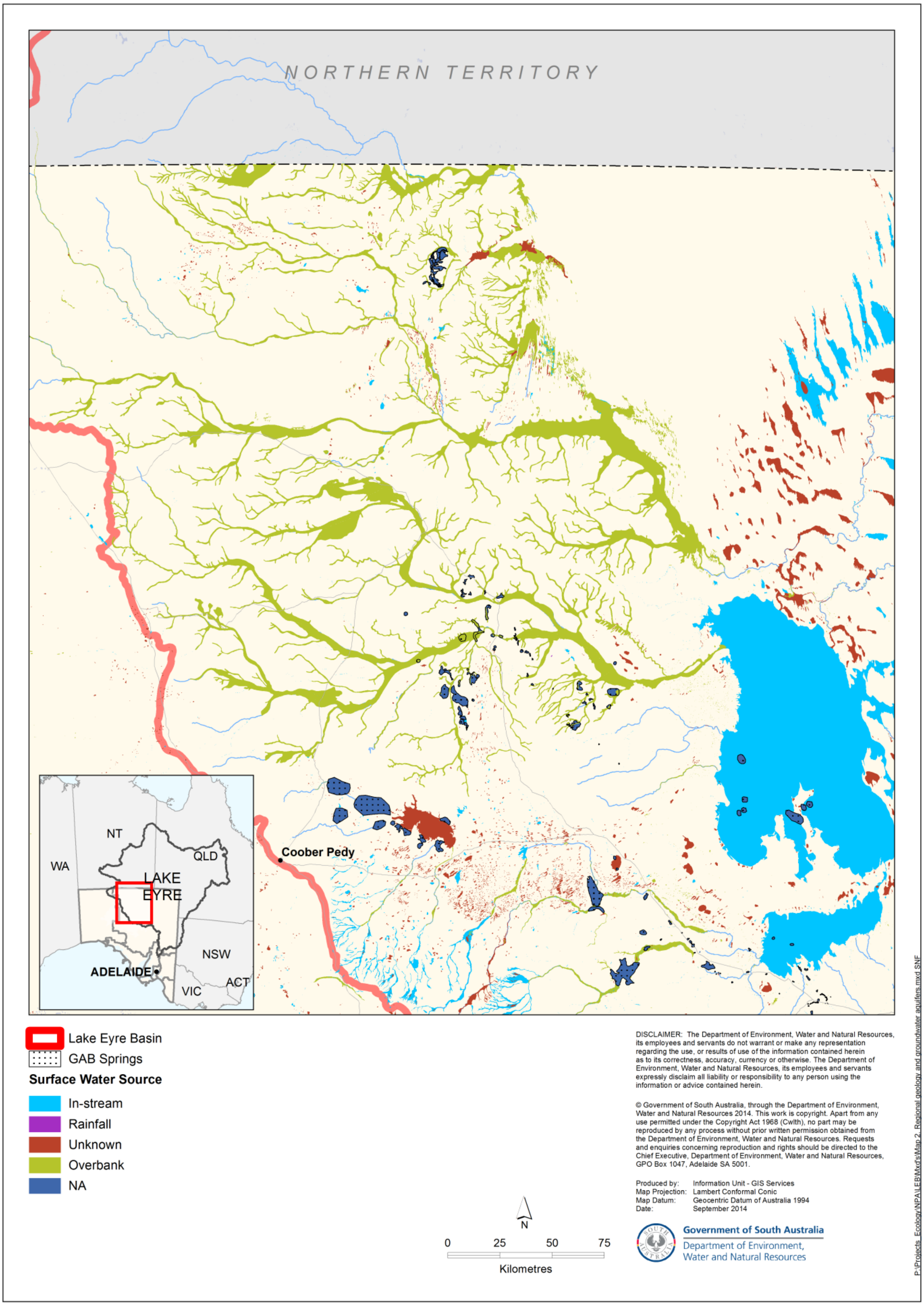


Figure 2-9 Aquatic ecosystems classified by surface water source

(note: due to the scale, the classification of some polygons is not visible)

2.2.3.9 *Salinity*

Description: Salinity has been found to be one of the critical drivers of ecosystem composition in the LEB, particularly in the western catchments and lower reaches of the Cooper and Georgina-Diamantina (Costelloe et al. 2004, 2005; Shiel et al. 2006; McNeil et al. 2011). However, the salinity of many LEB water bodies varies significantly through time in response to preceding flow conditions and stratification within waterbodies may occur. These factors, in combination with the high spatial variability of salinity and lack of spatial and temporal coverage in salinity data made it difficult to classify the LEB aquatic ecosystems for salinity. It was determined that the average salinity range should be used based on best available data or knowledge.

Data Source: No existing spatial data were available to apply a whole of region classification of salinity. Salinity data were sourced from the following reports for sites (mainly waterholes) within the priority catchments:

- Costelloe (2011)
- McNeil et al. (2011)
- Cockayne et al. (2012, 2013)
- EPA (2012)
- DEH (2006) arid rivers survey.

The expert panel provided input to classifying salinity in the priority catchments.

Valid Options: The following salinity ranges are were adopted from the recommendations of Radke in the AETG (2012a):

- Fresh (< 1000 mg/L)
- Brackish (1000 - 3000 mg/L)
- Saline (3000 – 10 000 mg/L)
- Hypersaline (>10 000 mg/L)
- Unknown

Method: Salinity was manually classified for sites where information was available based on the above data sources, and referenced to the source in Salinity Methods. Due to the variability of salinity through time encountered at most sites, the salinity range was selected to represent the 'normal range' for the site (i.e. the median value).

For sites in the Macumba Catchment sampled by the Arid Rivers survey and not LEBRA or LEBRM, site notes and photographs were examined for evidence of salinity (e.g. salt tolerant /intolerant vegetation), and a salinity range assigned. The salinity classification for these sites is provided in Appendix B, Table 4-3.

Discussion: Salinity data are only available for a small proportion of sites in priority catchments, representing mostly permanent and mid-term riverine aquatic ecosystems (i.e. waterholes). Very few of these sites have long term data to support salinity classification.

For many aquatic ecosystems that are only very infrequently or temporarily inundated, the salinity of the soil and/or local alluvial groundwater environment may exert a stronger influence on structuring biotic community (i.e. the vegetation) than the salinity of the surface waters (Gillen and Reid 2013). The ANAE classification does not provide clear guidance about whether the salinity classification should apply to the waters or the salinity of the environment (e.g. soils).

Data confidence: The majority of polygons were classified as 'unknown.' Polygons that were classified for salinity were assigned confidences based on data reliability (e.g. long term or short term sampling) and how well data fitted within a single category.

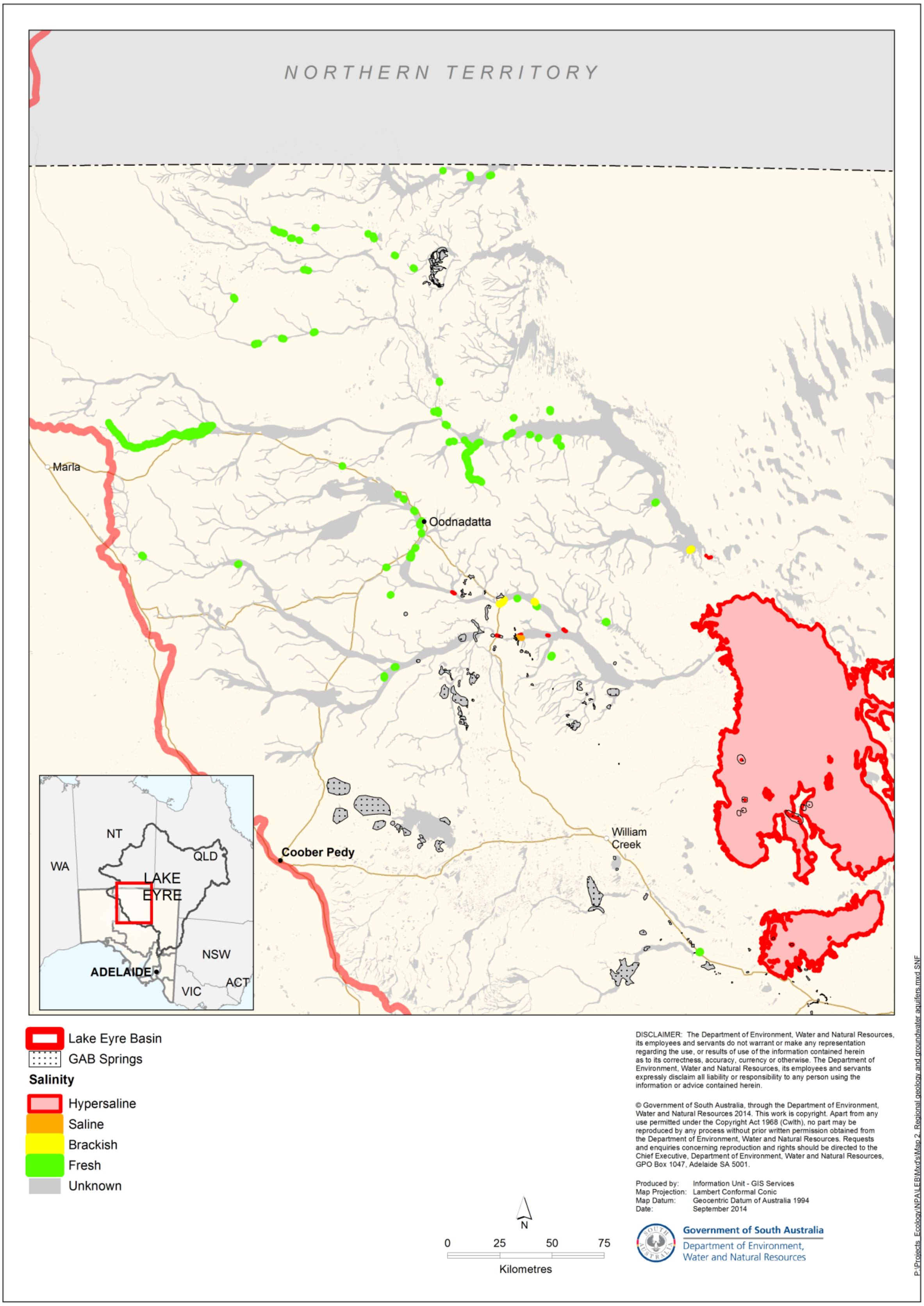


Figure 2-10 Aquatic ecosystems classified by salinity

2.2.3.10 Water Regime

Description: Flow regime is a critical driver of LEB aquatic ecosystems in time and space (Costelloe et al. 2004; Bunn et al. 2006; McNeil et al. 2011). The study region includes some of the most hydrologically variable ecosystems in the world, the rivers of the Cooper and Georgina-Diamantina (Puckridge et al. 1998), as well as GAB springs, where groundwater has been discharging at the same location for hundreds of thousands (Priestely et al. 2013) to a million or more years (Krieg 1989).

Flow in the western rivers of the LEB is not characteristic of the sorts of flows that occur in other, more temperate catchments. Rainfall events are often highly localised and may occur anywhere within a catchment. This results in flows that may be confined to a single subcatchment or reach, and do not result in hydrological connectivity between waterholes (Costelloe 2011). Therefore, whilst the hydrological modelling undertaken for LEBRM (Montazeri and Osti 2015) showed that in-channel flows occur on average at least annually in the modelled reaches, it should not be assumed that complete longitudinal connectivity occurs on such a frequent basis.

Data Source: Flow regime was one of the attributes included in the WAD and the flow regime attributes were brought across to the LEBRM AEMC for the whole of the study region. For the priority catchments, past reports and literature as well as the results of this project were used to assign water regime attributes where available.

Valid Options: In order to describe flow regime, the LEBRM AEMC adopts the attributes of inflow frequency and persistence as per the SAAE classification framework (Fee and Scholz 2010).

Inflows – how frequently water flows into the aquatic ecosystem. Valid options for this were:

- Permanent
- Seasonal/Intermittent (flow occurs on average at least once per year)
- Ephemeral (flow occurs on average less than once per year but more than once every five years)
- Highly ephemeral (flow occurs less than once every five years)
- Unknown.

Persistence – how long the aquatic ecosystem retains water once flow ceases for aquatic ecosystems with inflows that are infrequent enough to sustain them permanently, and for aquatic ecosystems where flows are sufficient to sustain them permanently, they are classified as permanent. Valid options are:

- Permanent (all systems not known to dry out in living memory)
- Mid-term (semi-permanent; holding water for more than a year once inflows cease but not permanent)
- Annual (short term; holding water for less than a year)
- Unknown.

Method: These attributes were classified based on the WAD for all features imported from that source as per Appendix A.

Information from reports, literature and modelling was manually entered where available in the priority catchments, and the source was listed as the method.

Where no other information was available, persistence was estimated based on the cease to flow depth of waterbodies after work by Costelloe (2011) and Hamilton et al. (2005) as follows:

- Waterholes with a cease to flow depth of less than 2.4 metres will not persist for more than a year without inflows or groundwater inputs
- Waterholes need to have a cease to flow depth greater than 4 metres to persist for two years without inflows or groundwater inputs (where such features exist within reaches receiving on

average flows every year these are considered permanent).

Cease to flow depth is only available for a small number of sites in the priority catchments. Cease to flow depth was estimated for waterholes surveyed in the Macumba Arid Rivers Survey based on visually assessing photographs. The vegetation line, particularly Lignum (*Duma florulenta*) was taken to indicate the cease to flow level. It is assumed but not confirmed there are no permanent surface-water fed waterholes in the Macumba.

The flow regime of manually attributed waterholes is shown in Appendix B, Table 4-2 and Table 4-4.

All watercourses and floodplains were classified as having a persistence of ‘annual’. Costelloe (2011) estimates catchment scale floods (where there is almost complete longitudinal and latitudinal inundation of floodplains throughout the catchment) have occurred almost annually between 2001 and 2010, and eight times between 1979 and 2003. Therefore the floodplains of the Neales Catchment were all classified as having an ephemeral inflow frequency.

Discussion: A range of flow regime attributes (e.g. different flow magnitudes, preceding flow conditions) have been found to be significant for ecological, water quality and geomorphological processes in the LEB (Miles and Risby 2010). Puckridge et al. (1998) identified 11 measures to describe flow variability. The LEBRM AEMC framework presents a simplified classification with two flow regime attributes (inflow frequency and persistence).

The classification is further simplified where a single polygon represents different flow regime zones. For example, the floodplain mapping for the Neales and Macumba Catchments represents a single floodplain extent. However, within the floodplain there are likely to be lower lying areas or areas close to the main channels that are more frequently inundated than higher areas and outer floodplains. Remotely sensed floodplain mapping for the Cooper and Georgina-Diamantina (Wainwright et al. 2006; Tunn and Cameron 2008) could be used to delineate zones of differing flood frequency. Preliminary mapping of the extent of flooding under differing flow events was undertaken as part of the LEBRM project (Hooper and Miles 2015). Further analysis of this work, potentially incorporating products being developed as part of the *Water Observations from Space* project (Geoscience Australia 2014) and elevation and flow analysis could be used to better delineate zones of different flow frequency.

Accurate data on flow regime are only available for a small proportion of sites within the study region and priority catchments. Therefore the water regime classification should be considered largely preliminary.

Data confidence: Confidence values were imported from the WAD. Where flow regime was manually attributed, a confidence value was assigned based on source data. Floodplains of the Neales Catchment were assigned low confidence.

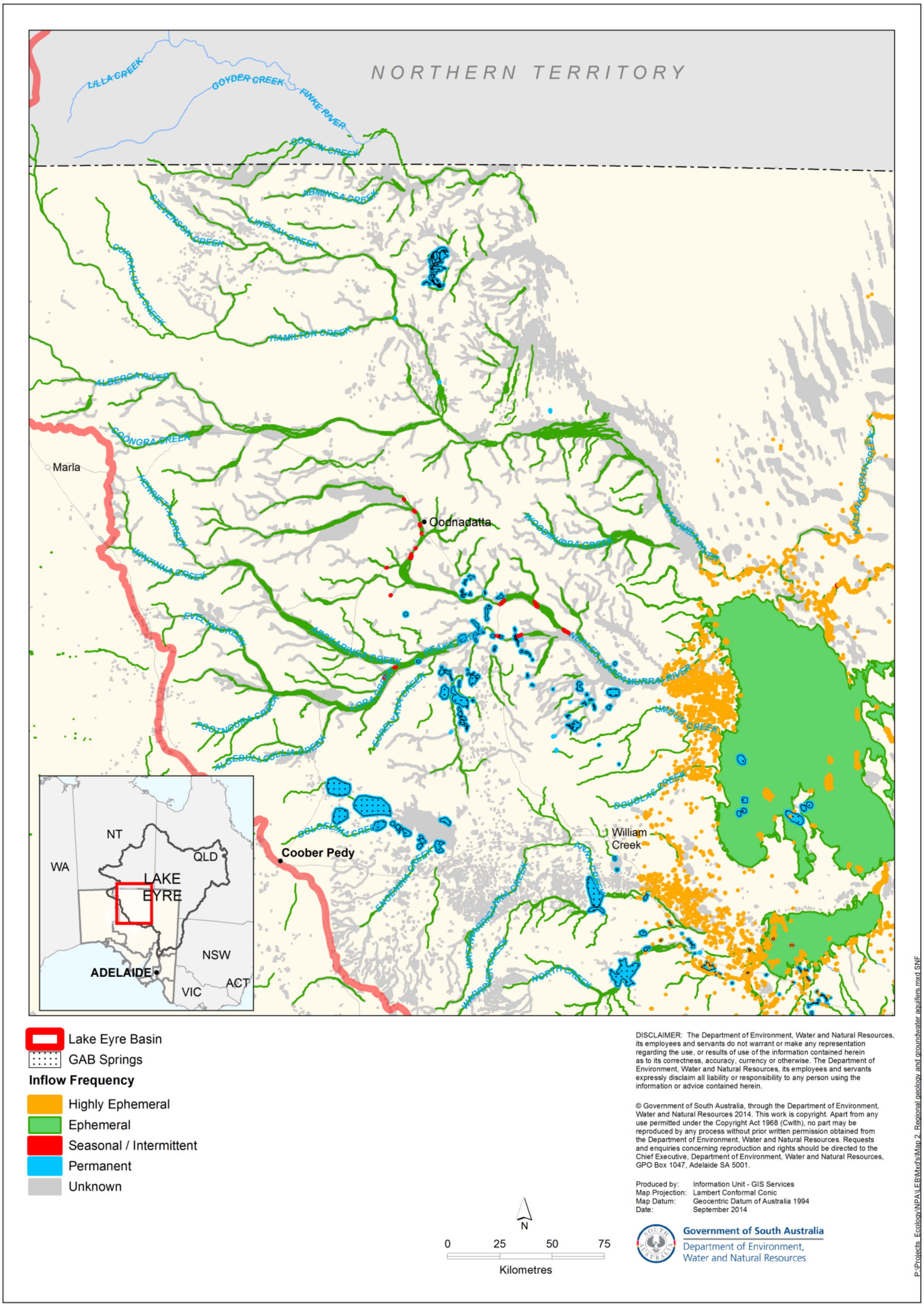


Figure 2-11 Aquatic ecosystems classified by inflow frequency

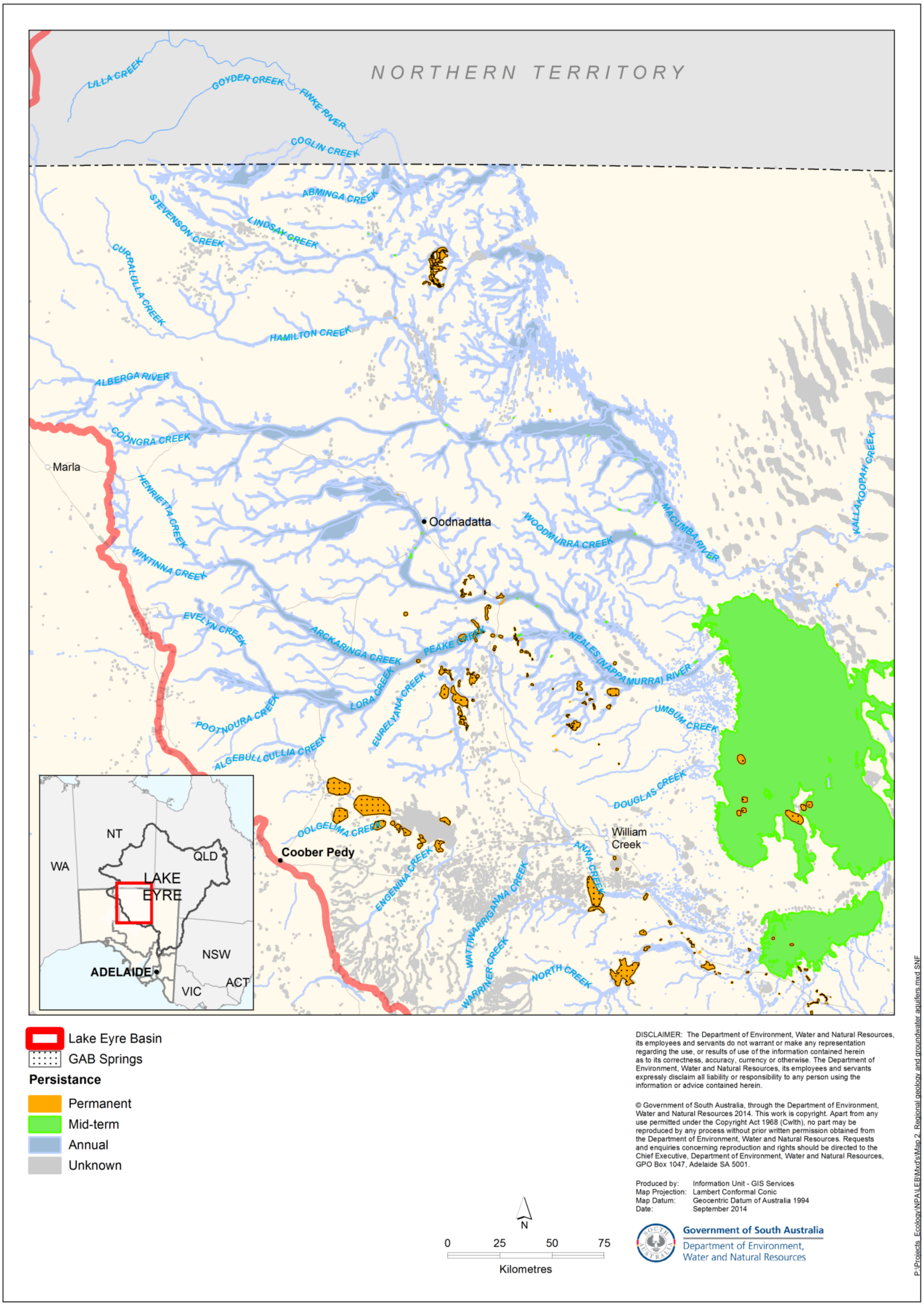


Figure 2-12 Aquatic ecosystems classified by persistence

2.2.3.11 *Hydrological connectivity*

Description: Hydrological connectivity describes the potential for obligate aquatic organisms and water-borne propagules and properties (e.g. chemicals) to move between aquatic ecosystems. This attribute is not included in the ANAE (AETG 2012a) but is included in the SAAE classification (Fee and Scholz 2010)

Data Source: There was no available data source on which to base the attribution of hydrological connectivity. The geometry of the polygons and their System Type classification was used to apply a whole-of-region classification for hydrological connectivity

Valid Options: For lacustrine, palustrine and floodplain ecosystems, valid options were:

- Overbank Flow
- Retained
- Terminal
- Through Flow (e.g. main channel waterholes)
- Unconnected
- End of System

For riverine ecosystems, valid options were:

- Always Connected
- Sometimes Connected

'Unknown' was valid for any type.

Method (whole of region): A mapping rules approach was used to assign hydrological connectivity as follows:

- All riverine types were classified as 'Sometimes Connected'
- All floodplain types were classified as 'Overbank Flow'
- All non-riverine and non-floodplain aquatic ecosystems with centroids in floodplains were assigned with 'Overbank Flow'
- All palustrine and lacustrine aquatic ecosystem polygons not joining or overlapping another polygon of any type were classified as 'Unconnected'
- All aquatic ecosystems in the Simpson Desert 'catchment' were assigned 'Unconnected.'

Method (priority catchments) Known 'End of System' lakes (e.g. Kati Thanda-Lake Eyre North and South and Lake Cadibarrawirracanna) and smaller polygons within these were classified as End of System.

Lakes Frome, Blanche, Callabonna and Gregory were classified as 'Through Flow', as were the aquatic ecosystems that link Kati Thanda-Lake North and South.

Lake Hope was classified as 'Terminal.'

Aquatic ecosystems classified as being in the Simpson Desert Catchment, but appearing (on Landsat imagery) to be connected to the Kallakoopah Creek, were re-classified as 'Retained.' Aquatic ecosystems on the perimeter of the Browns Creek floodplain were classified as 'Retained.'

The hydrological connectivity of GAB springs was refined at an expert panel workshop for those springs for which this was known.

Discussion: The method used to determine hydrological connectivity is reliant on the spatial geometry and System Type classification of aquatic ecosystems, particularly for floodplains, therefore the hydrological connectivity attribution will be more accurate where those attributes are accurate. Determination of which aquatic ecosystems were 'Retained' could only be undertaken manually and it is likely that many more 'Retained' aquatic ecosystems exist than were attributed in the LEBRM AEMC. Many aquatic ecosystems remained 'Unknown' for hydrological connectivity, the majority of which were situated the in the Georgina-Diamantina and Cooper Catchments due to the poor classification of floodplains.

Data confidence: Confidence was assigned as low for all features except 'Through flow', 'End of system' and 'Terminal branch' for which the confidence was high as these were manually attributed for known sites, and floodplains were assigned high confidence for having overbank flows.

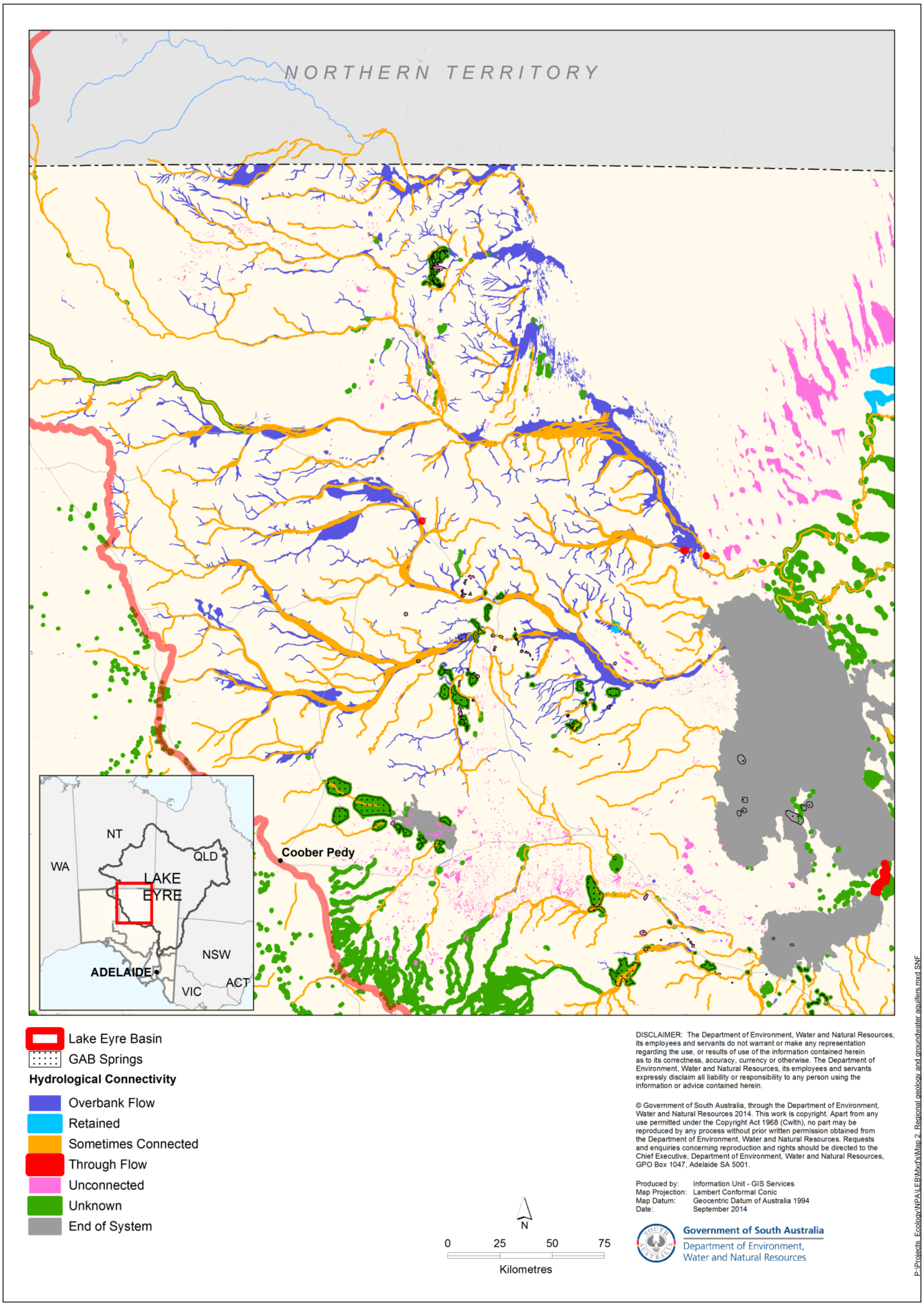


Figure 2-13 Aquatic ecosystems classified by hydrological connectivity

2.3 Determination of aquatic ecosystem types

'Typology is an extension to classification whereby those classified aquatic ecosystems are assembled into groups for a specific purpose i.e. a naming convention' (AETG 2012a p. 3). The determination of aquatic ecosystem types is not a requirement for classifying aquatic ecosystems in the ANAE classification framework but can be useful for assigning aquatic ecosystems into groups with common attributes (AETG 2012a). The selection of attributes upon which to determine types should be based on the purpose for which the typology is to be used. Fee and Scholz (2010) identified 17 surface wetland types and five riverine types for the SAAE.

2.3.1 Attribute combinations

An approach to determining types is to select the most relevant (and/or reliable) attributes for the classification purpose and apply an automated classification to identify the range of combinations. A process to determine the range of hydrological-attribute combinations was performed. This assisted to validate the data and identify gaps, in particular it highlighted that a high proportion of polygons were classified as unknown for many hydrological attributes. This classification identified 84 different groups, of which 20 contained unknown values for three or more of the attributes. Approximately 10% of the polygons contained unknown values for all the selected attributes. Such a classification could be used in future for understanding patterns in the distribution of water dependent species or communities and potential responses to changes in the attributes.

2.3.2 LEBRM types

Conceptual models were developed as part of the first phase of the LEBRM project to illustrate the hydroecological components and processes of key aquatic ecosystem types, and their potential vulnerability to CSG and coal mining development related activities (Imgraben and McNeil 2013). Using the LEBRM AEMC classification, aquatic ecosystems in the study region were assigned to the LEBRM types as specified in Imgraben and McNeil (2013) with the addition of four other major types not previously included: gilgais, GAB springs, floodplains and bore wetlands(Figure 2-14). The method used was to select from the attribute fields (see Table 2-2 below).

There were insufficient data in LEBRM AEMC to differentiate between clay pans and saline lakes in isolated basin systems. 12 906 polygons either had attributes that did not fit the LEBRM types or had insufficient data to classify them into types.

Table 2-2 Classification of aquatic ecosystems into LEBRM types

LEBRM Type	System type	Water source	Hydrological connectivity	Identified by	Number of polygons
Waterhole	Riverine	In-stream	Sometimes connected	Containing work waterhole or attributed at time of digitising	383
In-channel habitat	Riverine	In-stream	Sometimes connected	Source geometry: WAD Line	717
Lake (connected basin systems)	Lacustrine	In-stream	Retained / through flow / Overbank / Terminal branch	Lacustrine and hydrological connectivity	101
Terminal Lake (connected basin systems)	Lacustrine	In-stream	End of System	Hydrological connectivity	89**
Swamps (connected basin systems)	Palustrine	In-stream / overbank	Retained / through flow / Overbank	Palustrine, non-spring	75
Dam	Lacustrine	In-stream / overbank	Through flow / overbank	NY: named dams	224
Saline lakes (isolated basin systems)				Unable to distinguish	-
Clay pans (isolated basin systems)				Unable to distinguish	-
Floodplain*	Floodplain	Overbank	Overbank flow	System type	19222
Bore wetland*	Palustrine	Confined Artesian	Any	At time of digitising	6
GAB spring*	Palustrine	Confined Artesian		Palustrine and Confined Artesian	170
Gilgai*	Palustrine	Rainfall	Unconnected	Name field	NA
Unknown	-	-	-	Insufficient attributes to classify	12906
TOTAL					33 804

*Not in original LEBRM types (Imgraben and McNeil 2013)

** Some terminal lakes are represented by multiple polygons

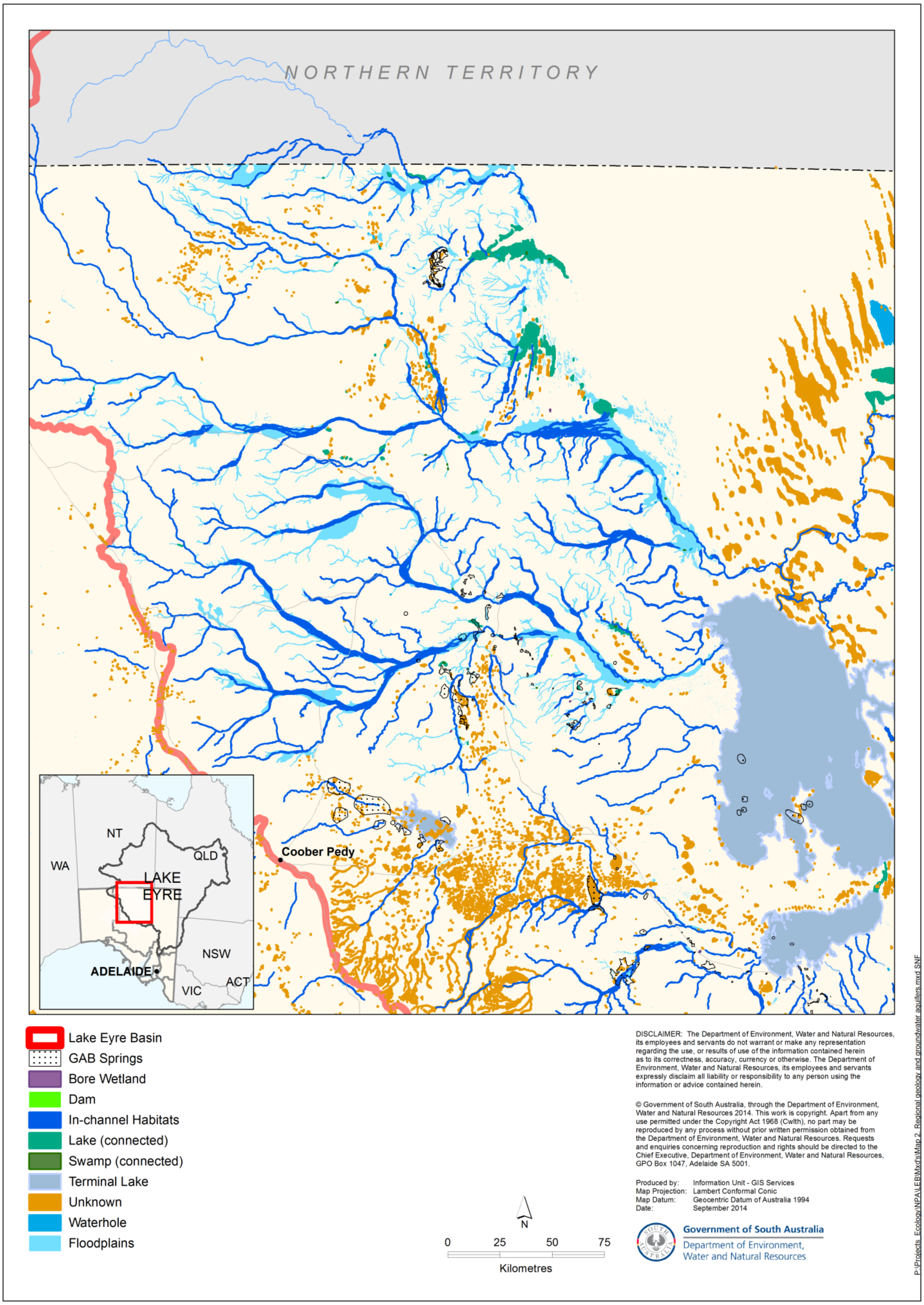


Figure 2-14 Aquatic ecosystems classified into LEBRM types

3 Discussion

3.1 Discussion of project objectives

Objective 1: Improve the spatial mapping of aquatic ecosystems

The project mapped additional aquatic ecosystem features in the priority catchments that were not included in the source datasets, namely floodplains and some additional water-holes, dams and bore wetlands known or likely to be important ecologically.

Objective 2: Build on the work undertaken for the water asset database project (Denny & Berens 2013)

The aquatic ecosystem geometries and system type, water regime and water source attributes from the WAD were used as the basis for the LEBRM AEMC. Some of the issues in classifying system types highlighted by Denny and Berens (2013) were addressed as part of the LEBRM AEMC, particularly misclassification of floodplain ecosystems as lacustrine in the priority catchments and conversion of watercourses to buffered polygons.

Objective 3: Align with the Australian National Aquatic Ecosystems classification framework (AETG 2012a)

The LEBRM AEMC framework is based on the ANAE classification framework, with the exception of the River Confinement attribute. Additional attributes were included for consistency with the SAAE classification framework (Fee and Scholz 2010) and to provide further detail to meet the overall objectives of the LEBRM project (i.e. to inform assessment of impacts of CSG and coal mining on aquatic ecosystems).

Objective 4: Identify groundwater dependent ecosystems

The LEBRM AEMC includes attributes for high level classification of groundwater dependent ecosystems (GDEs) (AQ_3INLAND_SOURCE) as well as a more detailed classification of likely groundwater source (AQ_3INLAND_GW_SOURCE). The LEBSA project will undertake further mapping and classification of groundwater dependent ecosystems which will be incorporated into the LEBRM AEMC.

3.2 Applications of the LEBRM AEMC

The LEBRM AEMC provides more accurate mapping and more comprehensive description of the aquatic ecosystems of the LEB than was previously available in a GIS format. In particular, the LEBRM AEMC identifies the location of aquatic refuges in the priority catchments and classification of their degree of permanence and groundwater dependency based on on-ground data. Previously much of this information had only been available in reports, GPS points and non-spatial datasets. The database also captures the source of the information by which the attributes have been assigned and a confidence ranking so that the user can assess the validity of the classifications. The priority attributes for the project to classify were water source, flow regime and hydrological connectivity of aquatic refuges as these attributes can be used to inform broadscale assessments of the vulnerability of aquatic ecosystems to CSG and LCM development-related activities (Wilson et al. 2013). More detailed information about the stressors, components and processes at the site scale would be required to assess site-scale risks and vulnerabilities. The results of the LEBRM hydro-ecological modelling (Hooper and Miles 2014) could be used to inform such an assessment, as could the identification of thresholds of potential concern as are being developed for the LEB Rivers Assessment. Previous assessments of cultural (White 2014) or ecological values (AETG 2012b,c) could also be linked to the LEBRM AEMC to inform risk assessments and management decisions.

Because the LEBRM AEMC uses a hierarchical and structured classification framework, the user can select individual or groups of aquatic ecosystems by whichever attributes are deemed relevant to their purpose. Pre-determined types identified for the LEBRM conceptual modelling project (Imgraben and McNeil 2013) have been included in the LEBRM AEMC, however these types are very broad and do not capture all aquatic ecosystems; more types could be determined if required for management purposes or risk assessments.

Whilst the LEBRM AEMC has built on the work undertaken for the WAD and retained the unique identifiers from that database, it would not be feasible nor potentially of any value to merge the 'updated' LEBRM AEMC attributes with the WAD due to the addition of new polygons and separation of multi-part polygons.

The Australian Hydrological Geospatial Fabric (geofabric) has been developed by the Bureau of Meteorology (BoM), in partnership with Geoscience Australia, CSIRO and the Australian National University (ANU) to provide a single, consistent, national geospatial framework for hydrological features. The geofabric will evolve and improve over time as new data becomes available. Comparison with the LEB AEMC could identify where geometry or attribution created in this project would benefit that evolution (e.g. the geofabric classification of perenniality).

The classification and mapping of GAB springs and their connectivity with surface-water driven systems will be further refined as part of the LEBSA project.

Work is on-going to integrate the LEB AEMC with DEWNR's corporate data systems and make data accessible for non-government users.

3.3 Knowledge gaps and limitations

Whilst the LEBRM AEMC represents a considerable advancement in mapping and classifying aquatic ecosystems in the study region, particularly the priority catchments, significant knowledge gaps still exist. Over a third of all polygons had insufficient data to enable them to be assigned to the broad types identified for the LEBRM project (see Section 2.3.1) and low confidence values applied to many hydrological attributes for the majority of sites. Within the priority catchments, the mapping of floodplains is considered preliminary. Outside of the priority catchments, the lack of differentiation of floodplains from lacustrine system types limited the automated classification of some other attributes, particularly hydrological connectivity. Further, the LEBRM AEMC focused on classifying the priority western catchments; however there is significantly more information available in reports and project datasets that could be used to classify the aquatic ecosystems of the major eastern catchments, the Georgina-Diamantina and Cooper.

Two related issues that could not be resolved through the LEBRM AEMC were the occurrence of overlapping polygons and multiple polygons representing a single aquatic ecosystem. These issues arise from the different methods employed to map aquatic ecosystems in the data sources accessed by the WAD, the WAD importing multiple datasets for the same features, and the LEBRM AEMC adopting a new source of floodplain mapping which overlapped with some prior floodplain mapping.

3.4 Recommendations

Further work will be undertaken in the short term to classify the soils and landform transport zone attributes as new products become available as part of national soil grid mapping (TERN 2014). As part of the LEBSA project, the spatial delineation of GAB springs will be refined and the LEBRM AEMC geometry for these springs will be updated accordingly. Information generated as part of the LEBSA project on the connectivity between GAB springs and surface water-driven ecosystems will also be incorporated into the LEBRM AEMC.

The useability of the LEBRM AEMC will ultimately be determined not only by its accuracy but also its compatibility with state and national mapping and classification frameworks and products.

The following are recommendations for improving the accuracy of the LEBRM AEMC:

- Improve floodplain mapping, particularly:
    - Improving the floodplain-extent mapping developed by Hooper and Miles (2015) with other lines of evidence such as remotely sensed data (e.g. Water Observations from Space project (Geoscience Australia 2014)), soil grid mapping, local knowledge and on-ground surveys
    - Distinguish lacustrine from floodplain systems in the Cooper and Georgina-Diamantina Catchments using the original data sources (Wainwright et al. 2006; Tunn and Cameron 2008)

- Undertaking floodplain extent mapping for parts of the LEB in SA not included in the above datasets
    - Refine the attributes or classification of types to distinguish flood*outs* from flood*plains*
- Improve the spatial geometry of watercourse mapping and undertake a stream order classification to better discriminate between major and minor watercourses
- Resolve the issues of overlapping polygons and multiple polygons representing the same feature; this may require further work to determine appropriate scales at which to delineate aquatic ecosystems
- Improve the classification of salinity, water source, water regime and hydrological connectivity through on-ground or aerial surveys and as information becomes available for new sites through sampling programs such as LEBRA and EPA aquatic ecosystem health assessments
- Develop a single 'official' map of the surface water catchments of the LEB in South Australia
- Classify aquatic ecosystems outside the priority catchments using available reports and project data sets
- When products become available through the Water Observations from Space project, revise the classification of flow regime attributes if appropriate.

4 Appendices

A. Attribution of water source and water regime attributes using the WAD

WAD Values		LEBRM Classification				
"Water_Source"	"Water_Regime"	Equals value in "AQ_3Inland_Source"	Equals value in "AQ_3Inland_GW_Source"	Equals value in "AQ_3Inland_SW_Source"	Equals value in "AQ_3Inland_Inflows"	Equals value in "AQ_3Inland_Persist"
<Null>	<Null>	Unknown	Unknown	Unknown	Unknown	Unknown
Combined: Groundwater dominant	Surface: Episodic, Groundwater: confined non-artesian	Combined: Groundwater dominant	Confined non-artesian	In-stream	Highly ephemeral	Annual
Combined: Groundwater dominant	Surface: Permanent	Combined: Groundwater dominant	Unknown	In-stream	Unknown	Permanent
Combined: Groundwater dominant	Surface: Permanent, Groundwater: Unconfined	Combined: Unknown	Unconfined	Unknown	Permanent	Permanent
Combined: Surface water dominant	Surface: combined	Combined: Surface water dominant	Unknown	In-stream	Unknown	Annual
Combined: Surface water dominant	Surface: Ephemeral, Groundwater: Combined	Combined: Surface water dominant	Unknown	In-stream	Ephemeral	Annual
Combined: Surface water dominant	Surface: Ephemeral, Surface: Seasonal, Groundwater: Combined	Combined: Surface water dominant	Combined	In-stream	Seasonal/ Intermittent	Annual
Combined: Surface water dominant	Surface: Episodic	Combined: Surface water dominant	Unknown	In-stream	Highly ephemeral	Annual
Combined: Surface water dominant	Surface: Episodic, Groundwater: confined artesian	Combined: Surface water dominant	Confined artesian	In-stream	Ephemeral	Mid-Term
Combined: Surface water	Surface: Episodic, Groundwater: confined	Combined: Surface water	Confined non-	In-stream	Unknown	Unknown

WAD Values		LEBRM Classification				
"Water_Source"	"Water_Regime"	Equals value in "AQ_3Inland_Source"	Equals value in "AQ_3Inland_GW_Source"	Equals value in "AQ_3Inland_SW_Source"	Equals value in "AQ_3Inland_Inflows"	Equals value in "AQ_3Inland_Persist"
dominant	non-artesian	dominant	artesian			
Combined: Surface water dominant	Surface: Episodic, Surface: Ephemeral, Groundwater:*	Combined: Surface water dominant	Combined	In-stream	Ephemeral	Annual
Combined: Surface water dominant	Surface: Seasonal	Combined: Surface water dominant	Unknown	In-stream	Unknown	Annual
Combined: SW/GW Unknown	Combined	Combined: Unknown	Unknown	Unknown	Unknown	Unknown
Combined: SW/GW Unknown	Surface: combined	Combined: Unknown	Unknown	In-stream	Ephemeral	Mid-Term
Combined: SW/GW Unknown	Surface: Episodic	Combined: Unknown	Unknown	In-stream	Ephemeral	Mid-Term
Combined: SW/GW Unknown	Surface: Permanent	Combined: Unknown	Unknown	Annual	Seasonal/ Intermittent	Permanent
Combined: SW/GW Unknown	Surface: Seasonal	Combined: Unknown	Unknown	In-stream	Seasonal/ Intermittent	Annual
Combined: SW/GW Unknown	Surface: Unknown	Combined: Unknown	Unknown	Unknown	Unknown	Unknown
Groundwater: confined artesian	Surface: Permanent, Surface: episodic, Surface: Waterlogged, Groundwater: confined artesian	Groundwater	Confined artesian	NA	Permanent	Permanent
Groundwater: confined artesian	Surface: Permanent, Surface: Waterlogged, Groundwater: confined artesian	Groundwater	Confined artesian	NA	Permanent	Permanent
Groundwater: unknown	Surface: Permanent	Groundwater	Unknown	NA	Unknown	Permanent
Surface water dominant	Surface: Permanent	Surface Water	NA	In-stream	Ephemeral	Permanent

WAD Values		LEBRM Classification				
"Water_Source"	"Water_Regime"	Equals value in "AQ_3Inland_Source"	Equals value in "AQ_3Inland_GW_Source"	Equals value in "AQ_3Inland_SW_Source"	Equals value in "AQ_3Inland_Inflows"	Equals value in "AQ_3Inland_Persist"
Surface water dominant	Surface: Unknown	Surface Water	NA	Unknown	Unknown	Unknown
Surface: In-stream	Surface: Ephemeral	Surface Water	NA	In-stream	Ephemeral	Annual
Surface: In-stream	Surface: Episodic	Surface Water	NA	In-stream	Ephemeral	Mid-Term
Surface: In-stream	Surface: Permanent	Surface Water	NA	Unknown	Ephemeral	Permanent
Surface: In-stream	Surface: Seasonal	Surface Water	NA	In-stream	Seasonal/ Intermittent	Annual
Surface: In-stream	Surface: Unknown	Surface Water	NA	In-stream	Unknown	Unknown
Surface: In-stream	Unknown	Surface Water	NA	In-stream	Unknown	Unknown
Surface: Overbank	Surface: Episodic, Surface: Ephemeral	Surface Water	NA	Overbank	Highly ephemeral	Annual
Surface: Rainfall	Surface: Ephemeral	Surface Water	NA	Rainfall	Ephemeral	Annual
SW/GW unknown	Unknown	Combined: Unknown	Unknown	Unknown	Unknown	Unknown
Unknown	Surface: Episodic	Unknown	Unknown	Unknown	Unknown	Unknown
Unknown	Surface: Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown

B. Waterhole attribution using project datasets, literature and expert opinion

Table 4-1 Neales Catchment waterholes: water source and salinity attributes

Asset Name	Water source	Ground-water source	Surface water source	Water source method	Water source confidence	Salinity	Salinity method	Salinity confidence
Afghan Waterhole	Surface Water	NA	In-stream	Costelloe 2011; Montazeri & Osti 2014	Medium	Fresh	Costelloe 2011	High
Algebuckina Waterhole	Surface Water	NA	In-stream	NPADB	Medium	Brackish	Costelloe 2011	Medium
Angle Pole Waterhole	Surface Water	NA	In-stream	Costelloe 2011	Medium	Fresh	Costelloe 2011	High
Baltucoodna Waterhole	Combined: Groundwater dominant	Alluvial	In-stream	Costelloe 2011	Medium	Hypersaline	Costelloe 2011	High
Birribiana Waterhole	Surface Water	NA	In-stream	Costelloe 2011	Medium	Fresh	Costelloe 2011	High
Blanket Waterhole	Combined: Unknown	Unknown	In-stream	NPADB	Low	Unknown		
Browns Waterhole	Combined: Unknown	Unknown	In-stream	Assumption	Low	Unknown		
Bulletin Waterhole	Surface Water	Unknown	Unknown	C Miles	Low	Unknown		
Cecilia Waterhole	Surface Water	NA	In-stream	NPADB	Medium	Unknown		
Cootanoorina Waterhole	Surface Water	NA	In-stream	Costelloe 2011	Medium	Fresh	Costelloe 2011	High
Cramps Camp Waterhole	Surface Water	NA	In-stream	Costelloe 2011	High	Fresh	Costelloe 2011	High
Fish Hole	Surface Water	NA	In-stream	Derived from Costelloe 2011	Medium	Fresh	Costelloe 2011 max salinity 1390	Low
Francis Camp Waterhole	Combined: Unknown	Alluvial	In-stream	C Miles	Low	Fresh	Presence of Red Gums	Low
Hagan Hole	Surface Water	Unknown	In-stream	Costelloe 2011 inferred	Medium	Fresh	Costelloe 2011	Medium
Hookey Waterhole	Surface Water	NA	In-stream	Derived from Costelloe 2011 data	Medium	Fresh	Costelloe 2011	High
Mathieson Waterhole	Surface Water	NA	In-stream	Montazeri & Osti (2014)	Medium	Fresh	Costelloe 2011	High
Nilkinina Waterhole	Combined: Unknown	Unknown	In-stream	Assumption	Low	Unknown		
Nummabirinna Waterhole	Combined: Unknown	Unknown	In-stream	Assumption	Low	Unknown		

Asset Name	Water source	Ground-water source	Surface water source	Water source method	Water source confidence	Salinity	Salinity method	Salinity confidence
Peake Crossing Waterhole	Combined: Groundwater dominant	Alluvial	In-stream	Costelloe 2011	Medium	Hypersaline	Costelloe 2011	High
Peake Crossing Waterhole 2	Combined: Groundwater dominant	Alluvial	In-stream	Costelloe 2011	Medium	Hypersaline	Costelloe 2011	High
Peracullanna Waterhole	Combined: Unknown	Unknown	In-stream	Assumption	Low	Fresh	D Schmarr's conversations w pastoralist	Low
Potential Waterhole	Combined: Unknown	Alluvial	In-stream	C Miles & G Wakelin-King	Low	Fresh	Presence of Red Gums	Medium
Potential Waterhole	Surface Water	Unknown	Unknown	C Miles	Low	Unknown		
Potential Waterhole	Surface Water	Unknown	Unknown	C Miles	Low	Unknown		
Potential Waterhole	Surface Water	Unknown	Unknown	C Miles	Low	Unknown		
Shepherds Waterhole	Surface Water	NA	In-stream	Costelloe 2011	Medium	Fresh	Costelloe 2011	High
South Cliff Waterhole	Surface Water	NA	In-stream	Costelloe 2011	Medium	Fresh	Costelloe 2011	High
South Stewart Waterhole	Surface Water	NA	In-stream	Costelloe 2011	High	Fresh	Costelloe 2011	High
Stewart Waterhole	Surface Water	NA	In-stream	Costelloe 2011	High	Fresh	Costelloe 2011	Medium
Tardetakarinna Waterhole	Combined: Groundwater dominant	Alluvial	In-stream	Costelloe 2011	Medium	Hypersaline	Costelloe 2011	High
The Cliff Waterhole	Surface Water	NA	In-stream	Costelloe 2011; Montazeri & Osti 2014	Medium	Brackish	Costelloe 2011	Medium
Unnamed Waterhole	Surface Water	Unknown	In-stream	Author assumed due to proximity to other sites	Low	Unknown		
Unnamed Waterhole	Combined: Unknown	Alluvial	In-stream	C Miles proximity to Tardetakarinna	Low	Unknown		
Warmakidyaboo Waterhole	Combined: Unknown	Unknown	In-stream	NPADB	Low	Unknown		
Warrawaroona Waterhole	Combined: Surface Water dominant	Alluvial	Overbank	Costelloe 2011 plus proximity to spring and Balta	Low	Saline	Costelloe 2011	Medium

Weedina Waterhole	Combined: Unknown	Unknown	In-stream	Assumption	Low	Unknown

NA = not applicable; CTFD = cease to flow depth (in metres); NPADB = Water asset database

Table 4-2 Neales Catchment waterholes: hydrological regime attributes

Asset Name	Inflows frequency	Inflows method	Inflows confidence	Persistence	Persistence method	Persistence confidence
Afghan Waterhole	Seasonal / Intermittent	NPADB	Medium	Annual	Costelloe 2011 CTFD 1.2m	Medium
Algebuckina Waterhole	Seasonal / Intermittent	LEBRM	Medium	Permanent	Costelloe 2011	Medium
Angle Pole Waterhole	Seasonal / Intermittent	LEBRM	Medium	Annual	Costelloe 2011 CTFD 2.16	Medium
Baltucoodna Waterhole	Seasonal / Intermittent	LEBRM	Medium	Mid-term	Costelloe 2011	Medium
Birribiana Waterhole	Seasonal / Intermittent	LEBRM	Medium	Annual	Costelloe 2011 CTFD 2.1m	High
Blanket Waterhole	Unknown	NPADB	Low	Mid-term	D Schmarr pers. com.	Medium
Browns Waterhole	Unknown	NPADB	Low	Unknown	NPADB	Low
Bulletin Waterhole	Unknown	NA	Low	Unknown	NA	Low
Cecilia Waterhole	Unknown	NPADB	Low	Unknown	NPADB	Low
Cootanoorina Waterhole	Seasonal / Intermittent	LEBRM	Medium	Annual	Costelloe 2011 CTFD 1.8m	High
Cramps Camp Waterhole	Seasonal / Intermittent	LEBRM	Medium	Mid-term	Costelloe 2011 CTFD 2.6 - 3.85m	Medium
Fish Hole	Seasonal / Intermittent	LEBRM	Medium	Annual	Costelloe 2011 CTFD 1.16	Medium
Francis Camp Waterhole	Unknown	NA	NA	Annual	C Miles & G Wakelin-King	Low
Hagan Hole	Seasonal / Intermittent	LEBRM	Medium	Annual	Costelloe 2011 CTFD 1.2m	Medium
Hookey Waterhole	Seasonal / Intermittent	LEBRM	Medium	Mid-term	Costelloe 2011 CTFD 2.56	Medium
Mathieson Waterhole	Seasonal / Intermittent	LEBRM	Medium	Mid-term	Costelloe 2011 CTFD 2.7	Medium
Nilkinina Waterhole	Unknown	NPADB	Low	Unknown	NPADB	Low
Nummabirinna Waterhole	Unknown	NPADB	Low	Unknown	NPADB	Low
Peake Crossing Waterhole	Seasonal / Intermittent	LEBRM	Medium	Mid-term	Costelloe 2011	Medium
Peake Crossing Waterhole 2	Seasonal / Intermittent	LEBRM	Medium	Annual	D Schmarr pers. com. (SARDI July 2014)	Medium
Peracullanna Waterhole	Unknown	NPADB	Low	Mid-term	D Schmarr pers. com. (SARDI July 2014)	Low

Asset Name	Inflows frequency	Inflows method	Inflows confidence	Persistence	Persistence method	Persistence confidence
Potential Waterhole	Unknown	C Miles	Low	Annual	C Miles	Low
Potential Waterhole	Unknown	NA	NA	Unknown	NA	
Potential Waterhole	Unknown	NA	NA	Unknown	NA	NA
Potential Waterhole	Unknown	NA	NA	Unknown	NA	NA
Shepherds Waterhole	Seasonal / Intermittent	LEBRM	Medium	Annual	Costelloe 2011	Medium
South Cliff Waterhole	Seasonal / Intermittent	LEBRM	Medium	Mid-term	Costelloe 2011 CTFD 2.4 - 2.5m	Medium
South Stewart Waterhole	Seasonal / Intermittent	LEBRM	Medium	Mid-term	Costelloe 2011 CTFD 2.4 - 2.5m	Medium
Stewart Waterhole	Seasonal / Intermittent	LEBRM	Medium	Mid-term	Costelloe 2011 CTFD 2.6 - 3.2m	Medium
Tardetakarinna Waterhole	Seasonal / Intermittent	LEBRM	Medium	Mid-term	Costelloe 2011	Low
The Cliff Waterhole	Seasonal / Intermittent	LEBRM	Medium	Annual	Costelloe 2011 CTFD 0.9 - 1.3m	High
Unnamed Waterhole	Seasonal / Intermittent	LEBRM	Low	Annual	C Miles	Low
Unnamed Waterhole	Seasonal / Intermittent	LEBRM	Low	Unknown	NPADB	Low
Warmakidyaboo Waterhole	Unknown	NPADB	Low	Mid-term	D Schmarr pers. com. (SARDI July 2014)	Medium
Warrawaroona Waterhole	Unknown	NA	NA	Annual	Costelloe 2011	Medium
Weedina Waterhole	Unknown	NPADB	Low	Unknown	NPADB	Low

NA = not applicable; NPADB = Water asset database: LEBRM = refers to hydrological modelling undertaken for LEBRM project (Montazeri & Ost 2014); CTFD = cease to flow depth (in metres)

Table 4-3 Macumba and Finke Catchment waterholes: water source and salinity attributes

Asset Name	Water source	Ground-water source	Surface water source	Water source method	Water source confidence	Salinity	Salinity method	Salinity confidence
Allillinna Waterhole	Surface Water	NA	In-stream	NPADB	Medium	Unknown	Likely fresh or brackish	
Anbaluala Waterhole	Surface Water	NA	In-stream	NPADB	Medium	Fresh	Arid rivers coolabah; could be brackish	Low
Antikoolirrinna Waterhole	Surface Water	NA	In-stream	NPADB	Medium	Fresh	Arid Rivers presence of Red Gums	Low

Asset Name	Water source	Ground-water source	Surface water source	Water source method	Water source confidence	Salinity	Salinity method	Salinity confidence
Arracootamarrinna Waterholes	Surface Water	NA	In-stream	NPADB	Medium			
Artillera Dam	Surface Water	NA	In-stream	Based on in-stream	Low	Fresh	Arid Rivers photos; could be brackish	Low
Big Ooranalatica Waterhole	Combined: Unknown	Unknown	In-stream	Assumption	Low	Fresh	Arid Rivers photos coolabah, could be brackish	Low
Bitchera Waterhole	Surface Water	NA	In-stream	NPADB	Medium	Fresh	Arid Rivers photos presence of red gums	Low
Carpamoongana Waterhole	Surface Water	NA	In-stream	NPADB	Medium	Fresh	LEBRA sampling SARDI	Medium
Christmas Creek Waterhole	Unknown	Unknown	In-stream			Fresh	Arid Rivers photos; could be brackish	Low
Cliff Waterhole	Combined: Surface Water dominant	NA	In-stream	As for creek	Low	Unknown	fresh or brackish; coolabah over lignum	Low
Ekeetatrinna Waterhole	Surface Water	NA	In-stream	NPADB	Medium	Fresh		
Erabena Waterhole	Surface Water	NA	Surface Water	Based on Macumba waterhole	Low	Fresh (< 1000 mg/L)	Arid Rivers photos coolabah	Low
Eringa Waterhole	Surface Water	NA	In-stream	NPADB	Medium	Fresh	LEBRA sampling SARDI data	Medium
Ethawarra Waterhole	Surface Water	NA	In-stream	NPADB	Medium	Fresh	LEBRA sampling SARDI data	Medium
Garanarinna Waterhole	Surface Water	NA	In-stream	NPADB	Medium			
Gercheena Waterhole	Surface Water	NA	In-stream	NPADB	Medium	Fresh	Arid Rivers photo; could be brackish	Low
Horse Creek Waterhole	Surface Water	NA	In-stream	NPADB	Medium	Fresh	Arid Rivers photos	Low
Hughes Waterhole	Surface Water	NA	In-stream	Based on being in-stream	Low	Fresh	Arid Rivers photos	Low
Ilwantanillinna Waterhole	Surface Water	NA	In-stream	NPADB	Medium			
Indeda Waterhole	Surface Water	NA	In-stream	Instream and Red gums	Medium	Fresh	Arid Rivers:	Low

Asset Name	Water source	Ground-water source	Surface water source	Water source method	Water source confidence	Salinity	Salinity method	Salinity confidence
				indicate leaky			presence of Red Gums	
Jacky Waterhole	Surface Water	NA	Surface Water	Based on Macumba and waterhole	Low	Fresh (< 1000 mg/L)	Arid Rivers photos, Coolabah	Low
Kulpakuna Waterhole	Combined: Groundwater dominant	Unknown	Surface Water	Based on salinity in photo	Low	Hypersaline	Saline veg and salt crust in photo	Low
Little Ooranalatica Waterhole	Combined: Unknown	Unknown	In-stream	Assumption	Low	Fresh	Arid river photos Coolabah; could be brackish	Low
Manarrinna Waterhole	Combined: Surface Water dominant	Unknown	In-stream	As for creek	Low			
Mongulina Waterhole	Surface Water	NA	In-stream	NPADB	Medium	Fresh	Arid Rivers presence of red gums	Low
Moorulpurina Waterhole	Surface Water	NA	In-stream	Based on in-stream	Low	Fresh	Arid Rivers photos; could be brackish	Low
Mosquito Waterhole	Combined: Surface Water dominant	Unknown	Surface Water	NPADB classification for Erabena Creek	Low	Fresh (< 1000 mg/L)	Arid Rivers photos; could be brackish	Low
Oorawangera Waterhole	Surface Water	NA	In-stream	NPADB	Medium			
Ooroowangarinna Waterhole	Surface Water	NA	In-stream	NPADB	Medium			
Oppossum Waterhole	Surface Water	NA	In-stream	Assumed as sited in-stream	Low	Fresh	Arid Rivers photos; could be brackish	Low
Peerless Pool	Unknown	Unknown	In-stream	Assumption	Low			
Poonina Waterhole	Surface Water	NA	In-stream	NPADB	Medium	Fresh	Arid Rivers presence of coolabah; could be brackish	Low
Ross Waterhole	Surface Water	NA	In-stream	NPADB	Medium	Fresh	Arid Rivers photos presence Red Gums	Low
Sandhill Waterhole	Surface Water	NA	Surface Water	Assumed based on Macumba waterhole	Low	Fresh (< 1000 mg/L)	Arid Rivers coolabah and red gum	Low
Tidnabucca Waterhole	Surface Water	NA	In-stream	NPADB	Medium	Unknown		

Asset Name	Water source	Ground-water source	Surface water source	Water source method	Water source confidence	Salinity	Salinity method	Salinity confidence
Ullabaracoola Waterhole	Combined: Surface Water dominant	Unknown	In-stream	As for Macumba	Low	Unknown		
Ulowarrina Waterhole	Combined: Surface Water dominant	Unknown	In-stream	As for Macumba	Low	Unknown	Likely fresh or brackish, coolabah over lignum	
Undooldina Waterhole	Surface Water	NA	Surface Water	Based on Macumba waterhole and in-stream	Low	Fresh (< 1000 mg/L)	Arid Rivers photos coolabah some red gum	Low
Unginginna Waterhole	Surface Water	NA	In-stream	NPADB	Medium	Fresh	Presence of Red Gums	Medium
Unnamed	Combined: Surface Water dominant	Unknown	Surface Water	Based on creek	Low	Unknown	Fresh or brackish, coolabah over lignum	
Unnamed	Combined: Groundwater dominant	Unknown	Surface Water	Based on salinity	Low	Hypersaline	salt crust visible in photo	Low
Unnamed Waterhole	Combined: Surface Water dominant	Unknown	Surface Water	Based on creek	Low	Unknown	fresh or brackish	
Unnamed Waterhole east of Indeda	Surface Water	NA	Surface Water	Based on in-stream & red gums indicate leaky	Low	Fresh (< 1000 mg/L)	Presence of Rd Gums	Low
Unnamed Waterhole near Erabena Waterhole	Combined: Surface Water dominant	Unknown	Surface Water	Based on NPADB Erabena Creek	Low	Fresh (< 1000 mg/L)	Arid River photo coolabah; could be brackish	Low
Unnamed Waterhole west of Gap waterhole	Surface Water	NA	Surface Water	based on in-stream	Low	Fresh (< 3000 mg/L)	Arid Rivers photos; could be brackish	Low
Unnamed waterhole near Hughes Waterhole	Surface Water	NA	In-stream	Based on in-stream	Low	Fresh	Arid Rivers photos; could be brackish	Low
Untercooracoorana Waterhole	Surface Water	NA	In-stream	NPADB	Medium			
Upramuprawaringa Waterhole	Surface Water	NA	In-stream	Assumption	Low	Fresh	SARDI data	Medium
Walkinna Waterhole	Surface Water	NA	In-stream	NPADB	Medium	Fresh	Arid Rivers presence red gums	Low
Waterhole sth of Arina	Surface Water	NA	Surface	based on in-stream	Low	Fresh (<	Arid Rivers photos;	Low

Asset Name	Water source	Ground-water source	Surface water source	Water source method	Water source confidence	Salinity	Salinity method	Salinity confidence
Waterhole			Water			3000 mg/L)	could be brackish	
Weebucca Waterhole	Surface Water	NA	In-stream	NPADB	Medium	Fresh	Arid Rivers photos, coolabah; could be brackish	Low
Winkies Waterhole	Combined: Unknown	Unknown	In-stream	Assumption	Low	Fresh	LEBRA sampling SARDI data & EPA 2012	High
Wonnobroba Waterholes	Combined: Surface Water dominant	Unknown	In-stream	Assumption	Low	Unknown	Fresh or brackish	
Woorana Waterhole	Combined: Surface Water dominant	Unknown	In-stream	As for creek	Low		Arid rivers fresh or brackish coolabah over lignum	
	Surface Water	NA	In-stream	NPADB	Medium	Unknown	Likely fresh or brackish	

NA = not applicable; CTFD = cease to flow depth (in metres); NPADB = Water asset database

Table 4-4 Macumba and Finke Catchment waterholes: hydrological regime attributes

Asset Name	Inflows frequency	Inflows method	Inflows confidence	Persistence	Persistence method	Persistence confidence
Allillinna Waterhole	Unknown	NPADB	Low	Annual	Arid Rivers photo est CTFD 1m	Low
Anbaluala Waterhole	Unknown	NPADB	Low	Annual	Arid Rivers photo est CTFD 2m	Low
Antikoolirrinna Waterhole	Unknown	NPADB	Low	Annual	Arid Rivers photos est CTFD 2m	Low
Arracootamarrinna Waterholes	Unknown	NPADB	Low	Unknown	NPADB	Low
Artillera Dam	Unknown			Annual	Arid Rivers photos est. CTFD 1.5m	Low
Big Ooranalatica Waterhole	Unknown	NPADB	Low	Annual	Arid Rivers photo est CTFD 1.5m	Low
Bitchera Waterhole	Unknown	NPADB	Low	Annual	Arid Rivers photo est CTFD 1.5m	Low
Carpamoongana Waterhole	Unknown	NPADB	Low	Mid-term	LEBRM observations	Medium

Asset Name	Inflows frequency	Inflows method	Inflows confidence	Persistence	Persistence method	Persistence confidence
Christmas Creek Waterhole	Unknown			Annual	Arid Rivers notes	Medium
Cliff Waterhole	Unknown	NPADB	Low	Mid-term	Arid Rivers est CTFD 3m	Low
Ekeetatrinna Waterhole	Unknown	NPADB	Low	Mid-term	D Schmarr pers. com. (SARDI July 2014)	Low
Erabena Waterhole	Unknown			Annual	Arid Rivers photo est CTFD 2m	Low
Eringa Waterhole	Unknown	NPADB	Low	Mid-term	NPADB	Low
Ethawarra Waterhole	Unknown	NPADB	Low	Unknown	NPADB	Low
Garanarinna Waterhole	Unknown	NPADB	Low	Unknown	NPADB	Low
Gercheena Waterhole	Unknown	NPADB	Low	Mid-term	Arid Rivers photo est CTFD 4m	Low
Horse Creek Waterhole	Unknown	NPADB	Low	Annual	Arid Rivers photos est CTFD 1m	Low
Hughes Waterhole	Unknown	NPADB	Low	Annual	Arid Rivers photos	Low
Ilwantanillinna Waterhole	Unknown	NPADB	Low	Unknown	NPADB	Low
Indeda Waterhole	Unknown	NPADB	Low	Mid-term	Arid Rivers photo est. CTFD > 3m	Low
Jacky Waterhole	Unknown			Annual	Arid Rivers photo est CTFD 2m	Low
Kulpakuna Waterhole	Unknown			Mid-term	Arid Rivers photo est CTFD >3m	Low
Little Ooranalatica Waterhole	Unknown	NPADB	Low	Annual	Arid River photo est CTFD 1.5m	Low
Manarrinna Waterhole	Unknown	NPADB	Low	Mid-term	Arid Rivers est CTFD 2-3m	Low
Mongulina Waterhole	Unknown	NPADB	Low	Annual	Arid Rivers photo est CTFD 2m	Low
Moorulpurina Waterhole	Unknown			Annual	Arid Rivers photos	Low
Mosquito Waterhole	Unknown			Annual	Arid Rivers photo est CTFD 1m	Low
Oorawangera Waterhole	Unknown	NPADB	Low	Unknown	NPADB	Low
Ooroowangarinna Waterhole	Unknown	NPADB	Low	Unknown	NPADB	Low
Oppossum Waterhole	Unknown			Mid-term	Arid Rivers survey notes	Medium
Peerless Pool	Unknown	NPADB	Low	Unknown	NPADB	Low
Poonina Waterhole	Unknown	NPADB	Low	Annual	Arid Rivers photo est CTFD 1.5m	Low
Ross Waterhole	Unknown	NPADB	Low	Mid-term	Arid River photo ext CTFD >3m	Low

Asset Name	Inflows frequency	Inflows method	Inflows confidence	Persistence	Persistence method	Persistence confidence
Sandhill Waterhole	Unknown			Annual	Arid Rivers photo est CTFD 1.5m	Low
Tidnabucca Waterhole	Unknown	NPADB	Low	Mid-term	D Schmarr pers. com. (SARDI July 2014)	Medium
Ullabaracoola Waterhole	Unknown	NPADB	Low	Annual	Arid Rivers photo est CTFD 1m	Low
Ulowarrina Waterhole	Unknown	NPADB	Low	Mid-term	Arid Rivers photo est CTFD >3m	Low
Undooldina Waterhole	Unknown			Annual	Arid Rivers photo est CTFD 1m	Low
Unginginna Waterhole	Unknown	NPADB	Low	Mid-term	Arid Rivers photos est CTFD >2.5m	Low
Unnamed	Unknown	NPADB	Low	Annual	Arid Rivers photo est CTFD 1m	Low
Unnamed	Unknown			Annual	Arid Rivers photo est CTFD 2m	Low
Unnamed Waterhole	Unknown			Mid-term	Arid Rivers photo est CTFD 3m	Low
Unnamed Waterhole east of Indeda	Unknown			Mid-term	Arid Rivers photos approx CTFD >3m	Low
Unnamed Waterhole near Erabena Waterhole	Unknown			Annual	Arid Rivers photo est CTFD 1.5m	Low
Unnamed Waterhole west of Gap waterhole	Unknown			Annual	Arid rivers photos est CTFD 1.5m	Low
Unnamed waterhole near Hughes Waterhole	Unknown			Mid-term	Arid Rivers survey notes up to 2 yrs	Medium
Untercooracoorana Waterhole	Unknown	NPADB	Low	Unknown	NPADB	Low
Upramuprawaringa Waterhole	Unknown	NPADB	Low	Mid-term	NPADB	Low
Walkinna Waterhole	Unknown	NPADB	Low	Annual	Arid Rivers photo est CTFD 1m	Low
Waterhole sth of Arina Waterhole	Unknown			Annual	Arid Rivers survey photos	Low
Weebucca Waterhole	Unknown	NPADB	Low	Annual	Arid Rivers CTFD 1m	Low
Winkies Waterhole	Unknown	NPADB	Low	Mid-term	Arid Rivers photo est CTFD 3m	Low
Wonnobroba Waterholes	Unknown	NPADB	Low	Annual	Arid Rivers est CTFD 1.5	Low
Woorana Waterhole	Unknown	NPADB	Low	Annual	Arid Rivers photo est CTFD 1.5m	Low

NA = not applicable; NPADB = Water asset database: LEBRM = refers to hydrological modelling undertaken for LEBRM project (Montazeri & Ost 2014); CTFD = cease to flow depth (in metres)

C. Soil and Landscape Attribution

Prepared by Craig Liddicoat, DEWNR, November 2014

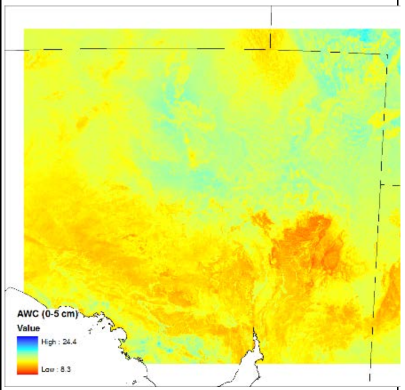
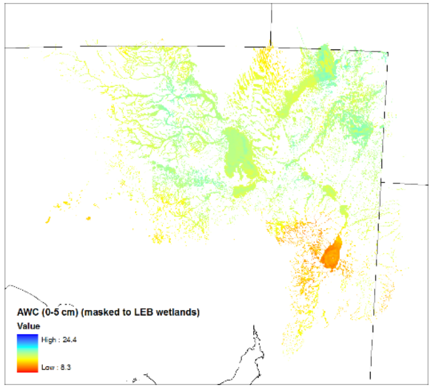
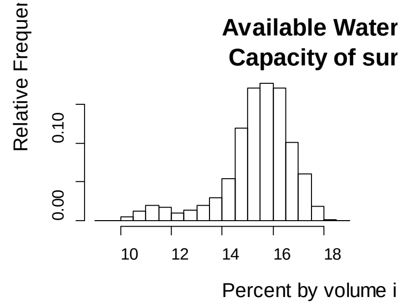
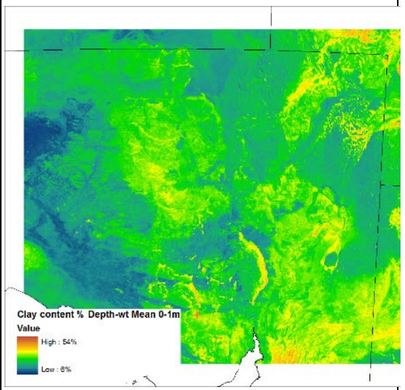
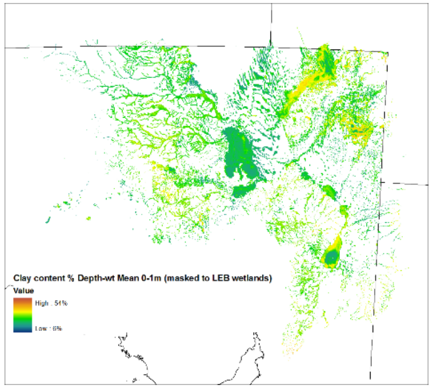
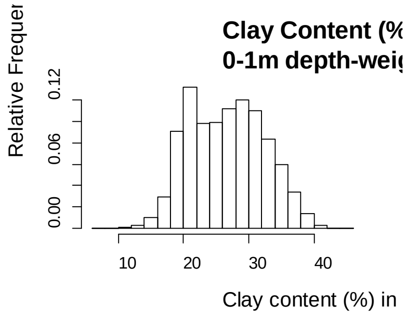
This appendix provides summary details of example soil and landscape grids (raster layers) prepared to support the LEB AEMC project (Table C-1).

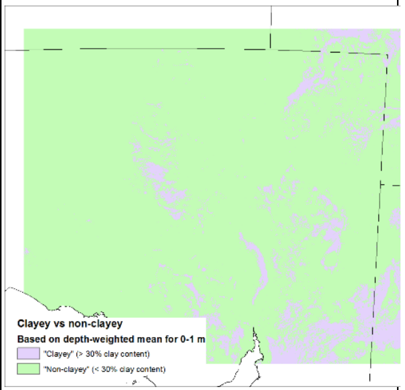
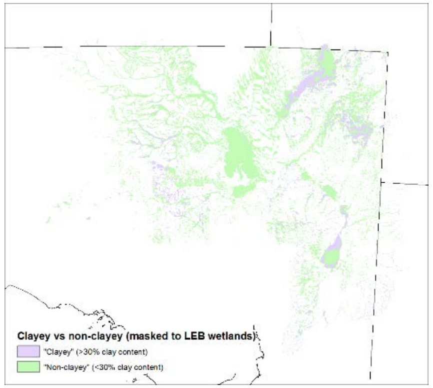
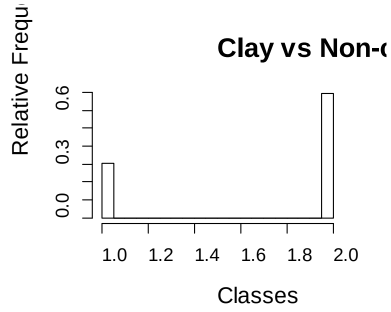
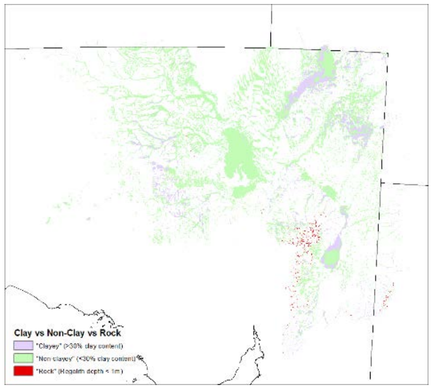
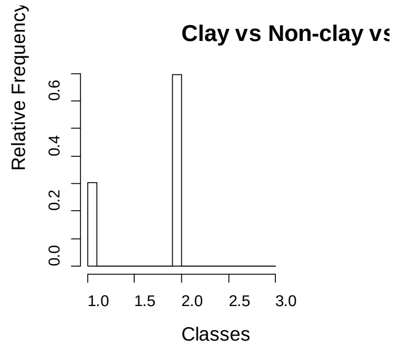
Many of the raster layers have been sourced or derived from datasets that will be released via the Soil and Landscape Grid of Australia (SLGA, www.clw.csiro.au/aclep/soilandlandscapegrid/) in Nov/Dec 2014. These are nationwide spatial predictions of soil and landscape properties developed through collaborative work under the Terrestrial Ecosystem Research Network (TERN) Program. SLGA provides spatial layers for the expected value (EV, or average) as well as 5th and 95th prediction limits to express uncertainty in the mapping. For this analysis, only EV layers are considered. At the time of writing there are additional layers (e.g. soil electrical conductivity / salinity), that will be of interest to AEMC that have not yet been made available from SLGA.

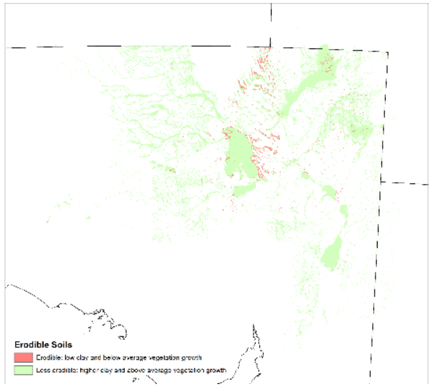
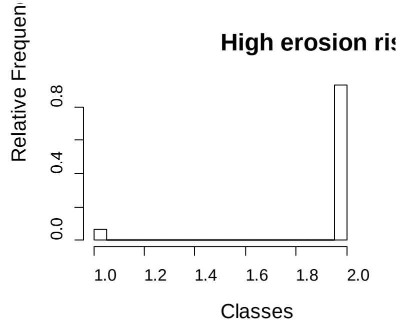
Raster layers have been prepared, further interpreted, re-classified and re-modelled using the R software environment (R Core Team 2014). R scripts are provided to allow these analyses to be repeated and/or tailored to new datasets (such as soil EC) and to meet other specific user needs as required. Metadata for each raster layer generated has also been provided.

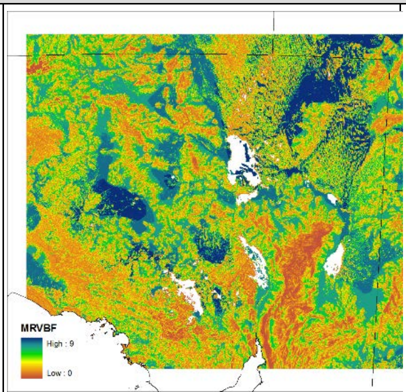
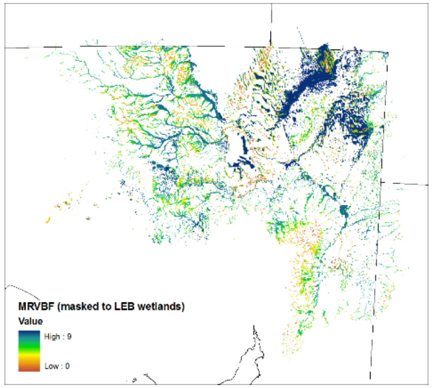
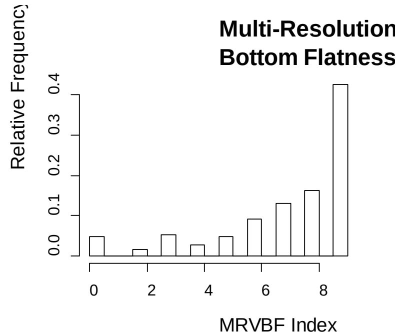
All rasters have been cropped and re-projected to suit the SA LEB study area. Further, the grids exhibit a range of development from raw data layers (sourced from other original work) to summarised, re-classified, and combined (or simple modelled) layers. Examples of statistical clustering are also provided for scenarios of: i) quantitative data only, and ii) combined quantitative and qualitative data; to demonstrate methods that aim to identify the key combinations of environmental variables as they occur in the landscape. Brooks et al. (2014) describe this type of approach as a 'bottom up' classification as it makes no a priori decisions on how features are assigned to classes; instead features are assigned to classes statistically.

Table C-1 Example soil and landscape grids for consideration in LEB AEMC

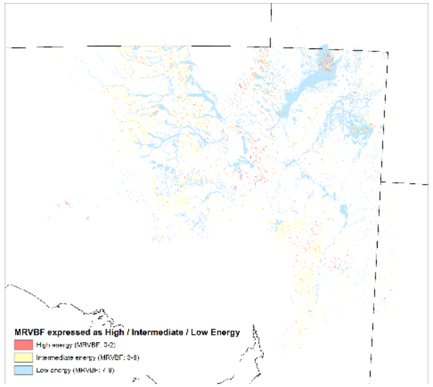
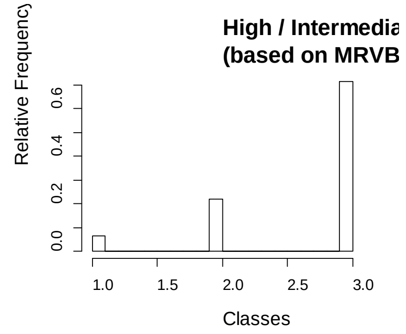
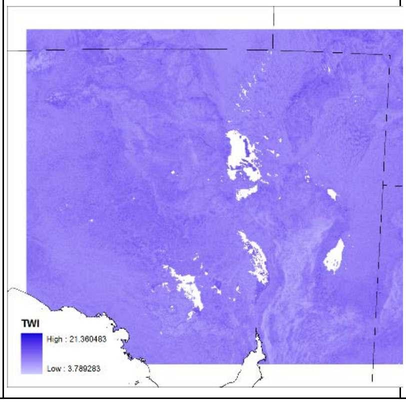
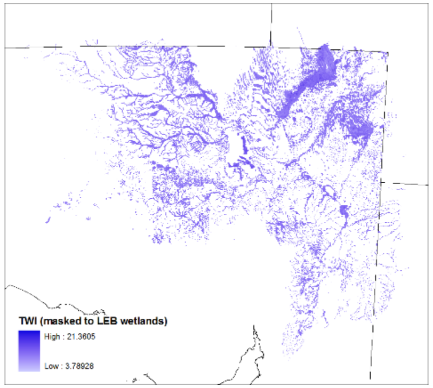
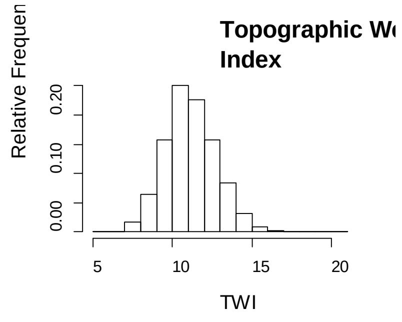
Layer	Summary information	Image cropped to max extent of LEB	Image masked to LEB wetlands	Distribution of values in LEB wetlands
	SOIL Properties			
Available Water-holding Capacity (AWC) 0-5 cm	Description: TERN SLGA National Soil Property map for surface (0-5 cm) plant-available water-holding capacity (AWC), expressed as a percentage of soil volume. AWC is the potential reservoir within a soil that is available to be filled by rainfall or irrigation and can be taken up by plants (between field capacity and wilting point). Data type: Continuous/numeric (FLT4S) Data source: CSIRO Data Access Portal, DOI: tbc Comments: AWC is generally higher for clayey soils and lower for sandy soils. Gravel or stone content will reduce AWC.			 Low values indicate sandy textures or higher rock and gravel content. High values indicate heavier texture surface soils.
Clay content % depth-weighted mean in upper 1 metre	Description: TERN SLGA National Soil Property maps for average clay content (mass% of fine earth) at each of the depths 0-5, 5-15, 15-30, 30-60, 60-100 cm were simplified to a single layer calculated as the depth-weighted mean for 0-100 cm. Data type: Continuous/numeric (FLT4S) Data source: Modified from original data in CSIRO Data Access Portal, DOI: 10.4225/08/544727EF2F60D Comments: Clay content % refers to fine earth (<2mm) component of soils. Gravel or coarse fragments (>2mm) may be present. Increasing surface clay content can indicate reduced permeability (depending on sodicity levels) and increased evaporative water loss. % Clay content levels associated with different textures are: <5%: sand, ~5%: loamy sand, 5-10%: clayey sand, 10-20%: sandy loam, ~25%: loam, 20-30%: sandy clay loam, 30-35%: clay loam, >35%: clay (NCST 2009).			 Low clay content = sandier textures; high clay content = clay loams and clays.

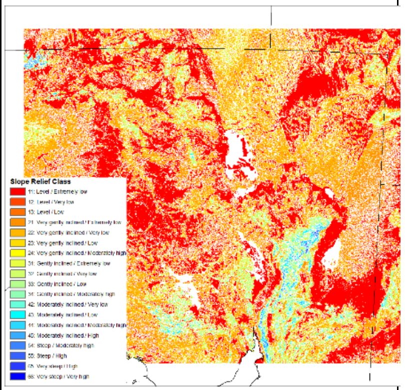
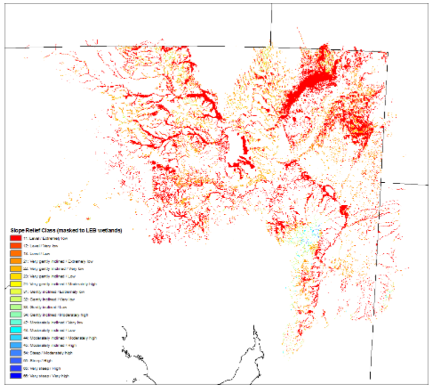
Layer	Summary information	Image cropped to max extent of LEB	Image masked to LEB wetlands	Distribution of values in LEB wetlands
Clayey versus non-clayey soil in upper 1 metre	Description: The above clay content % depth-weighted mean for 0-1m was converted to classes of 'clayey soils' (>=30%) which include clay loams and clays; and 'non-clayey soils' (<30%). Data type: Categorical (INT2S) Data source: Modified from original data in CSIRO Data Access Portal, DOI: 10.4225/08/544727EF2F60D Comments: TERN soil grid properties are spatial predictions based on nationally available site data and using an environmental correlation digital soil mapping approach.			 1. 'Clayey soils' (>= 30% content in 0-1m) 2. 'Non-clayey soils' (<30% content in 0-1m)
Clayey versus non-clayey soil versus rock in the upper 1 metre	Description: In this layer the presence of 'rock' is defined from the 'depth of regolith' layer (<1m) and this is over-written on the above 'clayey' versus 'non-clayey' layer to arrive at 3 classes: 1: 'clayey' soils, 2: 'non-clayey' soils, 3: 'rock'. Data type: Categorical (INT2S) Data source: Clay content information is modified from original data in CSIRO Data Access Portal, DOI: 10.4225/08/544727EF2F60D. 'Rock' information is derived from original regolith depth layer available from CSIRO Data Access Portal, DOI: tbc Comments: The scale and predictive accuracy of original layers may not be sufficient to accurately represent the presence of rock (or shallow soil) within the LEB wetlands. The presence of shallow rock (regolith depth <1m) is rare and largely occurs within the southern parts of the LEB wetlands (ie. drainage systems of the Flinders Ranges).	Not available		 1. 'Clayey soils' (>= 30% content in 0-1m) 2. 'Non-clayey soils' (<30% content in 0-1m) 3. 'Rock' (Regolith depth < 1m)

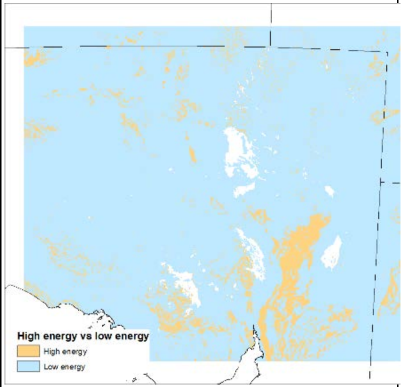
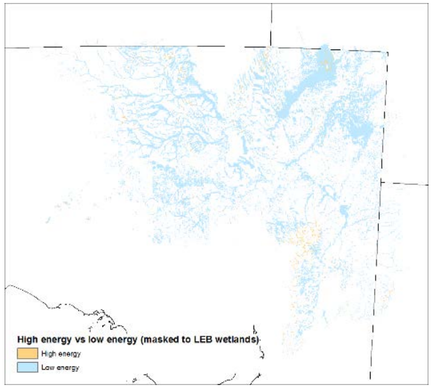
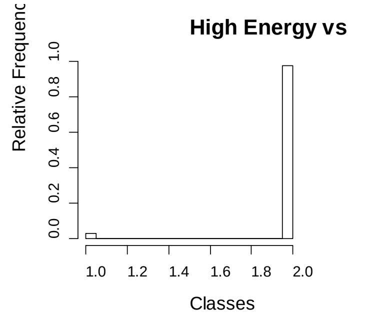
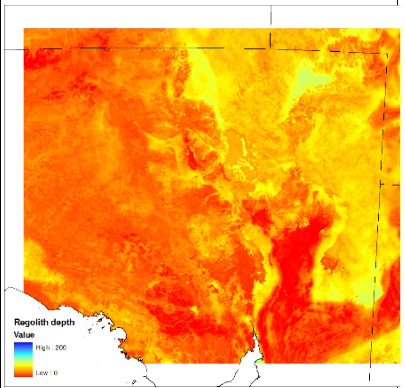
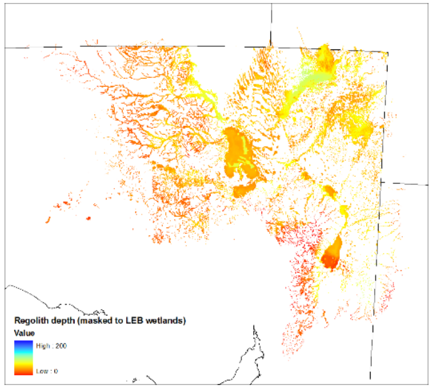
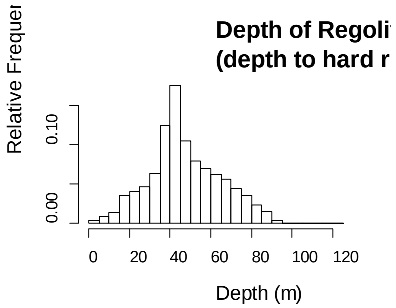
<table>
<tr><th>Layer</th><th>Summary information</th><th>Image cropped to max extent of LEB</th><th>Image masked to LEB wetlands</th><th>Distribution of values in LEB wetlands</th></tr>
<tr><td>High erosion risk soils [DRAFT]</td><td>Description: High erosion risk soils are indicated by the coincidence of low clay content soils (<20%, depth-weighted mean 0-1m) and less than average vigour of vegetation growth (ie. below average Veg FPAR Mean values, as described below).This is a simplistic draft model layer demonstrating the combination of different layers to examine higher-level issues. More detailed analysis is likely to be needed to give a more accurate representation of areas with higher risk of soil erosion.
Data type: Categorical (INT2S)
Data source: Derived from Clay content % depth-weighted mean 0-1 m and Veg FPAR Mean layers described below.
Comments: this is a preliminary draft analysis only.</td><td>Not available</td><td>
</td><td>

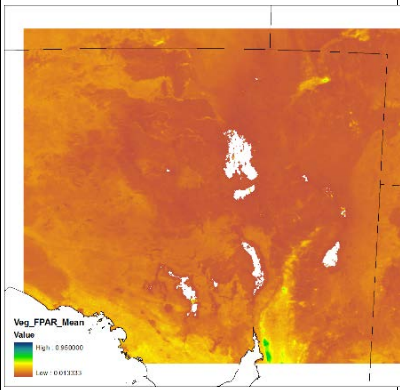
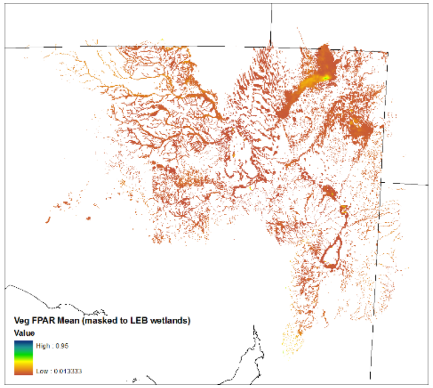
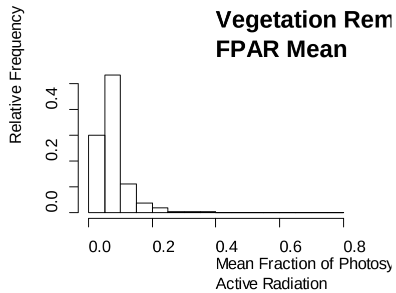
1. Higher erosion risk, 2. Lower erosion risk</td></tr>
<tr><td></td><td>LANDSCAPE Properties</td><td></td><td></td><td></td></tr>
<tr><td>Multi-Resolution Valley Bottom Flatness (MrVBF) Index</td><td>Description: MrVBF is a topographic index designed to identify areas of deposited material at a range of scales based on the observations that valley bottoms are low and flat relative to their surroundings and that large valley bottoms are flatter than smaller ones. Zero values indicate erosional terrain with values 1 and larger indicating progressively larger areas of deposition. There is some evidence that MrVBF values correlate with depth of deposited material.
Data type: Continuous/numeric (FLT4S)
Data source: CSIRO Data Access Portal, DOI: 10.4225/08/512EF27AC3888
Comments: Some wetland areas are masked out in this national layer.</td><td>
</td><td>
</td><td>

Larger values indicate larger depositional areas.</td></tr>
</table>

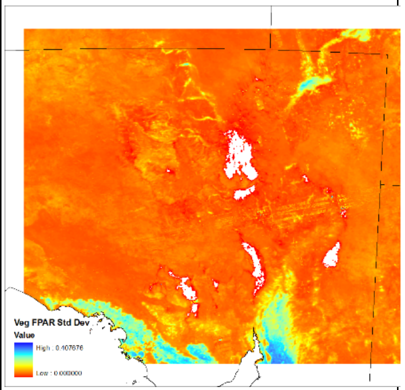
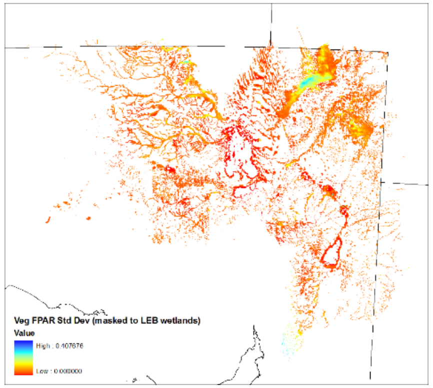
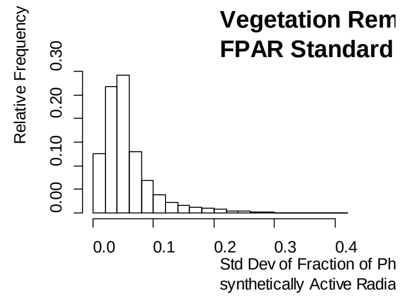
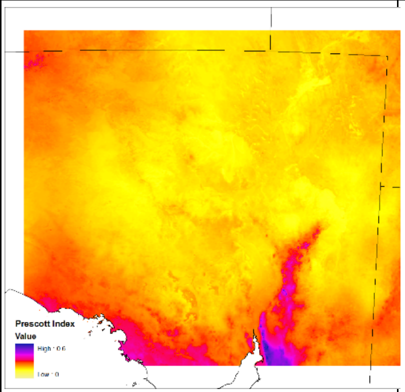
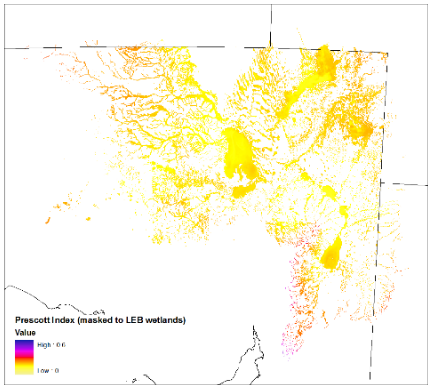
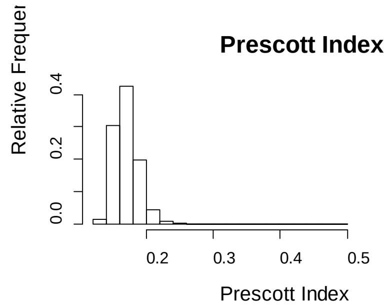
Layer	Summary information	Image cropped to max extent of LEB	Image masked to LEB wetlands	Distribution of values in LEB wetlands
Landform energy (#1) [DRAFT] based on MRVBF (High/ Int / Low)	Description: MrVBF layer is a topographic index designed to identify areas of deposited material at a range of scales based on the observations that valley bottoms are low and flat relative to their surroundings and that large valley bottoms are flatter than smaller ones. Zero values indicate erosional terrain with values 1 and larger indicating progressively larger areas of deposition. In this draft layer the MRVBF coverage has been divided into three classes to indicate landform energy levels: 1: high energy (MrVBF scores of 0-2), 2: intermediate energy (3-6), and 3: low energy (7-9). Data type: Categorical (INT2S) Data source: Modified from original data in CSIRO Data Access Portal, DOI: 10.4225/08/512EF27AC3888 Comments: Some wetland areas are masked out in this national layer.	Not available		 1. High, 2. Intermediate, 3. Low
Topographic Wetness Index (TWI)	Description: TWI indicates the relative wetness or tendency to accumulate water from the surrounding landscape Data type: Continuous/numeric (FLT4S) Data source: CSIRO Data Access Portal, DOI: 10.4225/08/50A9DF3968422 Comments: TWI contains significant variability at fine scales and may not be suited to defining larger scale management units. Some wetland areas are masked out in this national layer.			 Low values indicates areas that shed water. High values indicate water accumulation.

Layer	Summary information	Image cropped to max extent of LEB	Image masked to LEB wetlands	Distribution of values in LEB wetlands
Slope Relief Classification	Description: This is a classification of landform patterns based on relief and modal slope, based on Speight (2009), as shown in Table C-2 below. Speight's original high relief class (H, 90-300 m) has been split in two (HL and HH) and numeric codes have been assigned to every combination of relief and modal slope (John Wilford, Geoscience Australia, pers. comm.). Data type: Categorical (INT2S) Data source: John Gallant; Jenet Austin (2012): Slope Relief (3" resolution) derived from 1" SRTM DEM-S. v1. CSIRO. Data Collection. 10.4225/08/50A9D1D1BA1C1 [Available via TERN Data Discovery Portal] Comments: Some wetland areas are masked out in this national layer.			 Dominant classes: 11. Level + extremely low, 21. Very gently inclined + extremely low 31. Gently inclined + extremely low (Slope relief classes defined by Speight 2009)

Layer	Summary information	Image cropped to max extent of LEB	Image masked to LEB wetlands	Distribution of values in LEB wetlands
Landform energy (#2) [DRAFT] based on Slope Relief Classification (High / Low)	Description: This is a draft delineation between high energy (erosional) versus low energy (depositional) landscapes based on the abovementioned slope relief classes. [Alternatively, landform energy can be indicated by MrVBF, as described earlier.] Data type: Categorical (INT2S) Data source: Modified from original 'Slope Relief Classification' dataset: John Gallant; Jenet Austin (2012): Slope Relief (3" resolution) derived from 1" SRTM DEM-S. v1. CSIRO. Data Collection. 10.4225/08/50A9D1D1BA1C1 [Available via TERN Data Discovery Portal] Comments: Some wetland areas are masked out in this national layer. According to this particular delineation LEB wetlands are largely low energy systems so this will not be of widespread use to differentiate LEB wetlands. Another issue is that surface relief is not always a good attribute to split erosional and depositional landscapes (pers. comm. John Wilford Geoscience Australia). For example with incised or partly dissected alluvial fans where materials have been transported historically but are now being actively eroded. Additional information (e.g. geology maps) may be required to distinguish zones of erosion and deposition.			 1. High energy / erosional slope relief 2. Low energy / depositional slope relief
Depth of Regolith	Description: Depth of regolith provides an estimate of the depth to basement hard rock. Data type: Continuous/numeric (FLT4S) Data source: CSIRO Data Access Portal, DOI: not yet available Comments: Spatial predictions for depth of regolith have been produced by John Wilford of Geoscience Australia using nationally available site data through an environmental correlation modelling approach.			 Values indicate depth to hard (basement) rock. Values close to zero indicate rocky outcrop or shallow soils on rock.

<table>
<tr><th>Layer</th><th>Summary information</th><th>Image cropped to max extent of LEB</th><th>Image masked to LEB wetlands</th><th>Distribution of values in LEB wetlands</th></tr>
<tr><td>Veg FPAR Mean</td><td>Description: Veg FPAR Mean indicates average vegetation greeness. Specifically, this is the fraction of photosynthetically active radiation (FPAR), expressed as the mean of a time series (2000-2012). Veg FPAR coverages have been derived from satellite remote sensing (Advanced Very High Resolution Radiometer or AVHRR) using a CSIRO Land and Water algorithm and raw temporal raster time series coverages were processed by Ross Searle (CSIRO) to produce a summary mean coverage.
Data type: Continuous/numeric (FLT4S)
Data source: raw FPAR coverages at- https://remote-sensing.nci.org.au/u39/public/data/avhrr/fpar-clw/v4/Aust_Persistent_fPAR_1km_v4.zip
Metadata for raw FPAR coverages: http://data.auscover.org.au/geonetwork/srv/en/main.home?uuid=16c0b114-9563-4e4e-8dd6-096a0daebbd8
Comments: Higher values suggest better average growth of vegetation.</td><td>
</td><td>
</td><td>

Values indicate the mean relative strength of vegetation greenness over period 2000-2012. Higher values suggest better average growth of vegetation.</td></tr>
</table>

Layer	Summary information	Image cropped to max extent of LEB	Image masked to LEB wetlands	Distribution of values in LEB wetlands
Veg FPAR Std Dev	Description: Veg FPAR Std Dev indicates variability in vegetation greeness. Specifically, this is the fraction of photosynthetically active radiation (FPAR) expressed as the standard deviation of a time series (2000-2012). Veg FPAR coverages have been derived from satellite remote sensing (Advanced Very High Resolution Radiometer or AVHRR) using a CSIRO Land and Water algorithm and raw temporal raster time series coverages were processed by Ross Searle (CSIRO) to produce a summary standard deviation coverage. Data type: Continuous/numeric (FLT4S) Data source: raw FPAR coverages at- https://remote-sensing.nci.org.au/u39/public/data/avhrr/fpar-clw/v4/Aust_Persistent_fPAR_1km_v4.zip Metadata for raw FPAR coverages: http://data.auscover.org.au/geonetwork/srv/en/main.home?uuid=16c0b114-9563-4e4e-8dd6-096a0daebbd8 Comments: Low values suggest a stable trend while higher values suggest greater year to year fluctuation. Images show some correspondence between higher values of Veg FPAR Mean and higher values of Veg FPAR Std Dev. Combining Veg FPAR Mean and Std Dev may help identify the permanence or variability of water sources for wetlands. For example elevated mean values with low standard deviation may indicate consistency of water supply (ie. groundwater).			 Values indicate the standard deviation of vegetation greenness over period 2000-2012. Low values suggest a stable trend while higher values suggest greater year to year fluctuation.
Prescott Index	Description: Prescott Index is a measure of soil water balance indicating the intensity of leaching by excess water. Low values suggest reduced leaching by rainfall and potentially higher accumulation of salts. Higher values suggest more flushing from rainfall and soils that are less prone to build-up of salts. Soils with low buffering capacity (low clay content, low organic matter) that are excessively flushed (ie. in wetter regions) may also be prone to acidification. Data type: Continuous/numeric (FLT4S) Data source: CSIRO Data Access Portal, DOI: 10.4225/08/53EB2D0EAE377 Comments: Prescott Index values are at the lower range across much of the LEB wetlands. Prescott Index is an indicator of the ambient climatic influence on soil properties (and hence salinity levels), however it won't take account of transient flushing/leaching events arising from surface water flow			 Low values indicate less leaching from rainfall and potentially higher build-up of salts.

Layer	Summary information	Image cropped to max extent of LEB	Image masked to LEB wetlands	Distribution of values in LEB wetlands
	events.			

Table C-2 Classification of landform patterns based on relief and modal slope, based on Speight (2009),

		Modal terrain slope						
		LE 10	VG 20	GE 30	MO 40	ST 50	VS 60	PR 70
	Relief	Level < 1% (~ 1:300)	Very gently inclined 1 – 3% (~ 2%)	Gently inclined 3 – 10% (~ 6%)	Moderately inclined 10 – 32% (~ 20%)	Steep 32 – 56% (~ 40 %)	Very steep 56 – 100% (~ 70%)	Precipitous > 100% (~ 150%)
M 6	Very high > 300 m (~ 500 m)	16	26	36	RM 46 Rolling mountains	SM 56 Steep mountains	VM 66 Very steep mountains	PM 76 Precipitous mountains
HH 5	High (H) 150 – 300 m (~ 200 m)	15	25	UHH 35 Undulating hills	RHH 45 Rolling hills	SHH 55 Steep hills	VHH 65 Very steep hills	PHH 75 Precipitous hills
HL 4	High (L) 90 – 150 m (~ 120 m)	14	24	UHL 34 Undulating hills	RHL 44 Rolling hills	SHL 54 Steep hills	VHL 64 Very steep hills	PHL 74 Precipitous hills
L 3	Low 30 – 90 m (~ 50 m)	13	23	UL 33 Undulating low hills	RL 43 Rolling low hills	SL 53 Steep low hills	VL 63 Very steep low hills	B 73 Badlands
R 2	Very low 9 – 30 m (~ 15m)	12	GR 22 Gently undulating rises	UR 32 Undulating rises	RR 42 Rolling rises	SR 52 Steep rises	B 62 Badlands	B 72 Badlands
P 1	Extremely low < 9 m (~ 5 m)	LP 11 Level plain	GP 21 Gently undulating plain	UP 31 Undulating plain	RP 41 Rolling plain	B 51 Badlands	B 61 Badlands	B 71 Badlands

Key water-related attributes of the LEB wetlands were also converted to raster format (for subsequent demonstration of cluster analysis). The histograms in Figure C-1 show the relative frequency of these attributes within the LEB wetlands.

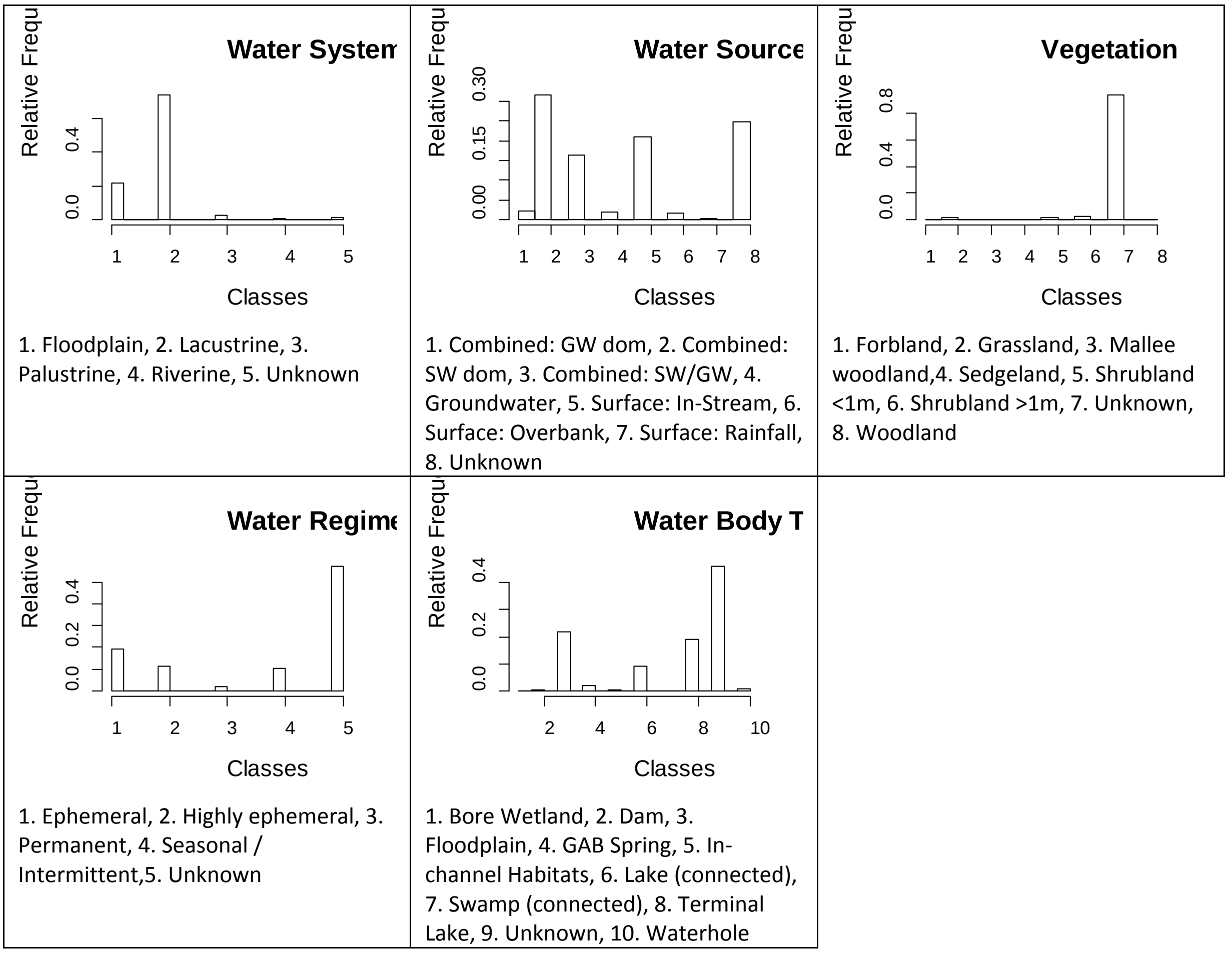


Figure C-1 Histogram plots for water-related attributes of LEB wetlands

R software provides powerful analytical tools for examining the inter-relationships of environmental variables that may influence LEB wetland aquatic ecosystems.

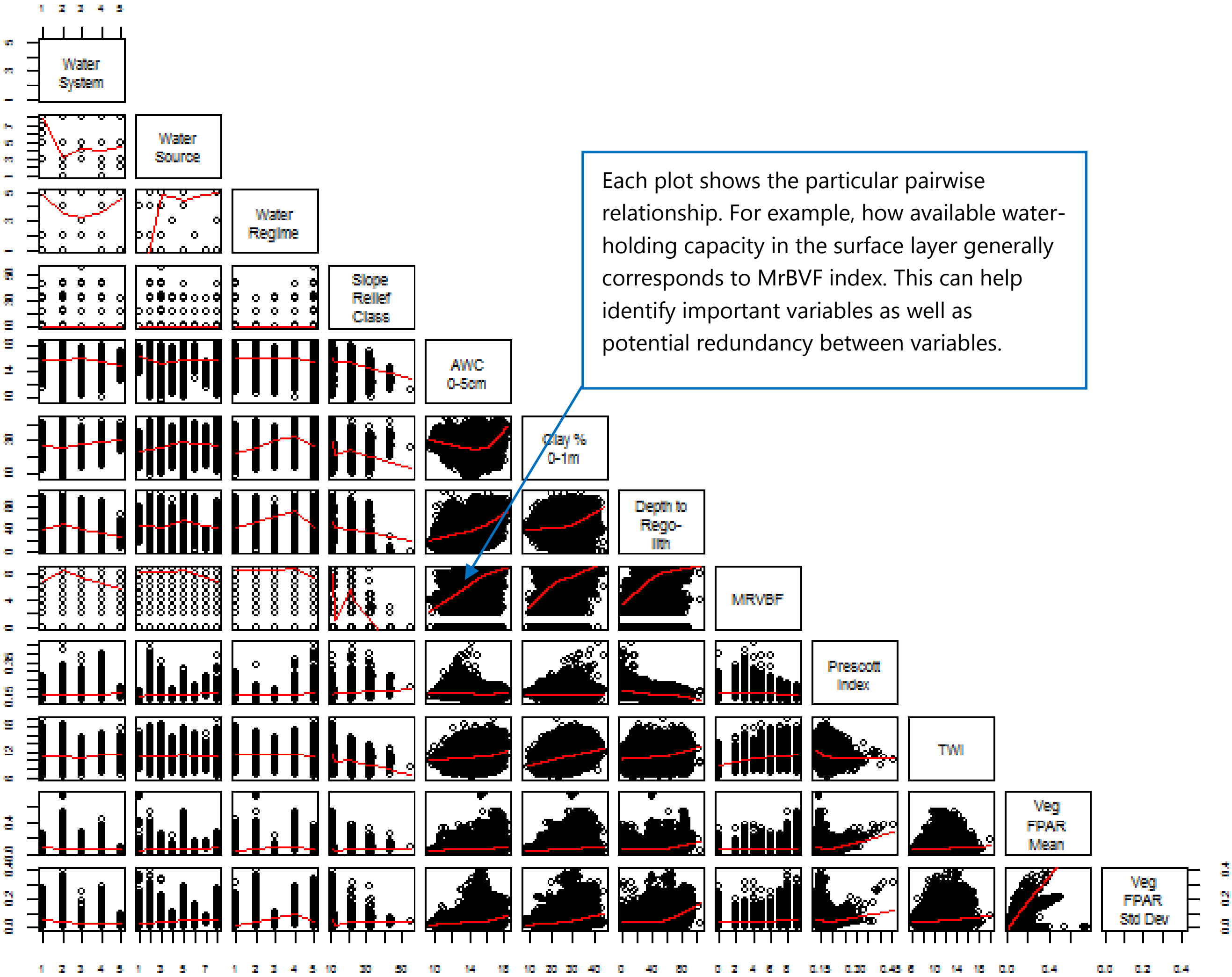


Figure C-2 This plot shows pairwise combinations of selected environmental variables (red lines indicate the highest density of values). The plot displays a random sample (n=100,000) from over 5 million grid cells spanning the LEB wetlands.

Two examples of clustering (unsupervised statistical classification) are shown below (Figure C3, C4) for demonstration purposes. Such analyses could be easily repeated using alternative variables to meet specific user needs.

Example 1: Cluster Analysis for quantitative variables – this used the R 'cluster' package (Maechler et al. 2014), function clara or clustering large applications. Six variables (AWC 0-5cm, Clay % depth-weighted 0-1m, Depth to regolith, Prescott Index, Veg FPAR Mean, Veg FPAR Std Dev) were used to define 10 clusters (Figure C-3). The number of clusters (classes) can be set by trial and error and central representative values (mediods) can be inspected to interpret each class. For example (see Table C-3 below), cluster 10 represents deep sediments, with high clay content in the root zone, in a very dry ambient environment but has highly variable and responsive vegetation. Cluster 4 represents areas of higher rainfall with good vegetation growth. Cluster 6 represents areas of very poor (and unresponsive) vegetation growth. Sandier soils are represented by clusters 5, 3, and 9.

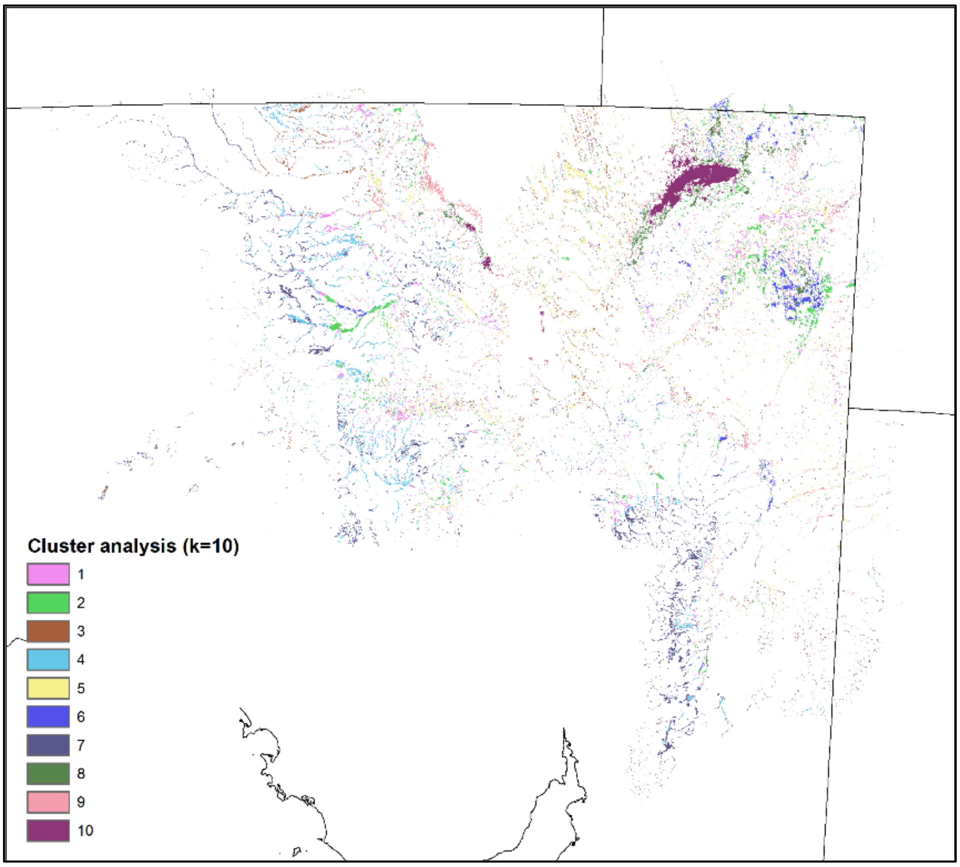


Figure C-3 Example cluster analysis for quantitative variables only.

Table C-3 Medoids or central representative values of each cluster

Cluster / class #	AWC (0-5cm)	Clay % (0-1m)	Depth of regolith (m)
1	15.3	27.2	39.4
2	16.6	32.5	50.6
3	15.3	23.3	34.6
4	14.6	28.4	28.3
5	14.5	21.8	50.8
6	16.4	32.2	62.9
7	14.5	27.8	17.9
8	16.9	33.0	71.6
9	15.9	25.3	63.9
10	15.9	34.0	81.0
Cluster / class #	**Prescott Index**	**Veg FPAR Mean**	**Veg FPAR Std Dev**
1	0.180	0.0474	0.0311
2	0.196	0.0645	0.0591
3	0.161	0.0962	0.0802
4	0.213	0.1714	0.0447
5	0.177	0.0605	0.0453
6	0.164	0.0200	0.0000
7	0.175	0.0526	0.0357
8	0.176	0.0646	0.0419

9	0.163	0.0488	0.0417
10	0.151	0.1093	0.0921

Example 2: Cluster analysis for quantitative and qualitative variables – this used the R 'FactoClass' package (Pardo et al. 2014), 'HillSmith' method dedicated for cluster analysis with qualitative (categorical) and quantitative (continuous numeric) variables (Figure C-4). Qualitative variables used were: water system, water source and water regime (Figure C-4). Quantitative variables used were: AWC 0-5cm, Clay % depth-weighted 0-1m, Depth to regolith, MrVBF, Prescott Index, Veg FPAR Mean and Veg FPAR Std Dev.

In this example 14 clusters were generated based on a random sample (n=50 000) of the rasters for ease of computation. Then classes were extended over all grid cells using the 'C5' classifier tool (Kuhn et al. 2013).

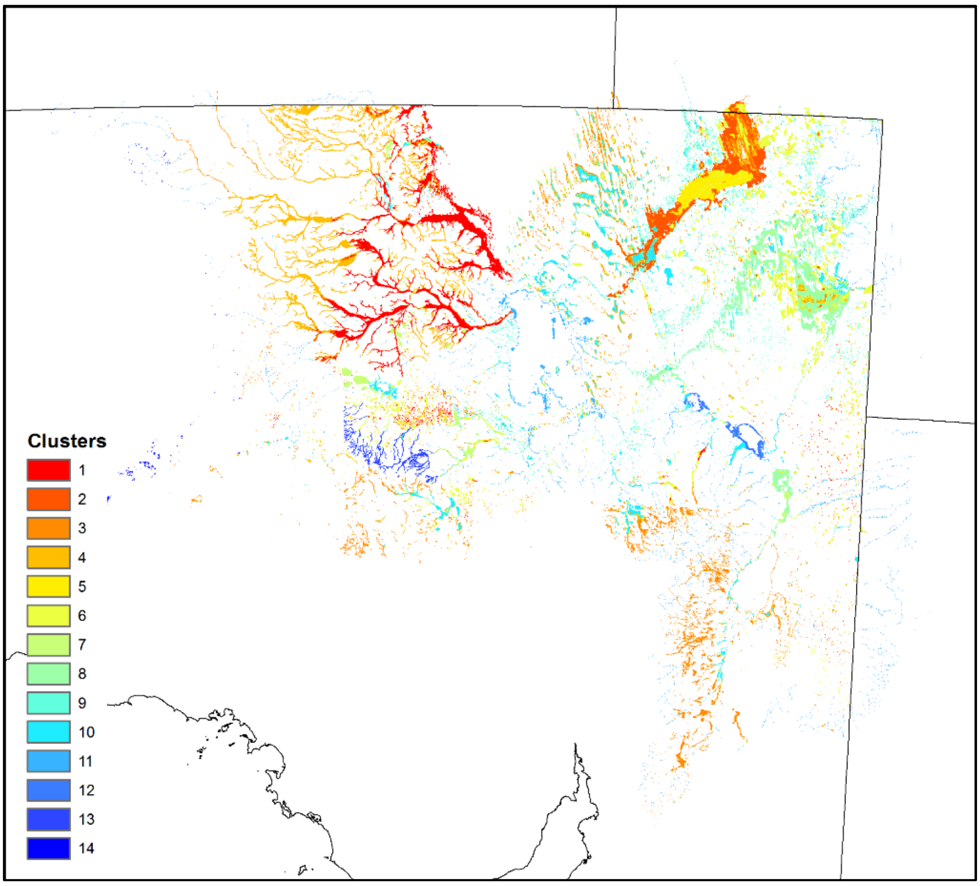


Figure C-4 Example cluster analysis using quantitative and qualitative variables.

The clustering process examines the data within a multi-dimensional conceptual space and looks for correspondence, core similarities and key differences among the variables. The data is re-formatted to highlight differences, reduce redundancy and then form groups. Such methods help to identify the natural groupings or sub-environments that occur amongst a wide array of interacting and potentially correlated environmental variables. However during this process there is a degree of loss of interpretability as the data is shifted to an altered set of multi-dimensional variables, which do not exactly equate with the initial input variables. To help overcome this issue there are interpretive aids (e.g. visual plots) to help make sense of the re-arranged data and the corresponding clusters that are formed. Examples of these are shown below (Figure C-5, C-6). Such interpretation would be required on a case-by-case basis, depending on the particular qualitative and quantitative variables used for clustering.

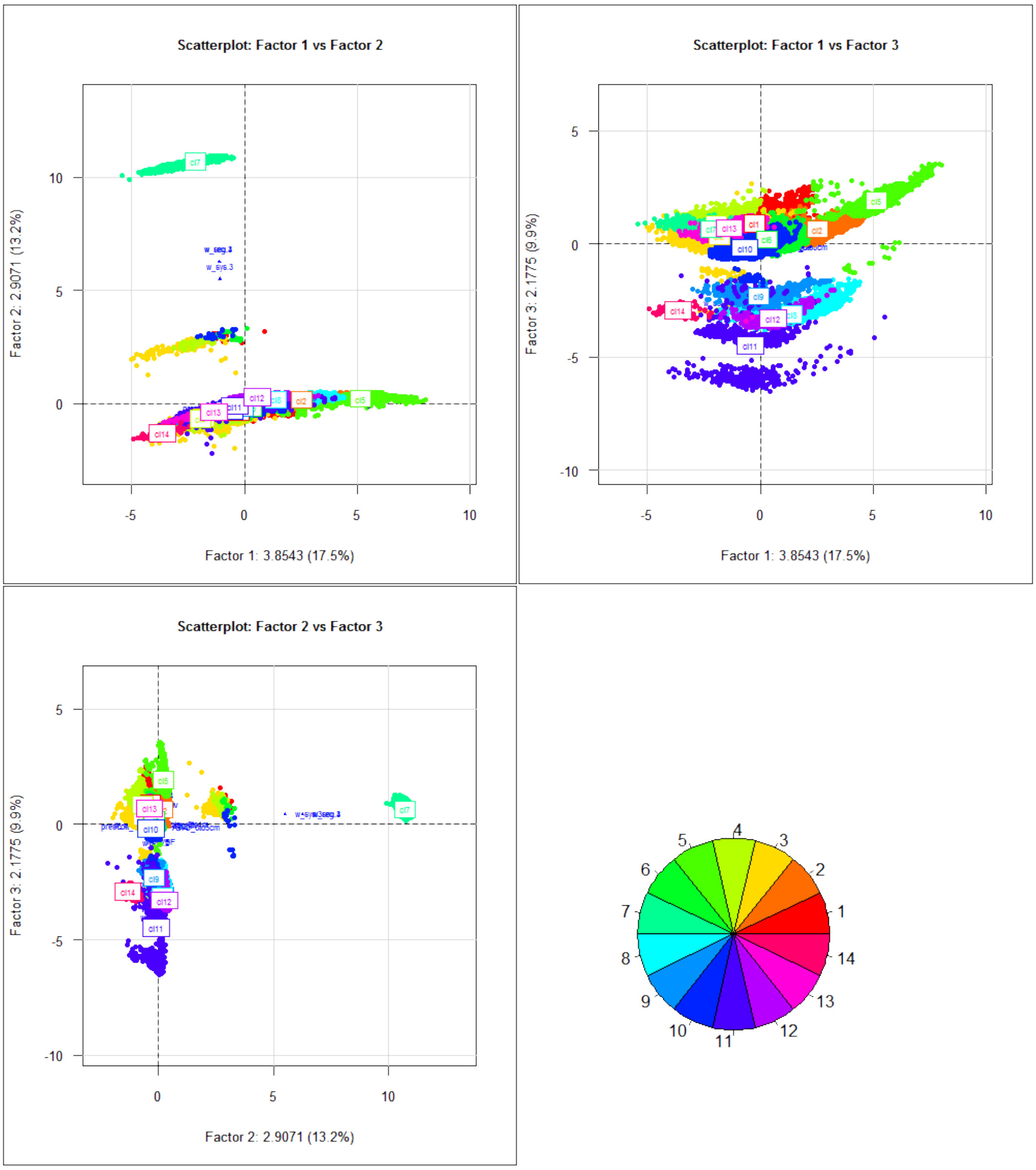


Figure C-5 Scatterplots show how each of the clusters (/classes) align with the original variables, as viewed from different dimensions. Cluster colours are shown.

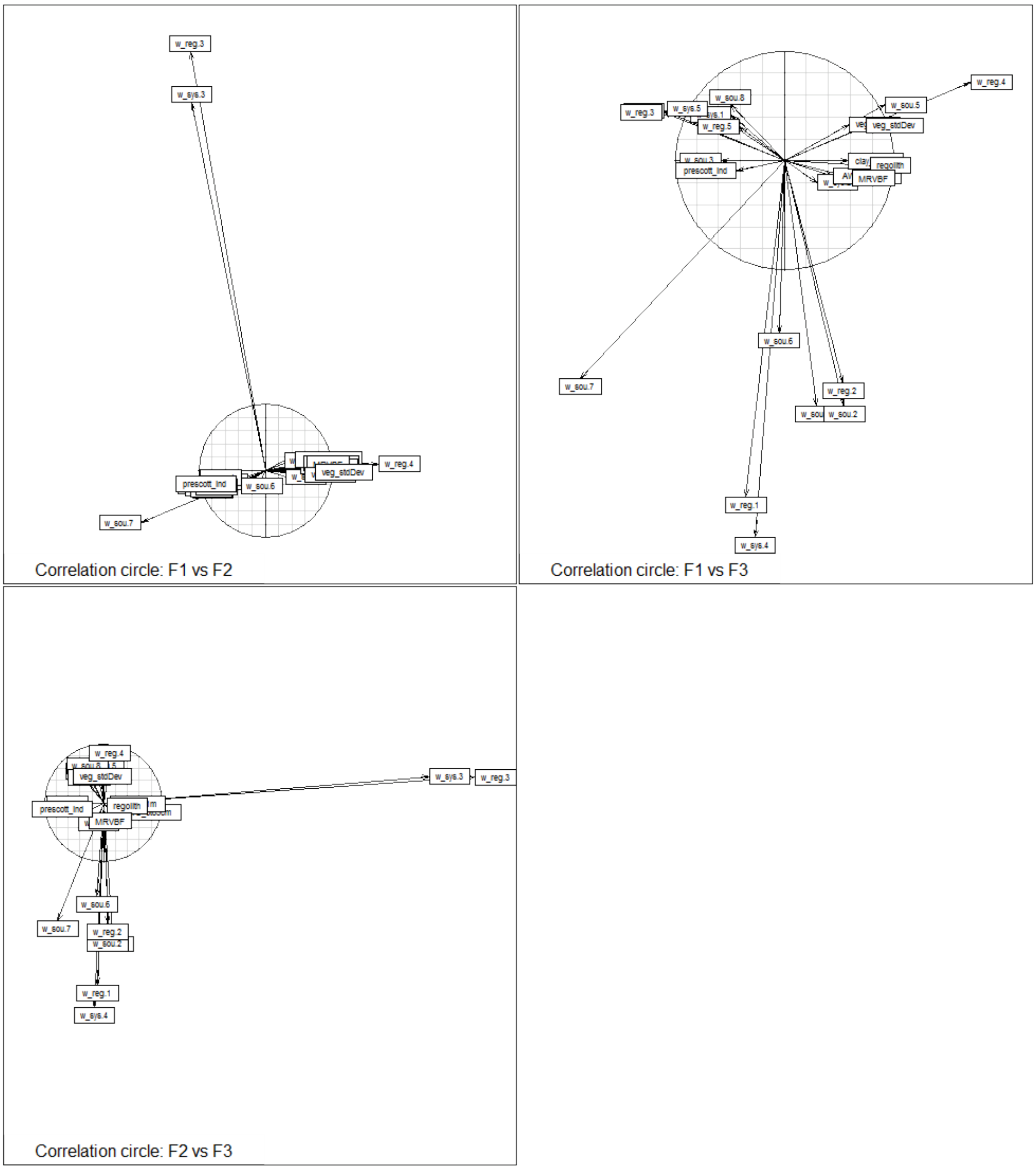


Figure C-6 Correlation circles show how the original variables align with (or are different from) each other, as viewed from different dimensions.

5 Acronyms

AEMC – Aquatic ecosystem classification and mapping (the LEBRM AEMC project)

AHGF – Australian Hydrological Geospatial Fabric

ANAE – Australian National Aquatic Ecosystems

DEWNR – Department of Environment, Water and Natural Resources

DWLBC – Department of Water, Land and Biodiversity Conservation

GAB – Great Artesian Basin

GDE – Groundwater dependent ecosystem

GIS – Geographical Information System

GPS – Global Positioning System

IBRA - Interim Biogeographical Regions (of Australia)

LEB – Lake Eyre Basin

LEBRA – Lake Eyre Basin Rivers Assessment

LEBSA – Lake Eyre Basin Springs Assessment (project)

LEBRM – Lake Eyre Basin River Monitoring (project)

LTZ – Landform Transport Zone

NRM – Natural Resources Management

NPA – National Partnership Agreement (on coal seam gas and coal mining)

SAAE – South Australian Aquatic Ecosystems

SAAL – South Australian Arid Lands (NRM Region)

WAD – Water asset database (sometimes referred to in the polygon file as NPADB)

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