PROVIDING SCIENTIFIC WATER RESOURCE INFORMATION ASSOCIATED WITH COAL SEAM GAS AND LARGE COAL MINES

Context statement for the Cooper subregion

Product 1.1 for the Cooper subregion from the Lake Eyre Basin Bioregional Assessment

10 July 2015

A scientific collaboration between the Department of the Environment, Bureau of Meteorology, CSIRO and Geoscience Australia

The Bioregional Assessment Programme

The Bioregional Assessment Programme is a transparent and accessible programme of baseline assessments that increase the available science for decision making associated with coal seam gas and large coal mines. A bioregional assessment is a scientific analysis of the ecology, hydrology, geology and hydrogeology of a bioregion with explicit assessment of the potential direct, indirect and cumulative impacts of coal seam gas and large coal mining development on water resources. This Programme draws on the best available scientific information and knowledge from many sources, including government, industry and regional communities, to produce bioregional assessments that are independent, scientifically robust, and relevant and meaningful at a regional scale.

The Programme is funded by the Australian Government Department of the Environment. The Department of the Environment, Bureau of Meteorology, CSIRO and Geoscience Australia are collaborating to undertake bioregional assessments. For more information, visit http://www.bioregionalassessments.gov.au.

Department of the Environment

The Office of Water Science, within the Australian Government Department of the Environment, is strengthening the regulation of coal seam gas and large coal mining development by ensuring that future decisions are informed by substantially improved science and independent expert advice about the potential water related impacts of those developments. For more information, visit http://www.environment.gov.au/coal-seam-gas-mining/.

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Authorship is listed in relative order of contribution.

Cover photograph

Cooper Creek near Innamincka, SA. 23 May 2013

Credit: Dr Anthony Budd (Geoscience Australia)

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Introduction

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) was established to provide advice to the federal Minister for the Environment on potential water-related impacts of coal seam gas (CSG) and large coal mining developments.

Bioregional assessments (BAs) are one of the key mechanisms to assist the IESC in developing this advice so that it is based on best available science and independent expert knowledge. Importantly, technical products from BAs are also expected to be made available to the public, providing the opportunity for all other interested parties, including government regulators, industry, community and the general public, to draw from a single set of accessible information. A BA is a scientific analysis, providing a baseline level of information on the ecology, hydrology, geology and hydrogeology of a bioregion with explicit assessment of the potential direct, indirect and cumulative impacts of CSG and coal mining development on water resources.

The IESC has been involved in the development of *Methodology for bioregional assessments of the impacts of coal seam gas and coal mining development on water resources* (the BA methodology; Barrett et al., 2013) and has endorsed it. The BA methodology specifies how BAs should be undertaken. Broadly, a BA comprises five components of activity, as illustrated in Figure 1. Each BA will be different, due in part to regional differences, but also in response to the availability of data, information and fit-for-purpose models. Where differences occur, these are recorded, judgments exercised on what can be achieved, and an explicit record is made of the confidence in the scientific advice produced from the BA.

The Bioregional Assessment Programme

The Bioregional Assessment Programme is a collaboration between the Department of the Environment, the Bureau of Meteorology, CSIRO and Geoscience Australia. Other technical expertise, such as from state governments or universities, is also drawn on as required. For example, natural resource management groups and catchment management authorities identify assets that the community values by providing the list of water-dependent assets, a key input.

The Technical Programme, part of the Bioregional Assessment Programme, will undertake BAs for the following bioregions and subregions:

- the Galilee, Cooper, Pedirka and Arckaringa subregions, within the Lake Eyre Basin bioregion
- the Maranoa-Balonne-Condamine, Gwydir, Namoi and Central West subregions, within the Northern Inland Catchments bioregion
- the Clarence-Moreton bioregion
- the Hunter and Gloucester subregions, within the Northern Sydney Basin bioregion
- the Sydney Basin bioregion
- the Gippsland Basin bioregion.

Technical products (described in a later section) will progressively be delivered throughout the Programme.

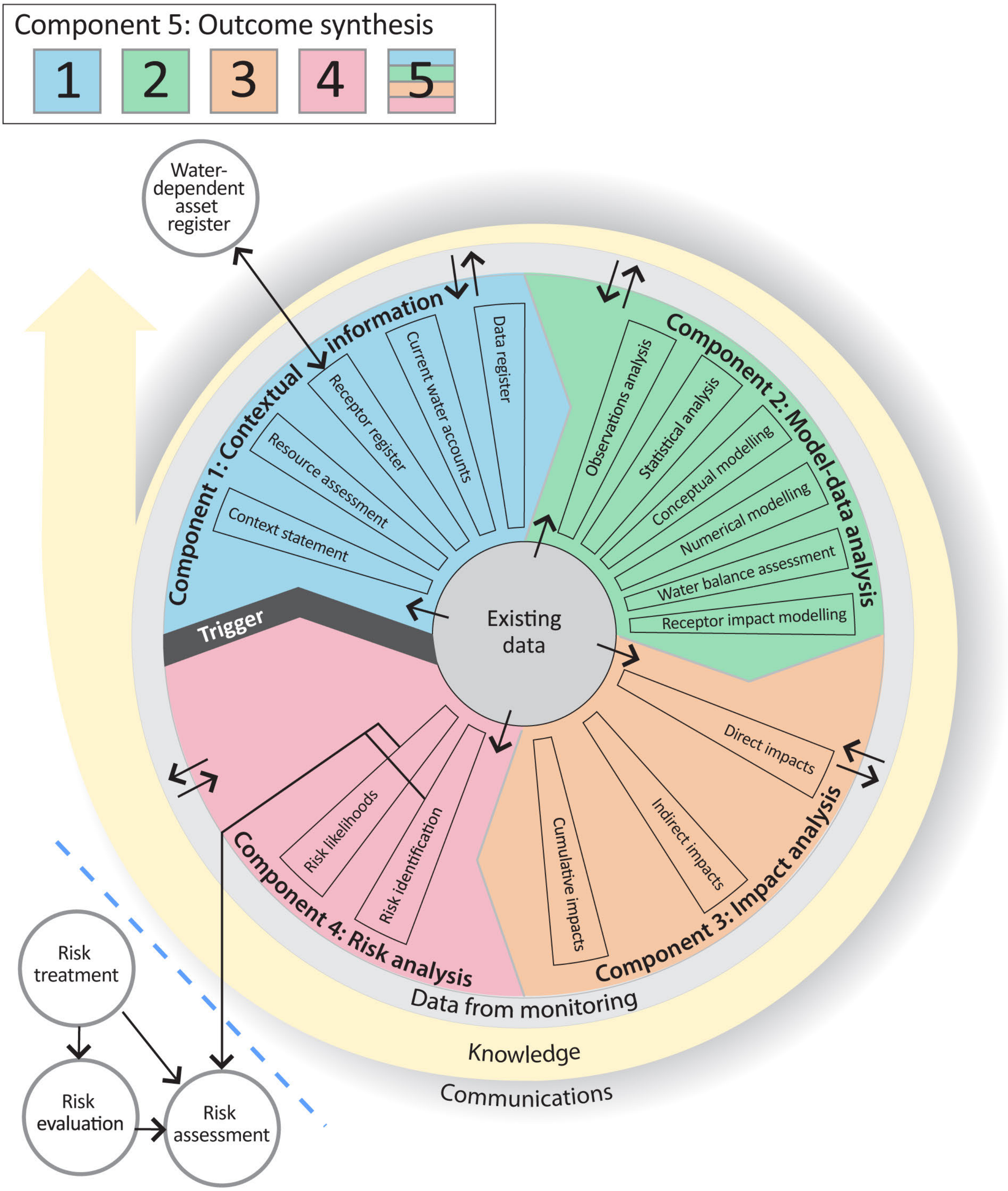

Figure 1 Schematic diagram of the bioregional assessment methodology

The methodology comprises five components, each delivering information into the bioregional assessment and building on prior components, thereby contributing to the accumulation of scientific knowledge. The small grey circles indicate activities external to the bioregional assessment. Risk identification and risk likelihoods are conducted within a bioregional assessment (as part of Component 4) and may contribute activities undertaken externally, such as risk evaluation, risk assessment and risk treatment. Source: Figure 1 in Barrett et al. (2013), © Commonwealth of Australia

Methodologies

For transparency and to ensure consistency across all BAs, submethodologies have been developed to supplement the key approaches outlined in the *Methodology for bioregional assessments of the impact of coal seam gas and coal mining development on water resources* (Barrett et al., 2013). This series of submethodologies aligns with technical products as presented in Table 1. The submethodologies are not intended to be 'recipe books' nor to provide step-by-step instructions; rather they provide an overview of the approach to be taken. In some instances, methods applied for a particular BA may need to differ from what is proposed in the submethodologies – in this case an explanation will be supplied. Overall, the submethodologies are intended to provide a rigorously defined foundation describing how BAs are undertaken.

Table 1 Methodologies and associated technical products listed in Table 2

Code	Proposed title	Summary of content	Associated technical product
M01	*Methodology for bioregional assessments of the impacts of coal seam gas and coal mining development on water resources*	A high-level description of the scientific and intellectual basis for a consistent approach to all bioregional assessments	All
M02	*Compiling water-dependent assets*	Describes the approach for determining water-dependent assets	1.3 Description of the water-dependent asset register
M03	*Assigning receptors and impact variables to water-dependent assets*	Describes the approach for determining receptors associated with water-dependent assets	1.4 Description of the receptor register
M04	*Developing a coal resource development pathway*	Specifies the information that needs to be collected and reported in product 1.2 (i.e. known coal and coal seam gas resources as well as current and potential resource developments). Describes the process for determining the coal resource development pathway (reported in product 2.3)	1.2 Coal and coal seam gas resource assessment 2.3 Conceptual modelling
M05	*Developing the conceptual model for causal pathways*	Describes the development of the conceptual model for causal pathways, which summarises how the 'system' operates and articulates the links between coal resource developments and impacts on receptors	2.3 Conceptual modelling
M06	*Surface water modelling*	Describes the approach taken for surface water modelling across all of the bioregions and subregions. It covers the model(s) used, as well as whether modelling will be quantitative or qualitative.	2.6.1 Surface water numerical modelling
M07	*Groundwater modelling*	Describes the approach taken for groundwater modelling across all of the bioregions and subregions. It covers the model(s) used, as well as whether modelling will be quantitative or qualitative. It also considers surface water – groundwater interactions, as well as how the groundwater modelling is constrained by geology.	2.6.2 Groundwater numerical modelling

Code	Proposed title	Summary of content	Associated technical product
M08	*Receptor impact modelling*	Describes how to develop the receptor impact models that are required to assess the potential impacts from coal seam gas and large coal mining on receptors. Conceptual, semi-quantitative and quantitative numerical models are described.	2.7 Receptor impact modelling
M09	*Propagating uncertainty through models*	Describes the approach to sensitivity analysis and quantifying uncertainty in the modelled hydrological response to coal and coal seam gas development	2.3 Conceptual modelling 2.6.1 Surface water numerical modelling 2.6.2 Groundwater numerical modelling 2.7 Receptor impact modelling
M10	*Risk and cumulative impacts on receptors*	Describes the process to identify and analyse risk	3 Impact analysis 4 Risk analysis
M11	*Hazard identification*	Describes the process to identify potential water-related hazards from coal and coal seam gas development	2 Model-data analysis 3 Impact analysis 4 Risk analysis
M12	*Fracture propagation and chemical concentrations*	Describes the likely extent of both vertical and horizontal fractures due to hydraulic stimulation and the likely concentration of chemicals after production of coal seam gas	2 Model-data analysis 3 Impact analysis 4 Risk analysis

Each submethodology is available online at http://www.bioregionalassessments.gov.au. Submethodologies might be added in the future.

Technical products

The outputs of the BAs include a suite of technical products variously presenting information about the ecology, hydrology, hydrogeology and geology of a bioregion and the potential direct, indirect and cumulative impacts of CSG and coal mining developments on water resources, both above and below ground. Importantly, these technical products are available to the public, providing the opportunity for all interested parties, including community, industry and government regulators, to draw from a single set of accessible information when considering CSG and large coal mining developments in a particular area.

The information included in the technical products is specified in the BA methodology. Figure 2 shows the information flow within a BA. Table 2 lists the content provided in the technical products, with cross-references to the part of the BA methodology that specifies it. The red rectangles in both Figure 2 and Table 2 indicate the information included in this technical product.

This technical product is delivered as a report (PDF). Additional material is also provided, as specified by the BA methodology:

- all unencumbered data syntheses and databases
- unencumbered tools, model code, procedures, routines and algorithms
- unencumbered forcing, boundary condition, parameter and initial condition datasets
- the workflow, comprising a record of all decision points along the pathway towards completion of the BA, gaps in data and modelling capability, and provenance of data.

The PDF of this technical product, and the additional material, are available online at http://www.bioregionalassessments.gov.au.

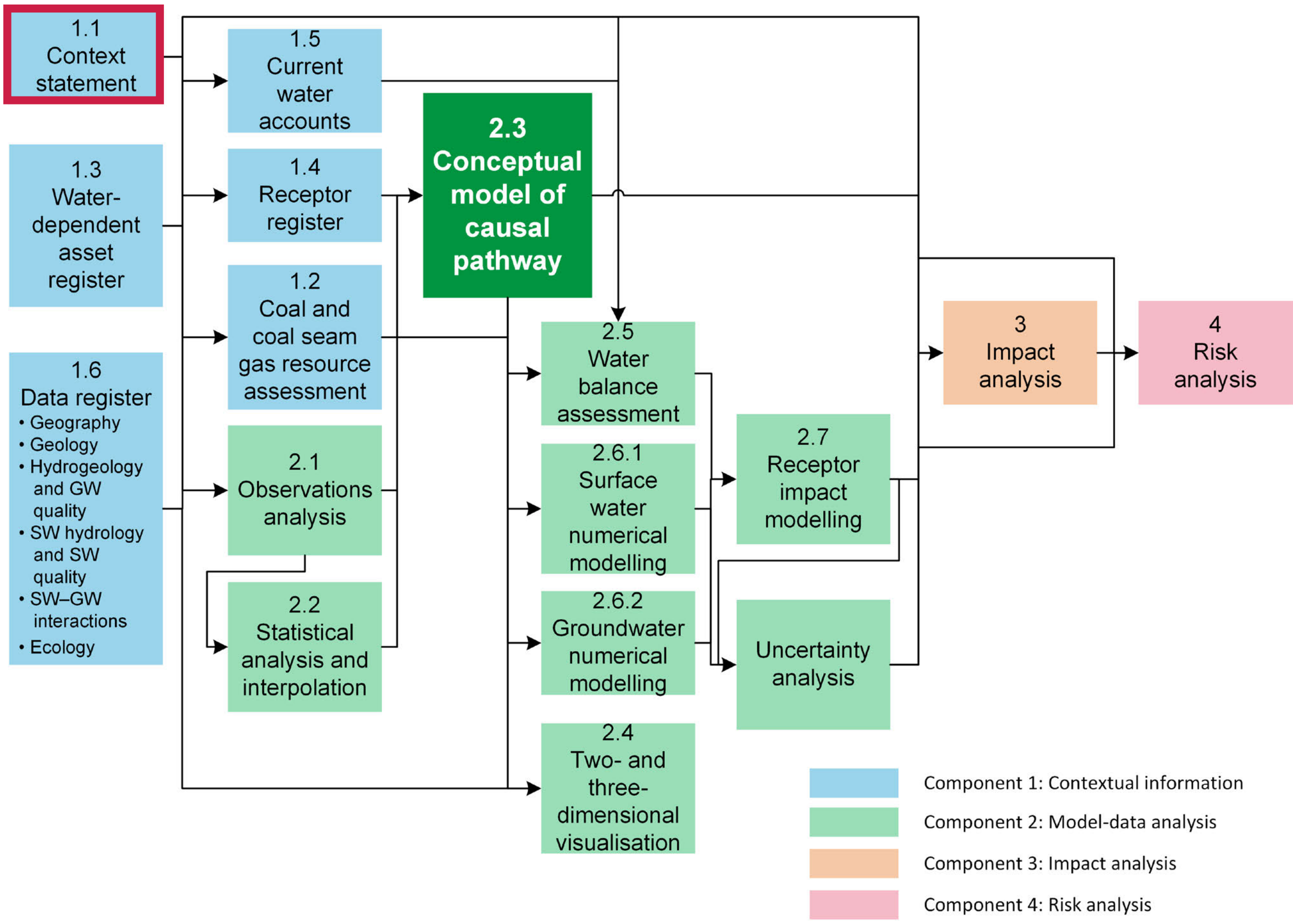

Figure 2 The simple decision tree indicates the flow of information through a bioregional assessment

The red rectangle indicates the information included in this technical product.

Table 2 Technical products delivered by the Lake Eyre Basin Bioregional Assessment

For each subregion in the Lake Eyre Basin Bioregional Assessment, technical products are delivered online at http://www.bioregionalassessments.gov.au, as indicated in the 'Type' column[a]. Other products – such as datasets, metadata, data visualisation and factsheets – are provided online.

Component	Product code	Title	Section in the BA methodology[b]	Type[a]
Component 1: Contextual information for the Cooper subregion	1.1	Context statement	2.5.1.1, 3.2	PDF, HTML
	1.2	Coal and coal seam gas resource assessment	2.5.1.2, 3.3	PDF, HTML
	1.3	Description of the water-dependent asset register	2.5.1.3, 3.4	PDF, HTML, register
	1.4	Description of the receptor register	2.5.1.4, 3.5	PDF, HTML, register
	1.5	Current water accounts and water quality	2.5.1.5	PDF, HTML
	1.6	Data register	2.5.1.6	Register
Component 2: Model-data analysis for the Cooper subregion	2.1-2.2	Observations analysis, statistical analysis and interpolation	2.5.2.1, 2.5.2.2	PDF, HTML
	2.3	Conceptual modelling	2.5.2.3, 4.3	PDF, HTML
	2.5	Water balance assessment	2.5.2.4	PDF, HTML
	2.6.1	Surface water numerical modelling	4.4	PDF, HTML
	2.6.2	Groundwater numerical modelling	4.4	PDF, HTML
	2.7	Receptor impact modelling	2.5.2.6, 4.5	PDF, HTML
Component 3: Impact analysis for the Cooper subregion	3-4	Impact analysis	5.2.1	PDF, HTML
Component 4: Risk analysis for the Cooper subregion		Risk analysis	2.5.4, 5.3	
Component 5: Outcome synthesis for the Lake Eyre Basin bioregion	5	Outcome synthesis	2.5.5	PDF, HTML

[a]The types of products are as follows:

- 'PDF' indicates a PDF document that is developed by the Lake Eyre Basin Bioregional Assessment using the structure, standards, and look and feel specified by the programme.
- 'HTML' indicates the same content as in the PDF document, but delivered as webpages.
- 'Register' indicates controlled lists that are delivered using a variety of formats as appropriate.

About this technical product

The following notes are relevant only for this technical product.

- The context statement is a collation of existing information and thus in some cases figures are reproduced from other sources. These figures were not redrawn for consistency (with respect to 'look and feel' as well as content), and the resolution and quality reflects that found in the source.
- All reasonable efforts were made to provide all material under a Creative Commons Attribution 3.0 Australia Licence.
- All maps created as part of this BA for inclusion in this product used the Albers equal area projection with a central meridian of 140.0° East for the Lake Eyre Basin bioregion and two standard parallels of –18.0° and –36.0°.
- Contact bioregionalassessments@bom.gov.au to access metadata (including copyright, attribution and licensing information) for all datasets cited or used to make figures in this product. At a later date, this information, as well as all unencumbered datasets, will be published online.
- The citation details of datasets are correct to the best of the knowledge of the Bioregional Assessment Programme at the publication date of this product. Readers should use the hyperlinks provided to access the most up-to-date information about these data; where there are discrepancies, the information provided online should be considered correct. The dates used to identify Bioregional Assessment Source Datasets are the dataset's created date. Where a created date is not available, the publication date or last updated date is used.

References

Barrett DJ, Couch CA, Metcalfe DJ, Lytton L, Adhikary DP and Schmidt RK (2013) Methodology for bioregional assessments of the impacts of coal seam gas and coal mining development on water resources. A report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of the Environment. Department of the Environment, Australia. Viewed 28 August 2015, http://www.iesc.environment.gov.au/publications/methodology-bioregional-assessments-impacts-coal-seam-gas-and-coal-mining-development-water.

1.1 Context statement for the Cooper subregion

The context statement brings together what is currently known about the geography, ecology, hydrology, geology and hydrogeology of a subregion or bioregion. It provides baseline information that is relevant to understanding the regional context of water resources and water-dependent assets, which might be impacted by coal and coal seam gas development. Information is collated that is relevant to interpret the impact analysis, risk analysis and outcomes of the bioregional assessment.

The context statement includes materially relevant characteristics of a subregion or bioregion that are needed to adequately interpret output from ecological, surface water and groundwater datasets and models, and from this develop improved knowledge of whole-of-system functioning.

No new analysis or modelling is presented in the context statement; rather it draws on existing information. Thus, some figures are reproduced from other sources and the look and feel of these external figures is not consistent with those produced in the bioregional assessment. Likewise, results from different sources may use different methods or inconsistent units.

1.1.1 Bioregion

The Cooper subregion is part of the Lake Eyre Basin bioregion (Figure 3). The Lake Eyre Basin bioregion covers an area of approximately 1.31 million km^2 of central and north-eastern Australia, including parts of Queensland, NSW, SA and the NT. The Lake Eyre Basin bioregion incorporates the whole of the Lake Eyre drainage catchment as well as portions of several adjacent surface drainage catchments. The main areas of interest within the Lake Eyre Basin bioregion are principally those underlain by four separate coal-bearing geological basins – the Pedirka and Arckaringa basins in the west, and the Galilee and Cooper basins in the east.

The extent of the geological Galilee, Cooper, Pedirka and Arckaringa basins each define subregions within the Lake Eyre Basin bioregion. Assessment of each of these subregions makes up the Lake Eyre Basin Bioregional Assessment.

1.1.1.1 Definitions used

The Cooper subregion is located in Queensland and SA (Figure 4), and is defined by the extent of the geological Cooper Basin (see Section 1.1.3 for further detail). The subregion spans an area of about 130,000 km^2. Approximately two-thirds of the subregion lies in south-west Queensland, with the remainder in north-eastern SA. Its north-eastern margin abuts the Galilee subregion. The Cooper subregion lies wholly within the Cooper Creek – Bulloo river basin, and includes a small portion of the Diamantina-Georgina river basin (see Section 1.1.5 for further detail).

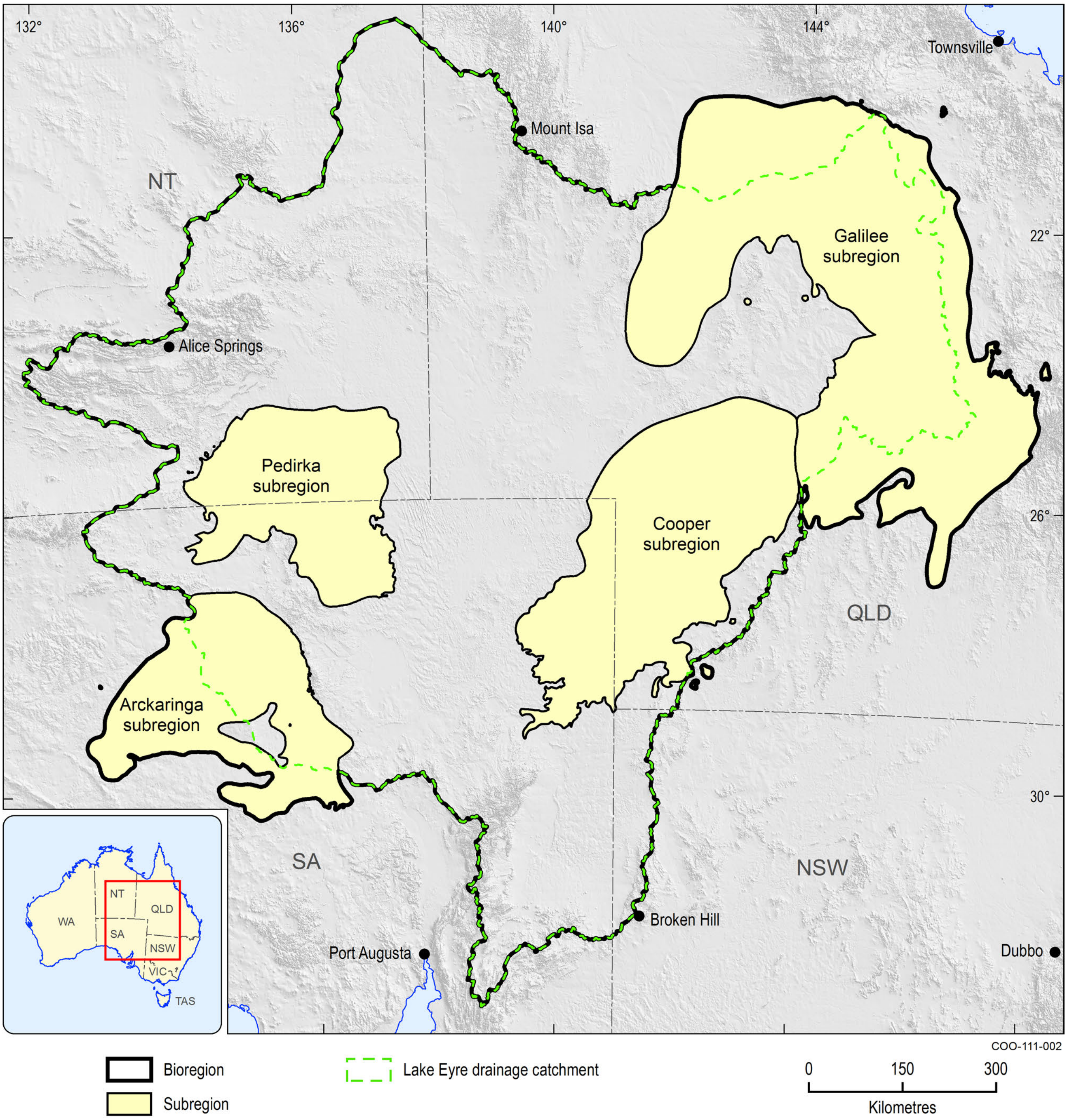

Figure 3 Lake Eyre Basin bioregion and subregions

1.1.2 Geography

Summary

The Cooper subregion is located across the SA–Queensland border. The subregion also covers a small part of NSW at Cameron Corner. The subregion spans an area of about 130,000 km^2 and is characterised by the braided channels of Cooper Creek and the Barcoo River. Most of the subregion is located within the Cooper Creek – Bulloo river basin. A small part of the north-west of the subregion is within the Diamantina–Georgina river basin.

The five main physiographic regions in the Cooper subregion are the Strzelecki Desert Plains, Innamincka Plains, Sturt Desert Plains and Cooper Plain, and the Eromanga Lowlands. Cooper subregion soils generally have low agricultural potential (Tenosols, Sodosols, Kandosols and Rudosols); areas of Vertosols mainly located within the Cooper and Innamincka plains have higher agricultural potential.

The Cooper subregion is sparsely populated with just 1032 residents and 626 dwellings recorded in mesh blocks which intersect the subregion in the 2011 census. The main localities in the subregion are Canterbury in Queensland, Innamincka and Moomba in SA and Cameron Corner on the border of NSW, Queensland and SA. The subregion covers parts of Diamantina Shire, Barcoo Shire, Longreach Regional, Quilpie Shire, Bulloo Shire and Outback Areas Community Development Trust local government areas (LGAs). The top industries of employment for these LGAs are mining, manufacturing, and agriculture, forestry and fishing.

The main land use class in the subregion is rangelands grazing. There is also an area of mining and intensive gas treatment, storage and distribution at Moomba, south-west of Innamincka. The subregion contains seven protected areas listed in the Collaborative Australian Protected Areas Database and eight wetlands listed in *A directory of important wetlands in Australia* (DIWA; Department of the Environment, Dataset 6). Several springs from the Lake Frome Supergroup supporting threatened ecological communities of native species dependent on the natural discharge of groundwater from the Great Artesian Basin occur just outside the Cooper subregion on the edge of Lake Blanche and further south near Lake Callabonna. These communities are listed as endangered under the Commonwealth's *Environmental Protection and Biodiversity Conservation Act 1999*. The Coongie Lakes and Lake Pinaroo (Fort Grey Basin) Ramsar wetlands also occur partly within the subregion.

The Cooper subregion lies within the Eyre region for Indigenous language groups and covers the Birria, Wangkumara, Yandruwandha, Yawarawarka and Karuwali tribal or language groups. There are 14 Indigenous Land Use Agreements in place within the Cooper subregion.

The climate is generally hot and dry with annual rainfall ranges from less than 200 mm to more than 300 mm and mean maximum temperatures above 20 °C year round. Rainfall is summer dominated and potential evapotranspiration exceeds rainfall in all months. Climate change projections suggest slightly higher warming for the Cooper subregion than the continental average, with a range of 1.1 to 1.2 °C by 2030 and up to 3 to 4 °C by 2070 under a high greenhouse gas emissions scenario. Projected changes in rainfall have more uncertainty

but a slight decline of 1 to 2.5% is projected by 2030 and this increases to 5 to 20% by 2070 under a high-emissions scenario. Most of these rainfall declines are projected to occur in winter and spring.

1.1.2.1 Physical geography

The Cooper subregion lies across the SA–Queensland border (including a small area of NSW at Cameron Corner), occupying approximately 130,000 km^2 (Figure 4). The subregion is generally flat, with dunes in the south-west. The topography ranges from –10 to 473 mAHD and is characterised by the braided channels of Cooper Creek and the Barcoo River, with very few lakes and salt lakes. More information on the surface water features of the subregion is provided in Section 1.1.5.

The Cooper subregion is located in the Lake Eyre drainage catchment. Most (approximately 118,500 km^2) of the Cooper subregion sits within the Cooper Creek – Bulloo river basin although a small part (approximately 11,500 km^2) in the north-west of the subregion sits within the Diamantina–Georgina river basin.

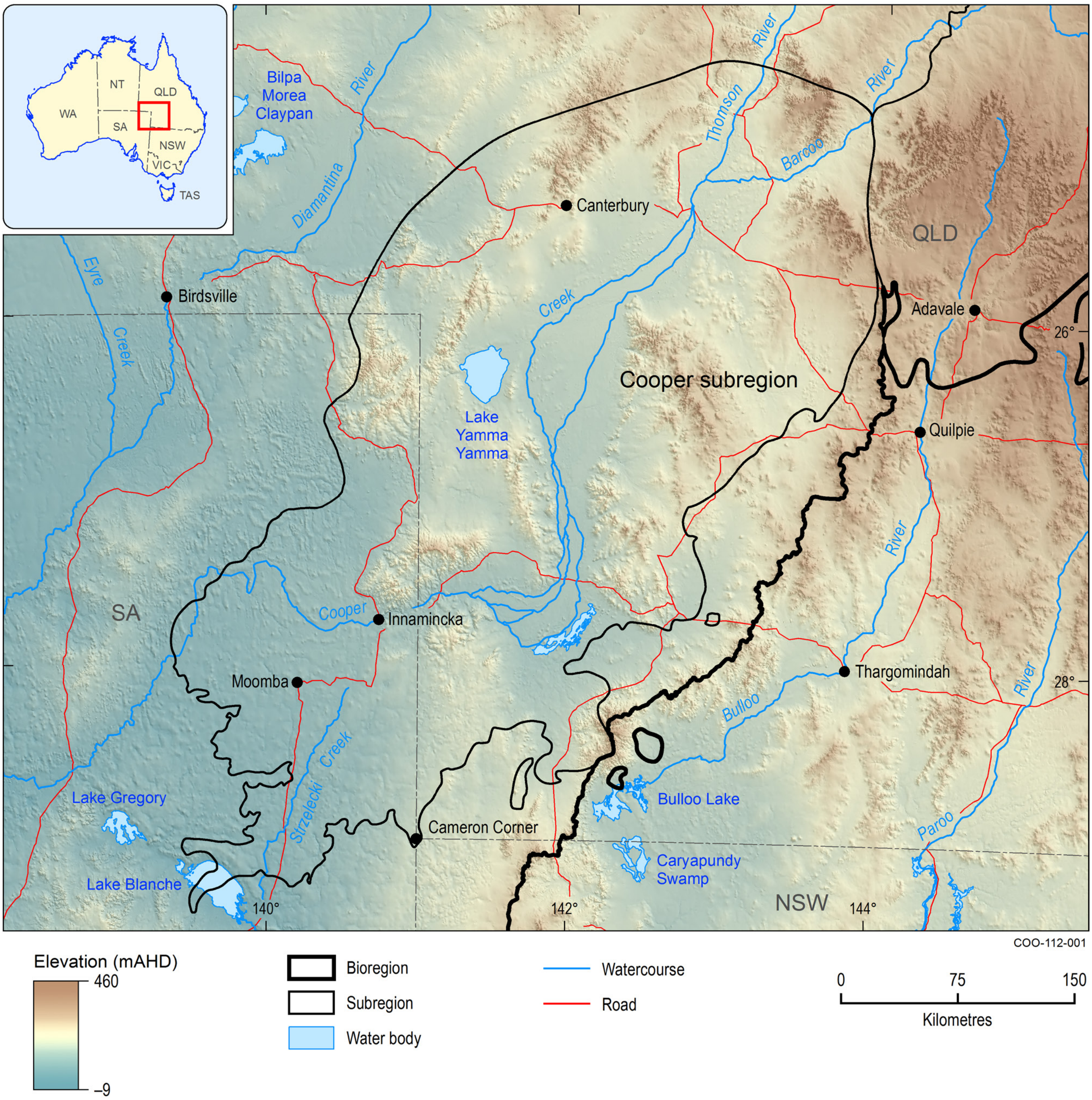

Figure 4 Location and topography of the Cooper subregion

Data: Geoscience Australia (Dataset 7)

1.1.2.1.1 Physiographic regions

A physiographic region is defined as a discrete morphological unit with internal coherence of its landform characteristics (Jennings and Mabbut, 1977). Physiographic regions are defined and mapped by landform characteristics that reflect uniform landform evolution, underlying geology and contained regolith materials (Pain et al., 2011). Early, largely descriptive, state-based treatments of Australian physiography that included Victoria (Hills, 1940) and WA (Jutson, 1914) progressed to continental-scale physiographic mapping by Jennings and Mabbut (1977) using improved topographic maps and other data. Physiographic mapping is descriptive and provides a regional-scale classification of landforms and related physical geography as they reflect underlying geological and climate controls. The most recent national-scale physiographic mapping by Pain et al. (2011) extends the mapping of Jennings and Mabbut (1977) by utilising the Shuttle Radar Topography Mission (SRTM) digital elevation model and other new data such as national and state soil and land survey data in a GIS mapping system. The classification has three divisions at the broadest level, 23 provinces distinguishing major physiographic changes, and 220 regions forming the basic subdivision of internally consistent landform morphology and inferred origin (Pain et al., 2011).

Five main physiographic regions cover the Cooper subregion (Figure 5). From south-west to north-east, these are the Strzelecki Desert Plains, Innamincka Plains, Sturt Desert Plains, Cooper Plain, and the Eromanga Lowlands. A sixth region (Winton-Blackall Downs, 20201) is mapped in the north-easternmost corner of the subregion, while a seventh (Grey Range, 20221) is present over a very small portion of the south-east of the subregion. Region descriptions from Pain et al. (2011) for these physiographic regions are provided in Table 3.

Table 3 Physiographic region descriptions for the Cooper subregion

Physiographic region	Description
Strzelecki Desert Plains (20220)	Longitudinal dunes and stony plains, minor clay pans and floodplains
Innamincka Plains (20228)	Aeolian sandplain with west to north-north-west trending seif dunes, and numerous claypans and alluvial areas (floodout of Cooper Creek)
Sturt Desert Plains (20219)	Stony plains with minor sand ridges
Cooper Plain (20211)	Floodplain
Eromanga Lowlands (20209)	Stony plains with silcrete-capped mesas, minor alluvial and sandy tracts
Winton-Blackall Downs (20201)	Undulating clay plains
Grey Range (20221)	Silcrete-capped tablelands

Data: Pain et al. (2011)

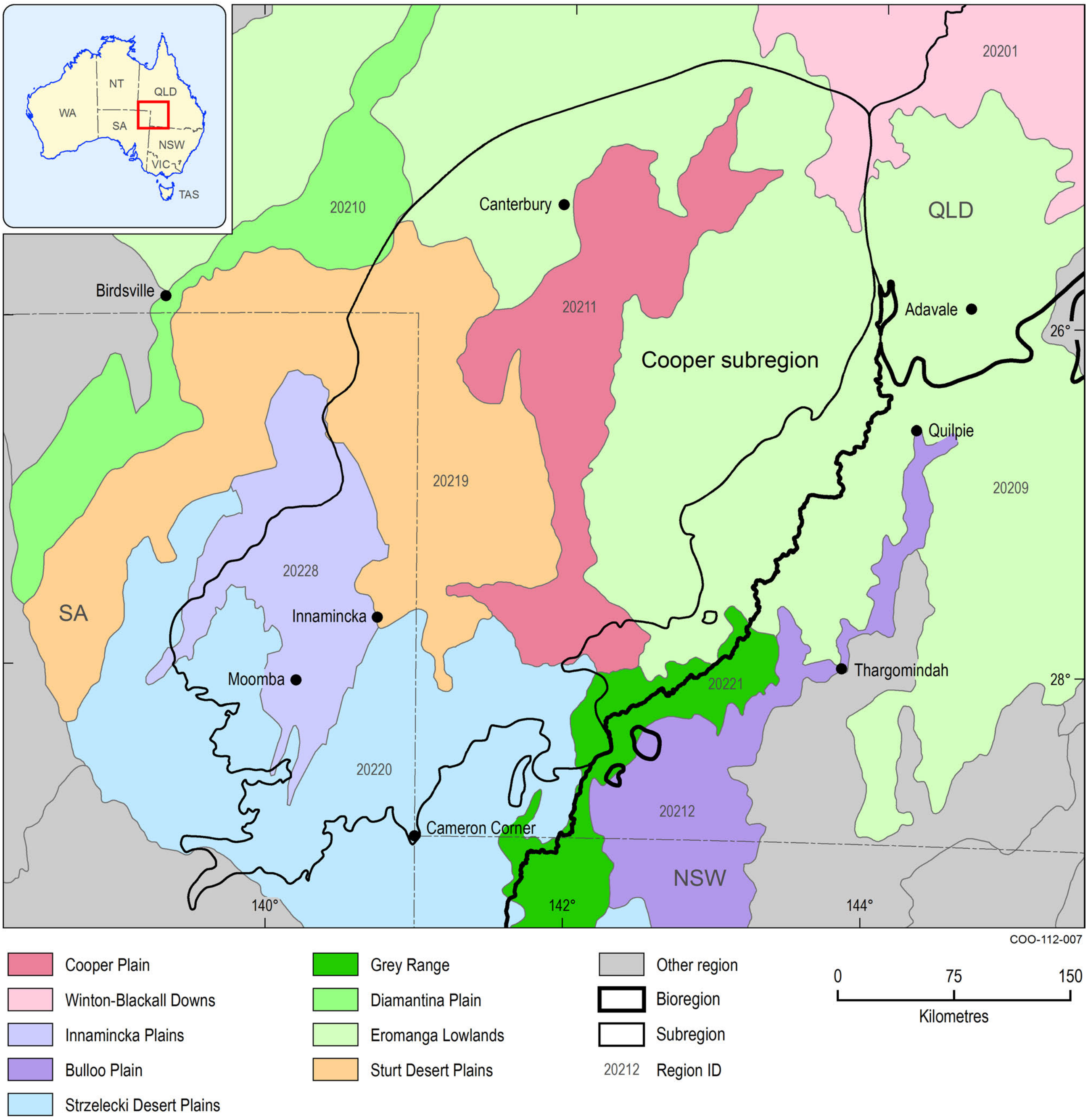

Figure 5 Physiographic regions of the Cooper subregion

Data: CSIRO (Dataset 5)

Region identification numbers are as used by Pain et al. (2011)

1.1.2.1.2 Soils and land capability

Figure 6 shows the Cooper subregion soils derived from the Australian Soil Classification (Isbell, 2002). This hierarchical classification features the B horizon characteristics and provides an assessment of the agricultural potential of the soil.

The Cooper Plain has Vertosols which are clay-rich soils characterised by shrink-swell properties that produce both strong cracking when dry and gilgai microrelief at the surface and slickensides and lenticular aggregates at depth. Gilgai microrelief is an irregular, generally polygonal pattern of alternating mounds and depressions, at variable scales, produced by physical subsoil movements in alternate shrink-swell cycles due to wetting and drying. Soil properties and profiles of gilgai mounds and depressions can vary. Vertosols have high agricultural potential with high fertility, variable structure depending on wetting state, and good water-holding capacity (Isbell, 2002). Vertosols are also characteristic of the Innamincka Plains.

The Eromanga Lowlands has a mix of Vertosols, Sodosols, Tenosols, and Kandosols. Sodosols show strong texture contrast with a highly sodic B horizon and pH greater than 5.5. They generally form on highly to moderately siliceous parent material and generally have low agricultural potential, low to moderate fertility, poor structure, low permeability, high erodibility and soil salinity. Sodosols are also characteristic of the Sturt Desert Plains. Tenosols are a diverse range of weakly developed sandy soils with an A horizon and are generally formed on highly siliceous parent materials. They tend to have low agricultural potential, low fertility, poor structure and low water-holding capacity. Kandosols are non-calcareous soils that lack a strong texture contrast and are developed on highly siliceous to intermediate parent material. They have low to moderate agricultural potential with moderate fertility and water-holding capacity (Isbell, 2002).

The Strzlecki Desert Plains are characterised by Rudosols and Kandosols. Rudosols are young soils with minimal pedogenic organisation and can vary widely in terms of texture, structure and depth. The Innamincka Plains also contains Rudosols.

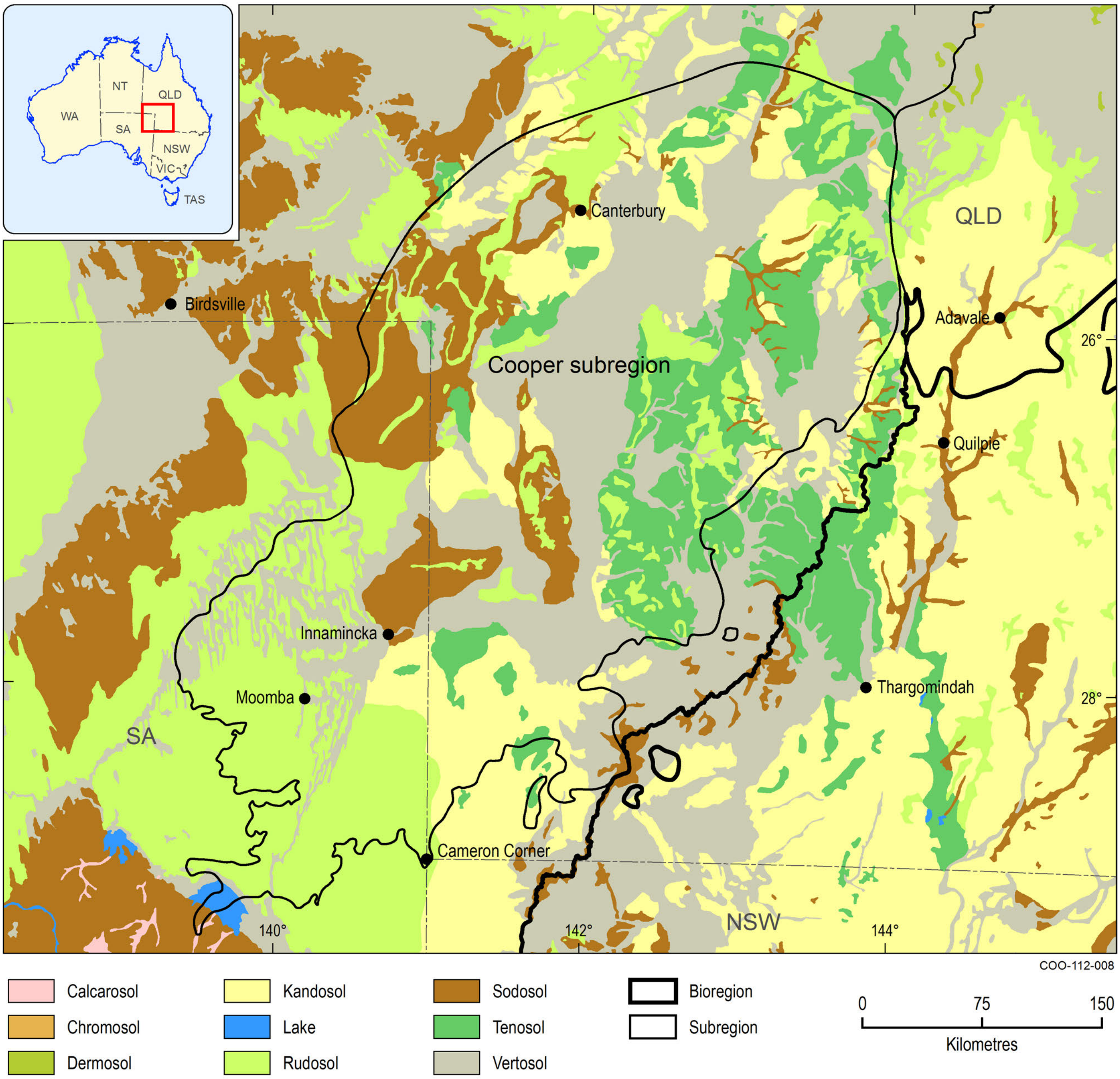

Figure 6 Cooper subregion soils from the Australian Soil Classification

Source: Ashton and McKenzie (2001); Bureau of Rural Sciences (Dataset 4)

1.1.2.1.3 Land cover

Figure 7 shows the dynamic land cover distribution across the Cooper subregion derived from Geoscience Australia remote sensing mapping which uses a time series analysis of 34 structural vegetation classes ranging from cultivated and managed land covers (crops and pastures) to natural land covers (forests and grasslands) (Lymburner et al., 2011).

The subregion is characterised by sparse shrubs, sparse hummock grass and scattered grassland; distributions of which do not seem much related to soils or physiographic regions. The most striking land cover feature is the distribution of tussock grasses which closely matches the Vertosols of the Cooper Plain.

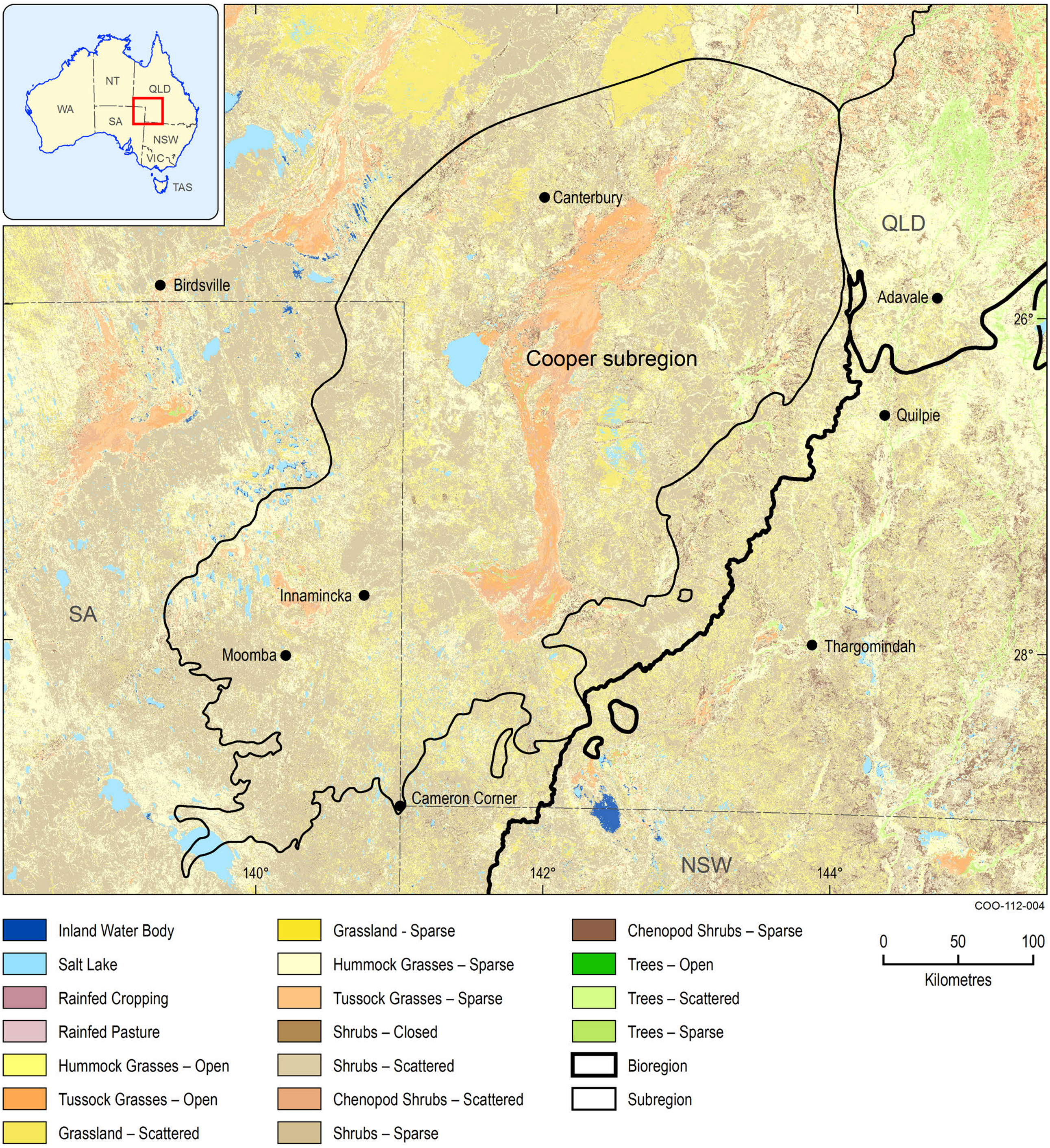

Figure 7 Cooper subregion land cover

Data: Geoscience Australia (Dataset 9)

1.1.2.2 Human geography

1.1.2.2.1 Population

The Cooper subregion is sparsely populated. Very little census data is available for the area of the subregion as it contains no 'Significant Urban Centres' and the entirety of the subregion is reported within the 'Balance of State' for census data. The mesh block is the smallest geographic area on which the Australia Bureau of Statistics (ABS) reports data and only usual residential population and number of dwellings are reported at this scale. A total of 37 mesh blocks lie within or partly within the Cooper subregion boundary. In 2011 the total population of these mesh blocks was 1032, and 626 dwellings were recorded (Australian Bureau of Statistics, 2013).

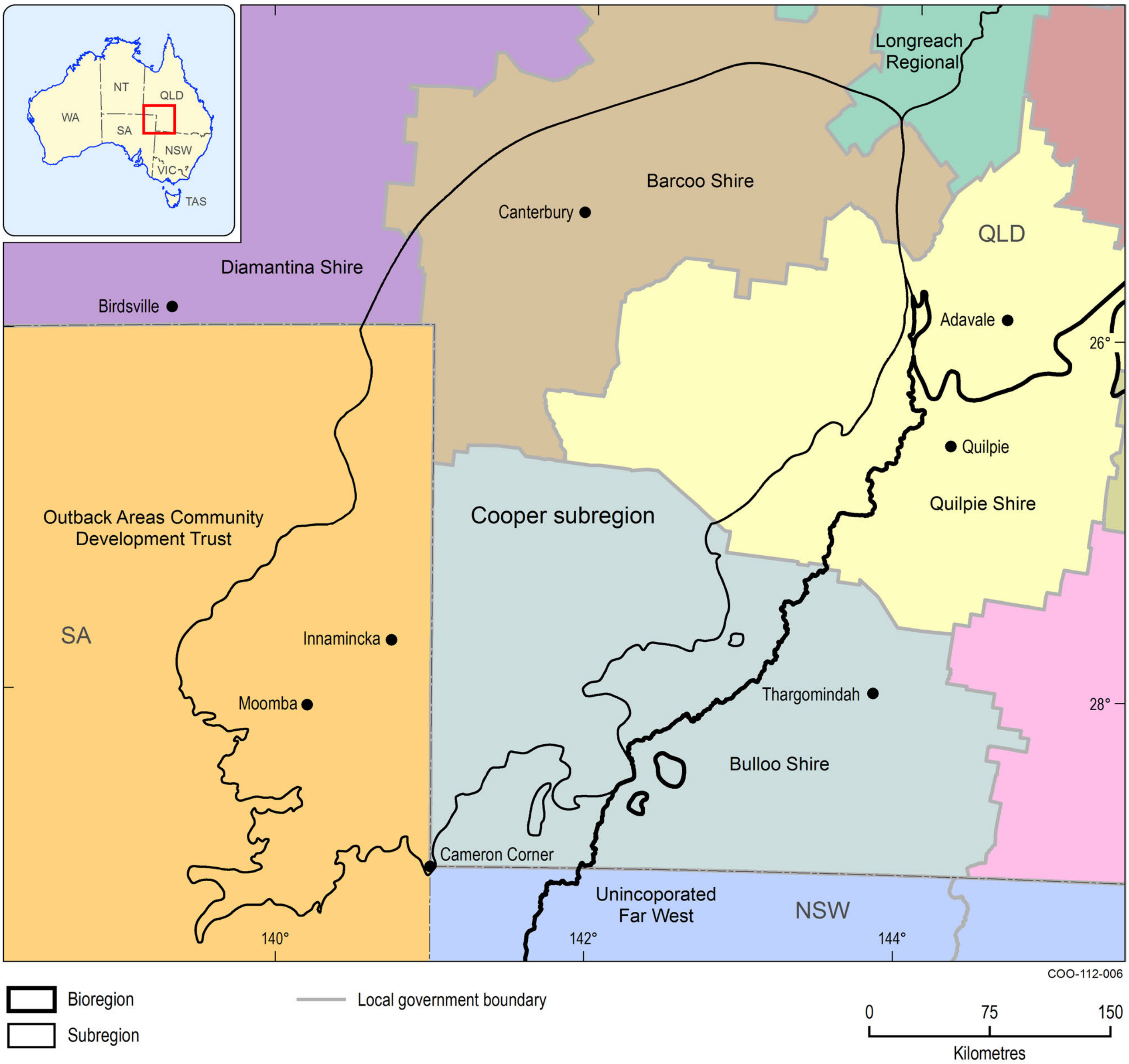

Figure 8 Cooper subregion local government areas, towns and localities

Source: Australian Bureau of Statistics (2013)

1.1.2.2.2 Economic activity

The local government areas (LGAs) of the Cooper subregion are: Barcoo Shire, Quilpie Shire, and Bulloo Shire, with small amounts of Diamantina Shire and Longreach Regional in Queensland, and part of the Outback Areas Community Development Trust in SA (Figure 8). The Unincorporated Far West LGA in NSW covers such a small amount of area in the Cooper subregion it has not been included in the employment statistics below.

Industry of occupation is shown in Table 4. As demonstrated by the township of Moomba with no permanent population but a large fly-in fly-out workforce, mining is the largest employer for the LGAs of the subregion at 30.1%, followed by manufacturing (15.2%), agriculture, forestry and fishing (9.5%) and construction (7.5%) (Australian Bureau of Statistics, 2013).

Table 4 Occupation categories in local government areas within the Cooper subregion[a]

Industry of occupation	Barcoo	Bulloo	Quilpie	Diamantina	Longreach Regional	Unincorporated SA[b]	Total employed (%)
Mining	3	64	30	0	6	3,177	3280 (30.1%)
Manufacturing	3	0	15	3	53	1,576	1650 (15.2%)
Agriculture, forestry and fishing	98	82	144	56	343	310	1033 (9.5%)
Construction	12	29	73	10	147	546	817 (7.5%)
Accommodation and food services	13	19	34	25	146	340	577 (5.3%)
Public administration and safety	43	49	68	22	196	73	451 (4.1%)
Health care and social assistance	7	4	29	6	274	93	413 (3.8%)
Transport, postal and warehousing	14	15	48	12	100	206	395 (3.6%)
Retail trade	0	9	38	9	223	97	376 (3.5%)
Education and training	15	9	30	6	211	100	371 (3.4%)
Electricity, gas, water and waste services	0	0	8	0	13	286	307 (2.8%)
Administrative and support services	0	15	3	0	38	200	256 (2.4%)
Professional, scientific and technical services	6	0	3	0	55	172	236 (2.2%)
Other services	0	3	6	0	88	129	226 (2.1%)

Industry of occupation	Barcoo	Bulloo	Quilpie	Diamantina	Longreach Regional	Unincorporated SA[b]	Total employed (%)
Wholesale trade	0	3	14	0	58	130	205 (1.9%)
Financial and insurance services	0	0	3	0	46	0	49 (0.5%)
Rental, hiring and real estate services	0	0	3	0	22	21	46 (0.4%)
Arts and recreation services	0	3	0	0	32	9	44 (0.4%)
Information media and telecommunications	0	0	3	0	25	7	35 (0.3%)
Inadequately described/Not stated	0	6	9	4	27	66	112 (1.0%)
Total	214	310	561	153	2103	7538	10,879

Data: Australian Bureau of Statistics (2013)
[a]The NSW part of the subregion is not included as it represents only a very small part of the subregion
[b]The LGA of Unincorporated SA covers a large area and only a small amount (which includes Innamincka and Moomba) of it lies within the Cooper subregion. This, combined with a large transient workforce, is the reason the employment numbers are so large compared to the population.

1.1.2.2.3 Land use

Most of the land in the subregion is used for natural vegetation grazing but there are also significant areas of nature conservation (see lists below of protected areas and wetlands) (Figure 9). The subregion also contains an area of mining and intensive gas treatment, storage and distribution at Moomba, a gas exploration and processing town with no permanent population.

Areas within the Cooper subregion that are listed in the *Collaborative Australian Protected Area Database* (Wang, Dataset 10):

- Innamincka Regional Reserve
- Strzelecki Regional Reserve
- Bulloo Downs Nature Refuge (in one of the subregion's outliers)
- Welford National Park
- Coongie Lakes National Park
- Lower Dinner Creek Nature Refuge
- Sturt National Park (in NSW, so only a very small amount lies in the Cooper subregion).

Wetlands within the Cooper subregion that are listed in DIWA (Department of the Environment, Dataset 6):

- Strzelecki Creek Wetland System
- Lake Cuddapan
- Cooper Creek Overflow Swamps – Windorah
- Cooper Creek Overflow Swamps – Nappa Merrie
- Cooper Creek Overflow Swamps – Wilsons River Junction
- Bulloo Lake (in one of the subregion's outliers)
- Coongie Lakes Ramsar site
- Lake Yamma Yamma
- Lake Pinaroo (Fort Grey Basin) Ramsar site (only a very small area is within the Cooper subregion).

Several threatened ecological communities of native species dependent on the natural discharge of groundwater from the Great Artesian Basin from the Lake Frome Supergroup are just outside the Cooper subregion on the edge of Lake Blanche and further south near Lake Callabonna. These communities are listed as endangered under the Commonwealth's *Environmental Protection and Biodiversity Conservation Act 1999*.

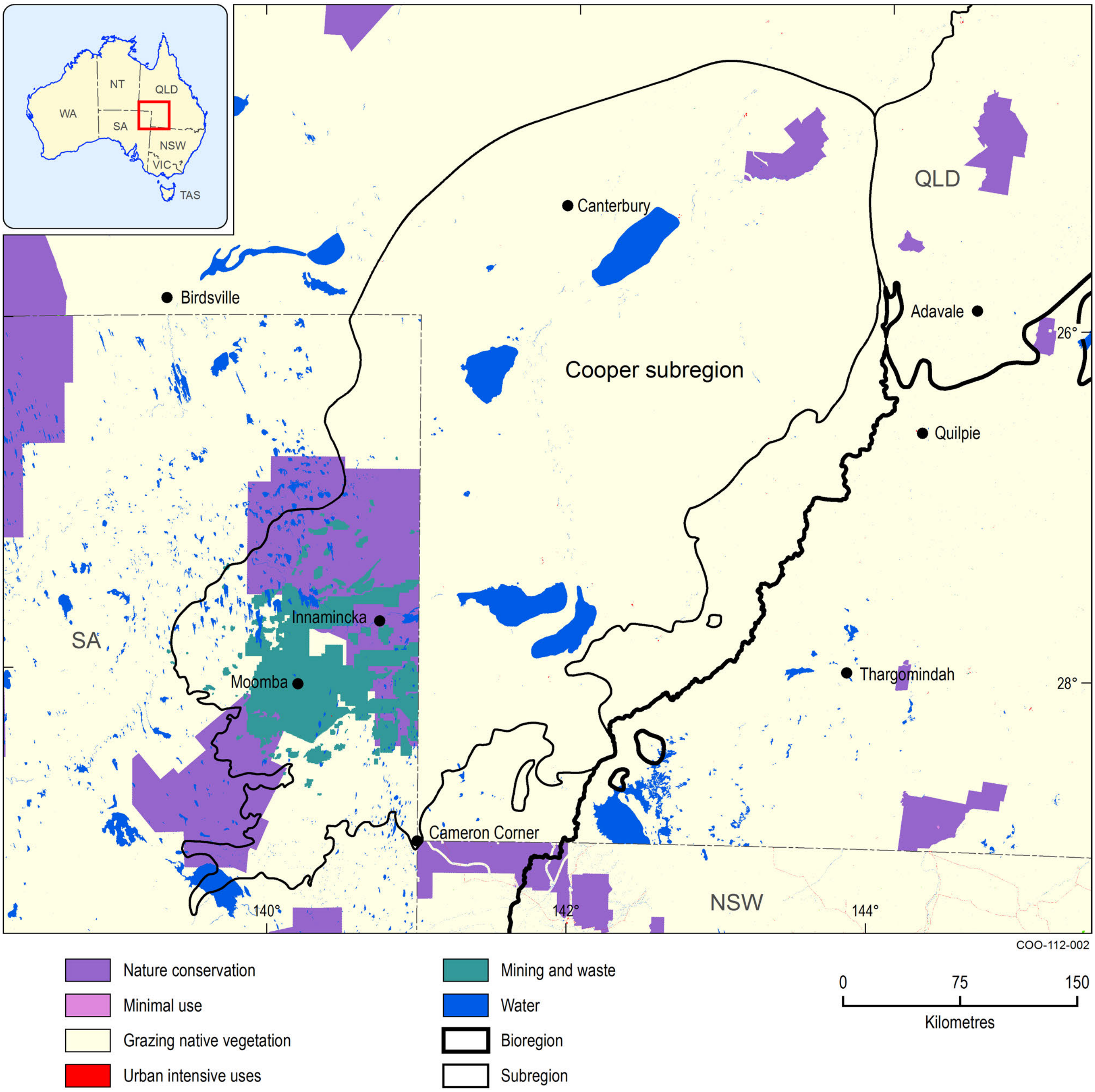

Figure 9 Cooper subregion land use

Data: Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) (Dataset 1)

1.1.2.2.4 Indigenous heritage

The Cooper subregion is within the Eyre region for Indigenous language groups (Horton, 1994) and has the following tribal or language groups:

- Birria
- Wangkumara
- Yandruwandha
- Yawarawarka
- Karuwali.

There are native title claims covering large portions of the subregion and a number of Indigenous Land Use Agreements (ILUAs) in place. ILUAs are negotiated agreements between native title claimants and others about the use and management of lands and waters and were introduced by amendments in 1998 to the Commonwealth's *Native Title Act 1993*. An ILUA can be negotiated and registered separately to a native title determination.

At the time of writing there were 14 ILUAs in the Cooper subregion (Commonwealth of Australia, 2014):

- Boonthamurra Opal ILUA
- Innamincka Township ILUA
- Yandruwandha/Yawarrawarrka Petroleum Conjunctive ILUA
- Yandruwandha/Yawarrawarrka Innamincka Pastoral ILUA
- Yandruwandha/Yawarrawarrka Tinga Tingana Pastoral ILUA
- Yandruwandha/Yawarrawarrka White Catch Pastoral ILUA
- Yandruwandha/Yawarrawarrka Bollards Lagoon Pastoral ILUA
- Yandruwandha/Yawarrawarrka Gidgealpa Pastoral ILUA
- Yandruwandha/Yawarrawarrka Merty Merty Pastoral ILUA
- Coongie Lakes National Park ILUA
- Strzelecki Regional Reserve ILUA
- Innamincka Regional Reserve ILUA
- Yandruwandha Yawarrawarrka Fishing ILUA
- Yandruwandha/Yawarrawarrka Cordillo Downs Pastoral ILUA.

1.1.2.3 Climate

The Köppen-Geiger climate classification scheme to classify world climate is based on the concept that native vegetation forms the best expression of climate. The modified Köppen-Geiger climate classification of Australia adopted by the Bureau of Meteorology (Stern et al., 2000) characterises most of the Cooper subregion as hot, persistently dry desert. A small area in the north-east is classified as hot, persistently dry grassland. The distribution of mean annual rainfall is shown in Figure 10. Most of the Cooper subregion receives between 200 and 300 mm/year of rain, it is drier in the west with less than 200 mm/year and wetter in the north-east with 300 to 400 mm/year rainfall. Evapotranspiration is highest in the north-west and decreases towards the south and east. The range is from 2300 to 2400 mm/year at Cameron Corner to 2800 to 2900 mm/year at Canterbury. The distribution of mean annual point potential evapotranspiration is shown in Figure 11. The contrast between Figure 10 and Figure 11 demonstrates the excess of potential evapotranspiration over precipitation across the region. Figure 12 (a) – which shows mean monthly rainfall and potential evapotranspiration – demonstrates that this applies to all months of the year.

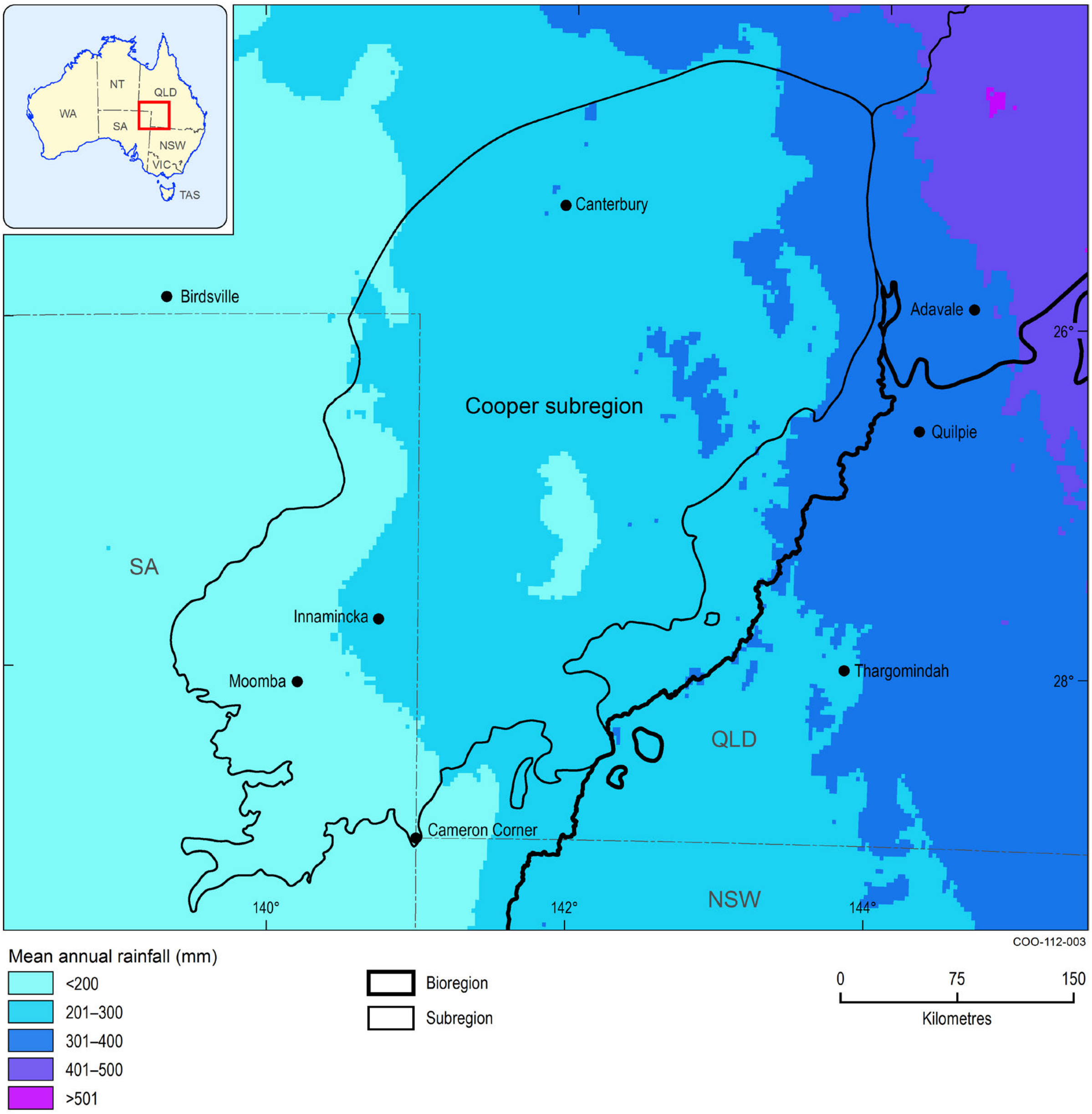

Figure 10 Cooper subregion mean annual rainfall

Data: Bureau of Meteorology (Dataset 2)

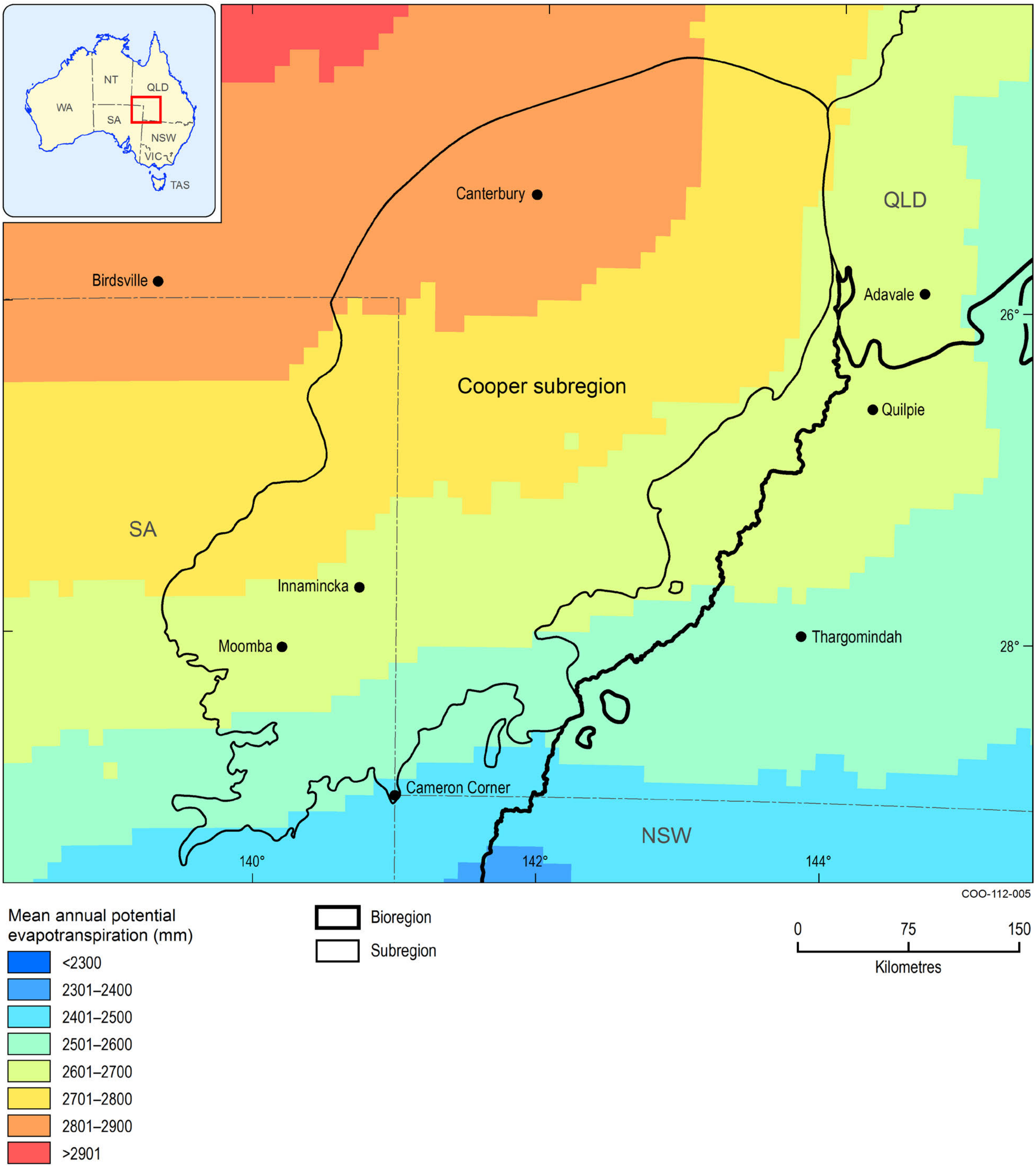

Figure 11 Cooper subregion mean annual potential evapotranspiration

Data: Bureau of Meteorology (Dataset 3)

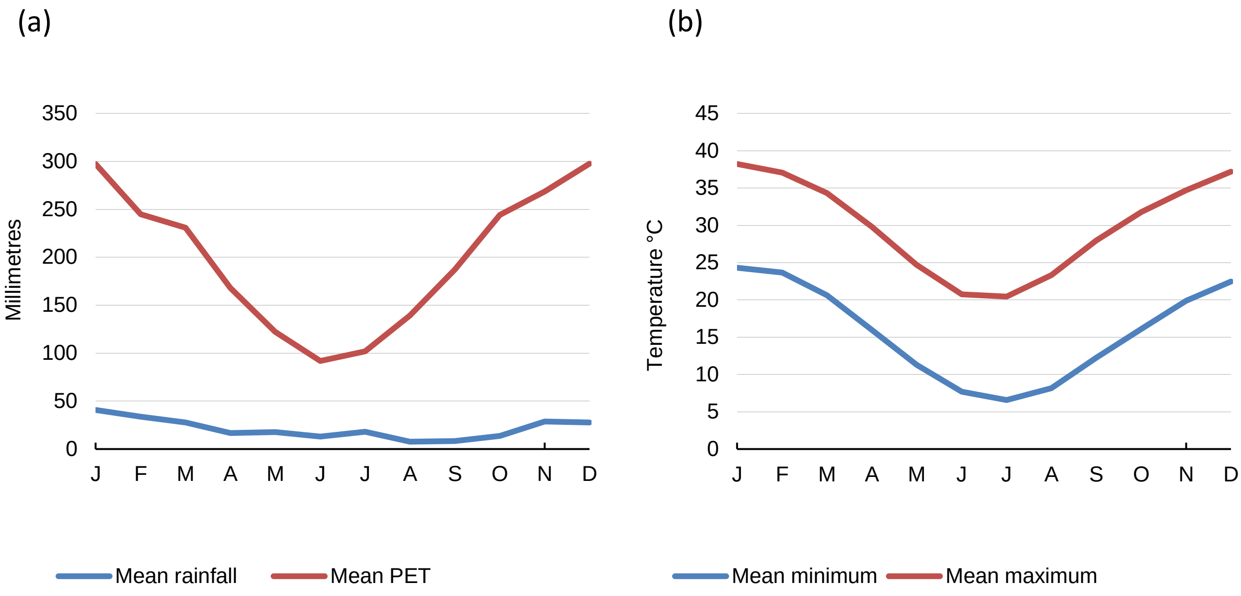

Figure 12 (a) Mean monthly rainfall and potential evapotranspiration and (b) mean monthly maximum and minimum temperatures averaged over the Cooper subregion

Data: Bioregional Assessment Programme (Dataset 8)

Figure 12 (b) shows that the region experiences hot summers with mean maximum temperatures over 35 °C and minima over 20 °C. Winter maxima are warm (greater than 20 °C) and minima cool (less than 10 °C) and the relatively large diurnal range throughout the year reflects the continental setting. Precipitation is generally low and shows a distinct summer maximum. Mean January precipitation for Canterbury in the east is 50 mm compared to 28.5 mm for Innamincka in the west. The lowest rainfall occurs in the late winter to early spring period (August to September) and is lower in the west than the east, with Canterbury averaging 8.5 mm and Innamincka 6.9 mm for August. Importantly, rainfall is highly variable from year to year across the whole subregion with Canterbury recording the lowest on record to highest on record figures for January of zero to 263.3 mm and for August of zero to 69.9 mm. The corresponding figures for Innamincka are zero to 536.0 mm and zero to 56.7 mm, respectively (Bureau of Meteorology, 2014a, 2014b).

CSIRO and Bureau of Meteorology (2012) is based on historical records and shows a 0.9 °C increase in mean annual temperature between 1910 and 2011. The records show little consistent change between 1910 and 1950 followed by a progressive increase since 1950, with each decade since 1950 being warmer than the previous decade. This clear warming trend is complicated by a background of natural variability due to factors such as the El Niño-Southern Oscillation (ENSO) and regional differences. Overnight minimum temperatures have warmed more than daytime maxima. The records show that the annual average daily mean temperature of the Cooper subregion warmed by 0.8 to 1.2 °C between 1960 and 2011. The Cooper subregion does not lie in a region with a strong rainfall trend but is likely to have had a slight decrease over recent decades. The CSIRO and Bureau of Meteorology (2012) survey concluded that both natural and human influences have affected climate over the past 100 years and that anthropogenic greenhouse gases have caused most of the surface warming, temperature extremes, ocean warming and sea-level rise, which is consistent with global patterns. The reduction in rainfall in the south-west of

Australia since the 1970s is also most likely to be due to increased anthropogenic greenhouse gases, though other less marked rainfall trends in other regions are more difficult to attribute.

CSIRO and Bureau of Meteorology (2007) provides projections of future changes in the Australian climate, under different emissions scenarios, and the application of those projections for impact studies and risk assessments. The study used 23 climate models used by climate research groups around the world with different Intergovernmental Panel on Climate Change (IPCC) greenhouse gas emission scenarios converted to radiative forcing of the climate system. Projections for annual and seasonal mean changes to temperature, rainfall, humidity, solar radiation, wind speed, potential evaporation and sea-surface temperature are provided in probabilistic form but only qualitative assessments were possible for other climate variables. Projections for 2030 showed varying patterns of regional change but minimal impact of different emission scenarios because such shorter-term future projections strongly reflect the impact of greenhouse gases already emitted. Projections for 2050 and 2070 show more variability according to emissions scenario. The median value (50th percentile) is used as the best estimate with the uncertainty range derived from the 10th and 90th percentile values.

According to CSIRO and Bureau of Meteorology (2007), the best estimate of Australia-wide warming is about 1.0 °C (uncertainty: 0.6 to 1.5 °C) by 2030; about 1.2 °C (uncertainty: 0.8 to 1.8 °C) under a low-emissions scenario by 2050; about 2.2 °C (uncertainty: 1.5 to 2.8 °C) under a high-emissions scenario by 2050; about 1.8 °C (uncertainty: 1.0 to 2.5 °C) under a low-emissions scenario by 2070; and about 3.4 °C (uncertainty: 2.2 to 5.0 °C) under a high-emissions scenario by 2070. Warming is higher inland than coastal and northern, which is higher than southern, and it is lower in winter than other seasons. In the Cooper subregion the projections of warming are generally higher than the continental average values. According to CSIRO and Bureau of Meteorology (2007) the 2030 projection is for a mean annual temperature increase in the range of 1.1 to 1.2 °C across the subregion. The 10th and 90th percentile figures are 0.6 to 0.8 °C and 1.4 to 1.8 °C, respectively. Under the 2050 low-emissions and high-emissions scenarios, projected increases are 1 to 1.5 °C and 2 to 2.5 °C, respectively; the corresponding values for 2070 are 1.5 to 2.0 °C and 3 to 4 °C. Under the low-emissions scenario there is a greater than 90% probability of the subregion exceeding a 1 °C warming by 2070 but less than 10% probability of exceeding 3 °C. Under the high-emissions scenario, there is a greater than 90% probability of exceeding 2 °C and a 20 to 40% probability of exceeding 4 °C.

CSIRO and Bureau of Meteorology (2007) provides the best current estimate of changes to Australia-wide precipitation. In the Cooper subregion the best estimate (50th percentile) of projected mean annual rainfall is for a slight decline in the range of 1 to 2.5% with a relatively large uncertainty range from a decrease of 10 to 15% (10th percentile) to an increase of 5 to 10% (90th percentile). However, the minimal annual change contains considerable seasonal variability with summer and autumn precipitation showing minimal increase or decrease, and winter and spring showing a stronger decrease from 2.5 to 10%. By 2050 the mean annual precipitation projection ranges from a decrease of 2 to 5% under the low-emissions scenario to 5 to 10% under the high-emissions scenario, with estimates of 2 to 10% and 5 to 20%, respectively, for 2070. By 2070 there is a 30 to 40% probability of a mean annual rainfall decline of at least 10% under the low-emissions scenario and a probability of 50 to 70% under the high-emissions scenario.

Solar radiation, relative humidity and potential evapotranspiration are projected to change little with a very slight increase for the former and a decrease for the latter two in 2030 with slightly greater changes for 2050 and 2070, especially under high-emission scenarios. Drought occurrence is projected to increase with increased effectiveness due to higher temperatures. There is a projected possibility of an increase in more-intense tropical cyclones but a decrease in the total number of cyclones. ENSO impact projections suggest that El Niño events will become drier and La Niña events will become wetter.

There was an update to the projections released in January 2015 (Watterson et al., 2015) after this assessment was prepared. The projected changes in the 2015 projections are broadly consistent with those included in this assessment.

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1.1.3 Geology

Summary

The Cooper subregion encompasses the surface footprint of the geological Cooper Basin. Most of the subregion is covered by undifferentiated Cenozoic sediments, with some Cretaceous rocks cropping out in the eastern and northern parts of the subregion. The geology of the subregion ranges in age from Cambrian to Holocene, although the main geological features are the Permian – Triassic Cooper Basin, the Mesozoic Eromanga Basin and the Cenozoic Lake Eyre Basin.

Sediment deposition in the Cooper Basin occurred from the Carboniferous to Early Triassic, and terminated due to widespread compressional deformation, regional uplift and erosion. It lies unconformably over early Paleozoic rocks of the Warburton Basin. Several major troughs are separated by structurally high ridges associated with the reactivation of north-west-directed thrust faults in the underlying Warburton Basin. These troughs contain up to 2500 m of sedimentary fill overlain by as much as 2850 m of Jurassic to Cenozoic cover. The Cooper Basin contains a number of stacked non-marine depositional sequences in the Late Carboniferous to Late Permian Gidgealpa Group and Late Permian to Early Triassic Nappamerri Group.

The Jurassic to Cretaceous Eromanga Basin unconformably overlies the Cooper Basin. Deposition within the Eromanga Basin was relatively continuous and widespread and was controlled by subsidence rates and plate tectonic events on the margins of the Australian Plate. Sedimentary rocks within the Eromanga Basin are divided into lower non-marine, middle marine and upper non-marine packages. The Early Cretaceous marine succession is dominated by thick transgressive shales, with thin sandstone units reflecting regressive cycles. In the Late Cretaceous upper non-marine succession, meandering fluvial systems crossed a floodbasin dominated by coal swamps and lakes.

The Cenozoic Lake Eyre Basin contains terrestrial sediments deposited following an extended period of erosion and deep weathering across the subregion. Significant periods of weathering, indicated by extensive silcrete and ferricrete formation, are recorded within the sediments of the Lake Eyre Basin.

Development of extensive aeolian dunes, fluvial systems, saline lakes, gibber plains and gypsum and carbonate paleosols occurred during the Pliocene–Quaternary. These surficial sediments reach a maximum thickness of 60 m in the Cooper subregion.

The Cooper subregion hosts Australia’s premier onshore hydrocarbon producing area. Oil and gas are produced from the rocks of the Cooper Basin, with some also produced from the Eromanga Basin. Unconventional hydrocarbon prospectivity in the Cooper Basin is high, with shale gas and deep coal seam gas currently under active exploration and appraisal. The coal within the Cooper and Eromanga basins is too deep for current mining methods (occurring at depths greater than 1 km), but is prospective for coal seam gas in parts.

1.1.3.1 Geological structural framework

The Cooper subregion is defined by the extent of the geological Cooper Basin and covers approximately 130,000 km^2 of south-western Queensland, north-eastern SA and a small area of NSW (Stewart et al., 2013, Figure 4). The basin is a north-east-trending, subsurface basin of non-marine clastic sedimentary rocks and coal, ranging from fluvial, lacustrine, and deltaic, with glacial sediments at base which formed during the Late Carboniferous through to the Triassic (305 to 230 Ma). It lies unconformably over early Paleozoic sedimentary rocks of the Warburton Basin to the south-west and the Devonian Warrabin Trough in the north-east (Radke, 2009). The Cooper Basin sedimentary rocks do not crop out, although the subsurface expression of the basin extends approximately 560 to 570 km north-east to south-west and is approximately 160 to 220 km wide.

The surface geology of the Cooper subregion is shown in Figure 13. Most of the subregion is covered by undifferentiated Quaternary and Cenozoic sediments, with outcrop of some Cretaceous rock, predominantly Winton Formation, in the central and eastern parts of the subregion.

The major structural features of the Cooper Basin are shown in Figure 14. The basin is divided into northern and southern areas, separated by the Jackson-Naccowlah-Pepita (JNP) ridge, which show different structural and sedimentary histories (Fergusson and Henderson, 2013; Heath, 1989). Three major troughs in the south-west, the Patchawarra, Nappamerri and Tenappera, are separated by the Gidgealpa-Merrimelia-Innamincka (GMI) and Murteree Ridges, which align with the main depositional axis of the basin (Fergusson and Henderson, 2013; Gravestock and Jensen-Schmidt, 1998). Other structural features in the Cooper Basin include the Windorah and Arrabury troughs, and Yamma Yamma, Ullenbury and Thompson depressions; the Roseneath, Mount Howitt, Harkaway and Windorah anticlines and Jackson-Naccowlah-Pepita (JNP) Trend ; and the Weena and Allunga troughs. This complex structural fabric appears to have been inherited from basement features (Radke, 2009), and was reactivated and superimposed on the Cooper sequence post-deposition during and after the Late Cretaceous. The Cooper Basin is bounded on the west by the Birdsville Track Ridge and Betoota Anticline, which separates the Cooper and Pedirka basins (Hibburt and Gravestock, 1995), and in the east by the Canaway Ridge, Ray Anticline and Pinkila Anticline which separate the Cooper and Galilee basins (Hoffmann, 1989). The Cooper Basin adjoins the Galilee Basin in the north-east. The Canaway Ridge marks the north-eastern limit of the Cooper Basin and represents a structural divide, separating deposition further east in the southern Galilee and Bowen basins (Radke, 2009).

Basement to the Cooper subregion consists of the Thomson Orogen, Warburton Basin, Warrabin Trough and the Delamerian Orogen (Korsch and Doublier, 2014). Basement is unconformably overlain by the Cooper Basin. The Eromanga Basin overlies the Cooper Basin, and Lake Eyre Basin sediments overlie the Eromanga Basin (Figure 15). The Cooper Basin sequence is up to 2500 m thick, whereas the Eromanga Basin is up to 2850 m thick, and the Lake Eyre Basin cover is up to 200 m thick.

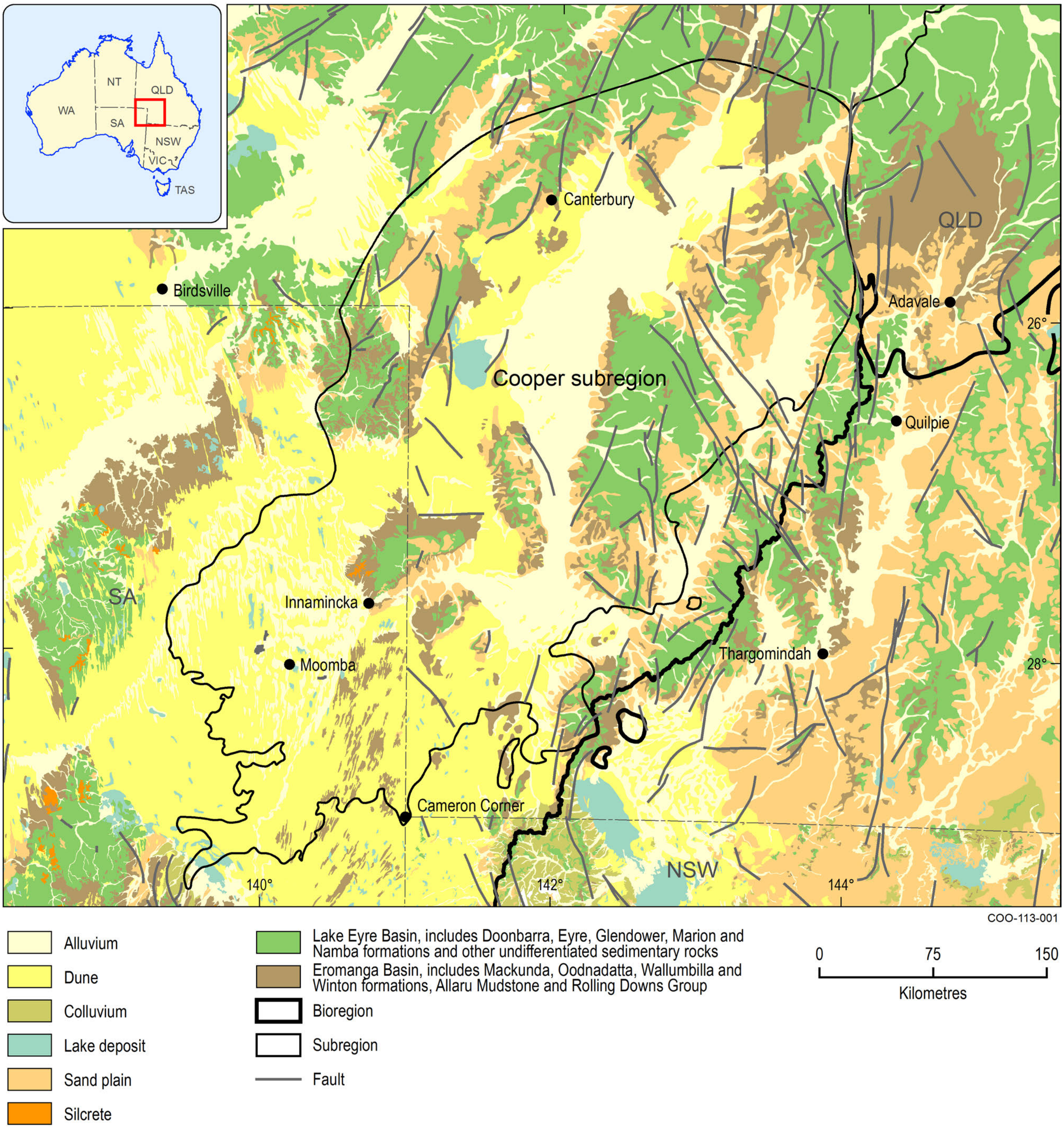

Figure 13 Surface geology of the Cooper subregion

Data: Geoscience Australia (Dataset 3, Dataset 4)
Cretaceous units shown are Winton Formation

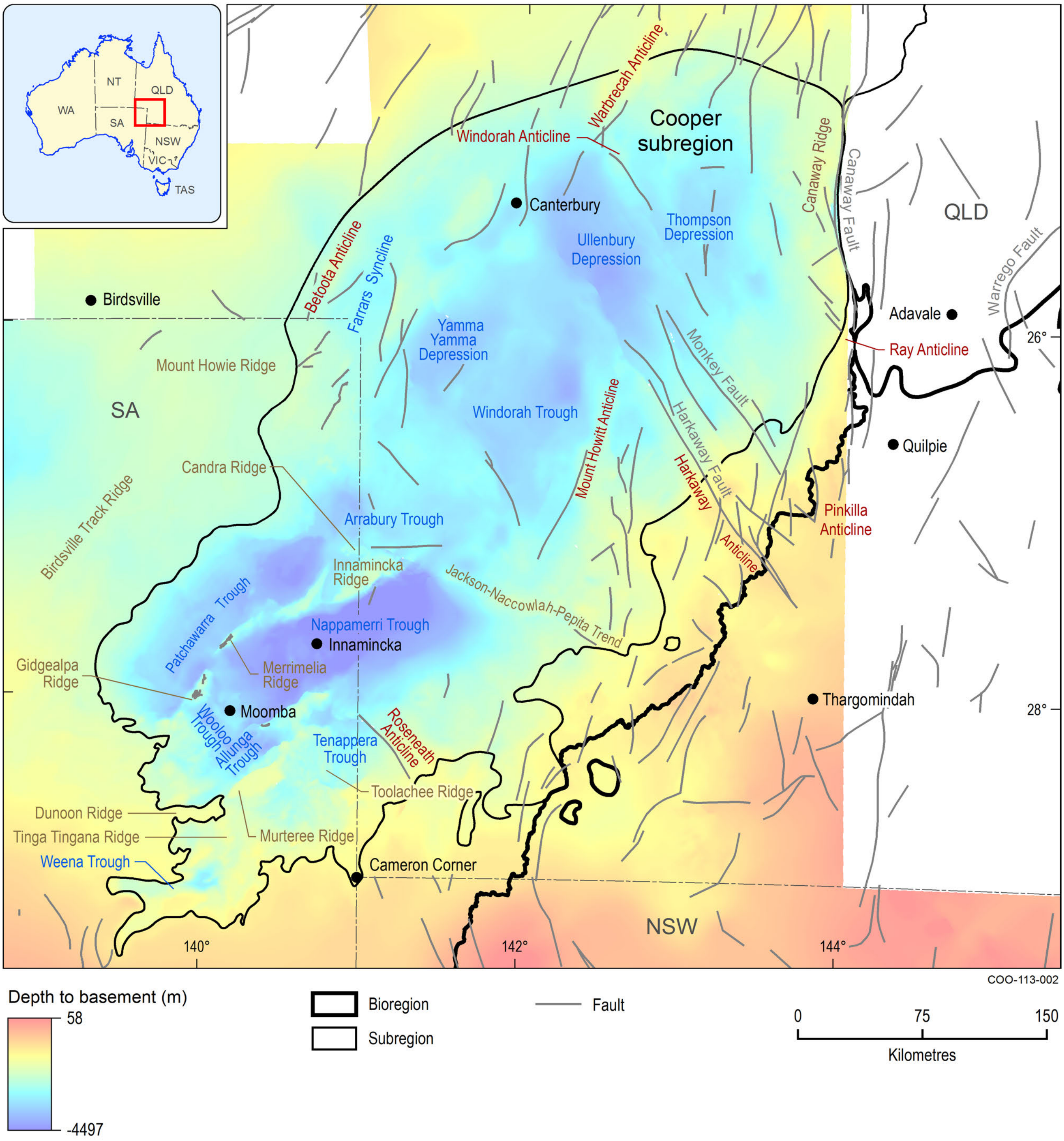

Figure 14 Cooper Basin structural elements shown over depth to basement image

Data: Draper (2002b); Geoscience Australia (Dataset 4); Gravestock and Jensen-Schmidt (1998); Ransley et al. (2012b); DMITRE (Dataset 7)

The Mesozoic Eromanga Basin overlies and extends well beyond the boundary of the Cooper subregion (see Figure 19). The Eromanga Basin is thickest where it overlies the Cooper Basin, an area known as the Central Eromanga Depocentre (Radke, 2009). The Central Eromanga Depocentre aligns north-east to south-west, overlying the Cooper Basin and Adavale basin system (including the Warrabin Trough and Barrolka Depression; Draper et al. (2004)), but with its axis offset to the north of these earlier-formed depocentres. Structural features of the Eromanga Basin in the Cooper subregion are shown in Figure 19. The structural elements of the Eromanga Basin reflect the structural trends of the underlying basins. In the Cooper subregion, structures generally trend north-north-east, with some north-west and north trending features.

1.1.3.2 Stratigraphy and rock type

The stratigraphy and rock types in the Cooper subregion are summarised below and in Figure 15. The stratigraphy includes crystalline basement rocks of the Thomson and Delamerian orogens, sedimentary rocks of Warburton Basin and Adavale Basin system, the thick sequences of the Cooper Basin, rocks of the Eromanga Basin and sediments of the geological Lake Eyre Basin.

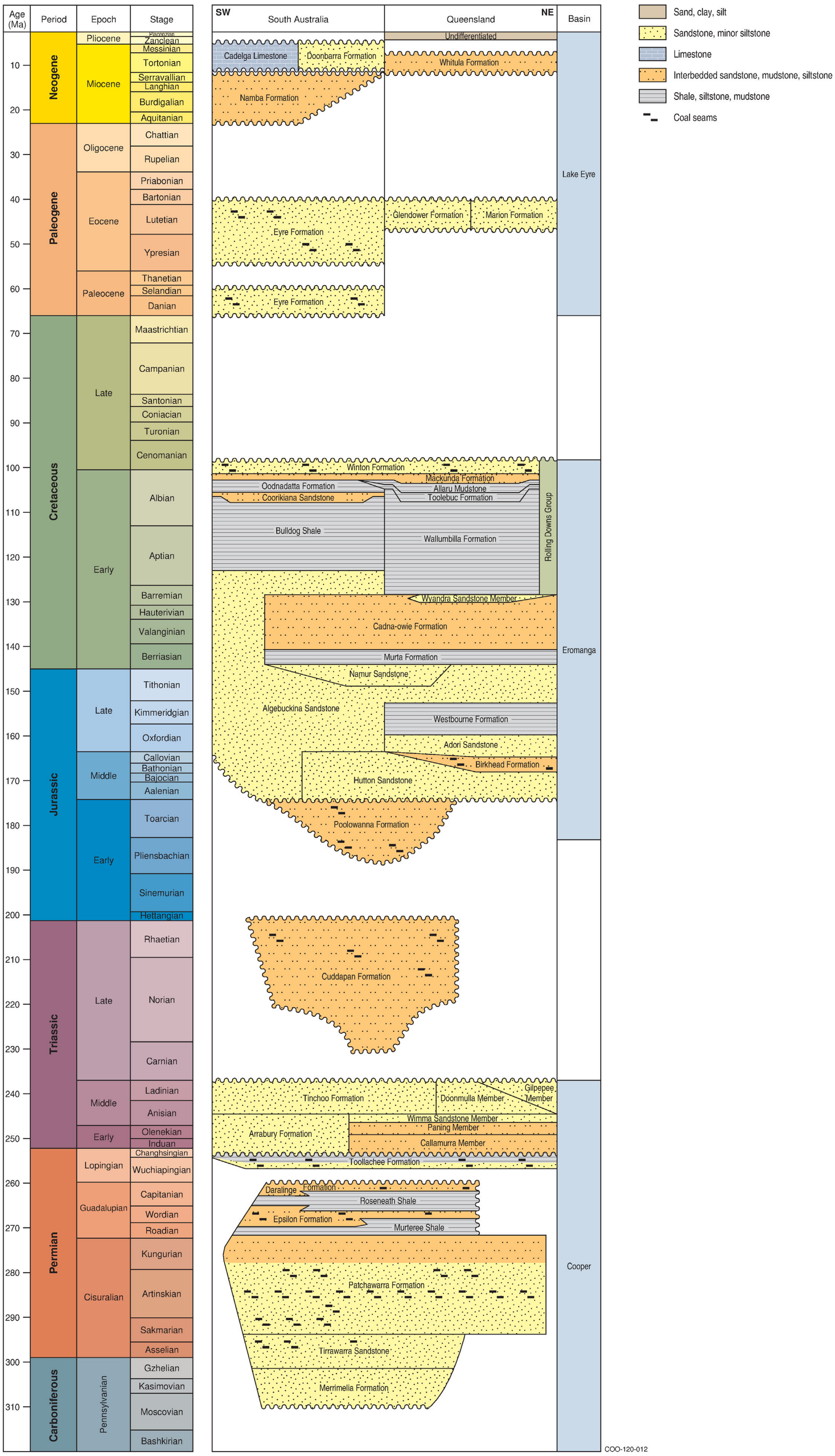

Figure 15 Stratigraphy of the Cooper subregion, showing geological ages, units, rock types and basin associations

Source: Alexander et al. (1998); Alexander et al. (2006); Alley (1998); Draper (2002a, 2002b); Golder Associates (2011); Gray and McKellar (2002); Gray et al. (2002); Moussavi-Harami (1996); Radke (2009); Ransley (2012a, 2012b); Santos (2003)

This figure has been optimised for printing on A3 paper (297 mm x 420 mm).

1.1.3.2.1 Pre-Permian Basement

The rocks of the Thomson Orogen consist of low-grade metamorphosed sedimentary rocks of Cambrian to Ordovician age. Sandstone and mudstone are the dominant metasedimentary rock types encountered in the Thomson Orogen underlying the Cooper Basin. Granites have been intersected by drilling in the Thomson Orogen with one sample from north of the Cooper Basin dated at 428 $\pm$ 5 Million years ago (Ma) (Fergusson and Henderson, 2013).

The Cooper Basin unconformably overlies the sedimentary and volcanic rocks of the Cambrian – Ordovician Warburton Basin. The Warburton Basin consists of a sequence of marine sedimentary rocks deposited in a range of environments from the continental shelf to the deeper ocean. These include carbonate rocks and shale, siltstone and chert (Fergusson and Henderson, 2013).

The Adavale Basin System as defined by Draper et al. (2004) refers to the Adavale Basin and remnants of Devonian sedimentary rocks in the region. Devonian rocks are intersected in the Warrabin and Barrolka troughs, beneath the north-east Cooper Basin and can be identified from seismic data (Draper et al., 2004; Fergusson and Henderson, 2013; Murray, 1994).

Numerous granite bodies intrude the Warburton Basin and underlie the Cooper Basin. Early Devonian granites occur beneath the southern part of the Cooper Basin in Queensland and SA. middle Carboniferous and early Permian granites are present beneath the Nappamerri Trough, and include the Big Lake Suite granodiorite (Gatehouse et al., 1995; Meixner et al., 2012).

1.1.3.2.2 Cooper Basin

The Cooper Basin is Australia’s largest producing onshore hydrocarbon basin. As such, the geology of the Cooper Basin has been studied in detail over a long period of time. The following summary is based on regional work carried out in SA (e.g. Alexander et al., 1998; Boucher, 2001; Gravestock and Jensen-Schmidt, 1998; Hill and Gravestock, 1995) and Queensland (e.g. Draper, 2002b; Fergusson and Henderson, 2013), as well as basin-wide studies (e.g. Meixner et al., 2012; Radke, 2009).

Gidgealpa Group

The Gidgealpa Group contains rocks which are entirely of non-marine origin. Initially formed in glacial environments, it is characterised by coal measures that are separated by lacustrine shales. The Gidgealpa Group is thickest in the south-western part of the Cooper Basin, where it reaches a maximum thickness of 1200 m (Geoscience Australia and Australian Stratigraphy Commission, 2012). On the Jackson-Naccowlah-Pepita (JNP) Trend, the Group is 200 to 400 m thick, whereas in areas immediately adjacent it is less than 100 m thick. In the northern and north-eastern Cooper Basin, intersected thickness is from 50 to 150 m (Gray and McKellar, 2002). The Gidgealpa Group incorporates rocks ranging in age from Late Carboniferous to the end of the early Permian. The group comprises rocks of the Merrimelia Formation, Tirrawarra Sandstone, Patchawarra Formation, Murteree Shale, Epsilon Formation, Roseneath Shale, the Daralingie Formation and the Toolachee Formation (Geoscience Australia and Australian Stratigraphy Commission, 2012).

The Merrimelia Formation includes sediments derived from the terminal stages of glaciation. This unit interfingers with the overlying Tirrawarra Sandstone, which includes conglomerate, sandstone, mudstone, siltstone and shale. The Tirrawarra Sandstone is a fine- to coarse-grained and pebbly sandstone, with minor carbon-rich silt beds, shale and coal (Alexander et al., 1998; Draper, 2002b; Radke, 2009).

The Patchawarra Formation is a widespread, upward-fining, interbedded sandstone, siltstone, mudstone and coal-bearing succession. At its thickest, three assemblages are distinguishable:

- a lower carbonaceous siltstone with minor sandstone and thin coal seams
- a middle assemblage dominated by sandstone, with grey-black shale interbeds and thick coal seams. The thickest seam, up to 30 m thick and most laterally extensive, corresponds to a distinct seismic horizon (known as the Vc horizon)
- an upper assemblage of siltstone and shale with minor sandstone interbeds.

The Patchawarra Formation overlies and interfingers with the Merrimelia Formation and Tirrawarra Sandstone, and is overlain by the Murteree Shale. Adjacent to the basin margin in SA, the Toolachee Formation and Eromanga Basin rocks overlie the Patchawarra Formation. The Patchawarra Formation is the thickest unit in the Gidgealpa Group, up to 680 m in the Nappamerri Trough (Draper, 2002b; Gray and McKellar, 2002; Radke, 2009).

The unit was deposited by fluvial systems on floodplains with peat swamps, lakes and coal swamps. It is thought that coal in the Patchawarra Formation was deposited in raised swamp environments (Alexander et al., 1998; Radke, 2009). Coal seams within the Patchawarra Formation can be up to 30 m thick, with an average of 2.1 m (Alexander et al., 1998). The cumulative thickness of coal in the Patchawarra Formation is spatially variable, and concentrated in various troughs, ranging from greater than 60 m in the Weena Trough, to 40 m in the Patchawarra Trough, less than 10 m in the Nappamerri Trough and between 10 and 15 m thick north of the JNP Trend (Draper, 2002b). The distribution and thickness of the Patchawarra Formation is shown in Figure 16. The Patchawarra Formation is a major coal-bearing formation in the subregion.

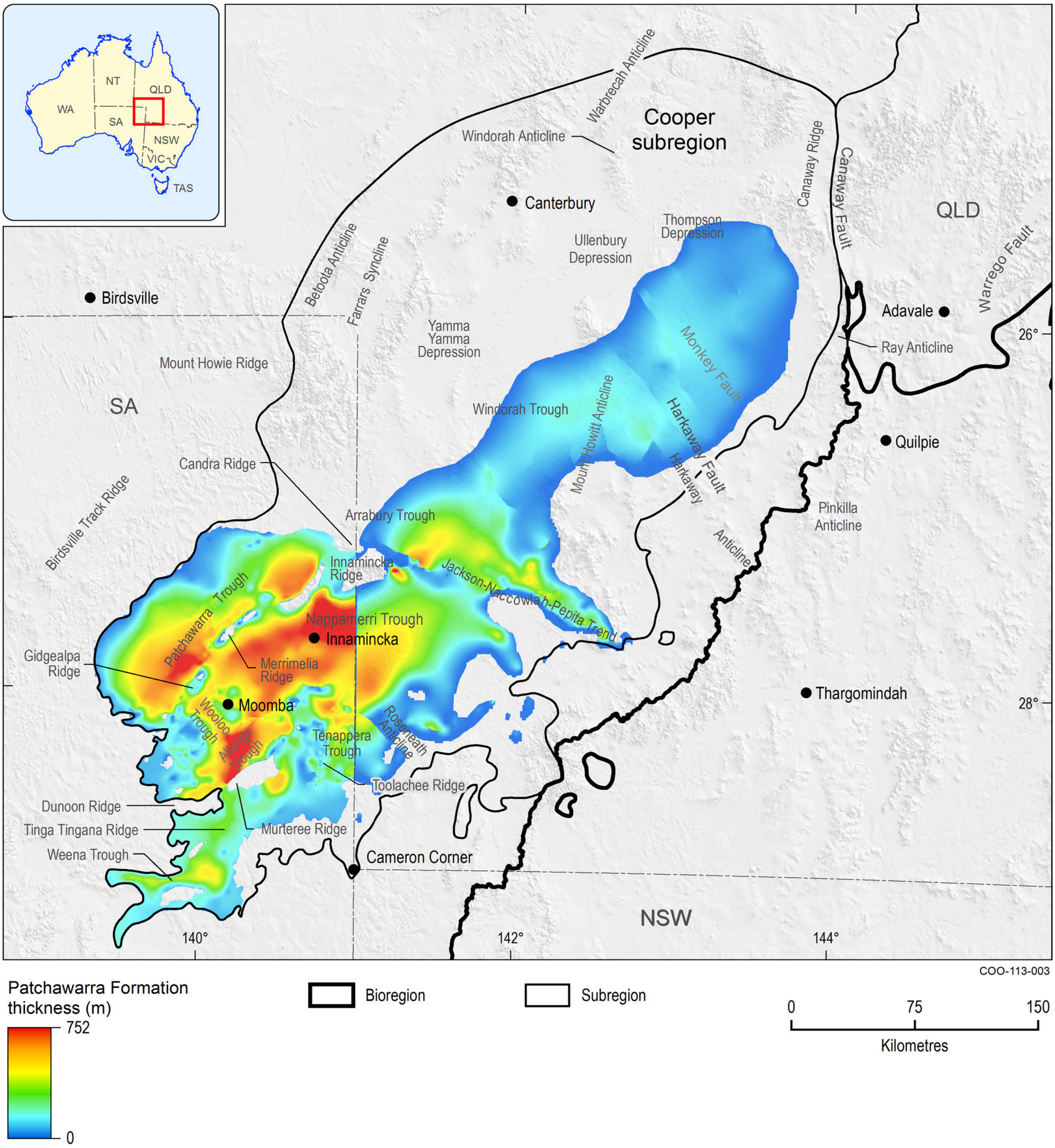

Figure 16 Distribution and thickness of the Patchawarra Formation in the Cooper subregion

Data: Draper (2002b); DMITRE (Dataset 10)
Discontinuities at state boundaries are a result of using different datasets compiled at different times by state agencies.

The Murteree Shale is a clay-rich siltstone with minor fine-grained sandstone, and some carbonaceous, muscovite and pyrite-rich sections. The unit becomes sandier towards the south of the Cooper Basin. The Murteree Shale averages 50 m thick, and is up to 80 m thick in the Nappamerri, Wooloo, Allunga and Tenappera troughs. The depositional environment is interpreted as deep lakes with minimal disturbance (Alexander et al., 1998). The Murteree Shale conformably overlies and interfingers with the Patchawarra Formation, and is in turn conformably overlain by the Epsilon Formation, although in places it is unconformably overlain by the Toolachee Formation (Alexander et al., 1998; Draper, 2002b).

The Epsilon Formation is a series of thinly bedded fine- to medium-grained sandstone interbedded with carbonaceous siltstone and shale and coal seams overlying the Murteree Shale and underlying the Roseneath Shale. The Epsilon Formation unconformably underlies the Toolachee Formation where the intervening units are absent. The Epsilon Formation is widespread across the southern Cooper Basin, but restricted to the Arrabury Trough across the JNP Trend. The maximum thickness of the Epsilon Formation is 156 m in the Nappamerri Trough, with the average thickness being 30 to 40 m. Three depositional stages are recognised in the Epsilon Formation, all representing fluvial, delta and lake environments. The lowermost stage is a coarsening upward sandy interval capped with coal and shale. This is followed by a coal-dominated stage, which is overlain by upward-coarsening sandstone. These represent deltaic and shoreline deposits, distributary channel, backswamp and peat swamp environments and lacustrine environments respectively (Alexander et al., 1998; Draper, 2002b).

The Roseneath Shale is restricted to the southern part of the Cooper Basin, and is found across the Nappamerri, Wooloo, Allunga and Tenappera troughs. The Roseneath Shale conformably overlies and interfingers with the Epsilon Formation, and is conformably overlain by and interfingers with the Daralingie Formation. The Roseneath Shale is a siltstone and mudstone, with minor fine-grained sandstone interbeds. This unit was deposited in a lacustrine setting. The unit is generally 50 to 80 m thick, and has a maximum thickness of 110 m in the Nappamerri and Tenappera troughs (Alexander et al., 1998; Draper, 2002b; Hill and Gravestock, 1995).

The Daralingie Formation consists of sandstone, shale and coal conformably overlying the Roseneath Shale. It is disconformably overlain by the Toolachee Formation. The Daralingie Formation is dominated by carbonaceous and micaceous siltstone and mudstone with interbedded, fine- to very fine-grained sandstone. These rocks form upward-coarsening cycles. The unit is restricted to the southern part of the Cooper Basin, averaging 15 to 30 m thick, with a maximum thickness of 120 m in the Nappamerri and Allunga troughs. The Daralingie Formation was deposited in prograding deltas and beaches developed as the lake in which the Roseneath Shale was deposited receded (Alexander et al., 1998; Draper, 2002b).

The uppermost and most extensive unit of the Gidgealpa Group is the Toolachee Formation. The Toolachee Formation comprises interbedded sandstone, siltstone, mudstone and shale with thin coal seams and conglomerates. Rocks are upward-fining in the lower part, and upward-coarsening in the upper part. Coal occurs as laterally continuous, thin seams (averaging 4.3 m, and up to 22 m thick, but generally less than 2 m thick; Alexander et al. (1998)). Basal conglomerate occurs adjacent to structural ridges. The lower part of the Toolachee Formation was deposited by meandering streams and in back swamps on floodplains. The upper part was deposited in flood basin lakes and during overbank flooding. Coarse-grained, upward-fining packages may represent higher energy alluvial channels (Alexander et al., 1998; Gray and McKellar, 2002). The Toolachee Formation disconformably overlies the Daralingie Formation, and unconformably overlies older units where the Daralingie Formation is absent. The Arrabury Formation conformably overlies the Toolachee Formation, or where the Arrabury is absent, Eromanga Basin rocks unconformably overlie the Toolachee Formation (Alexander et al., 1998).

In SA, the Toolachee Formation is thickest in the Nappamerri and Patchawarra troughs, with a maximum thickness of at least 200 m (Gray and McKellar, 2002; Meixner et al., 2012). In

Queensland it reaches up to 120 m in the Windorah Trough (based on well intersections; Real Energy Corporation Limited (2014)). The Toolachee Formation is generally 25 to 50 m thick, and thickens from north to south and south-west, approaching 130 m thick immediately north of the JNP Trend, and 150 m thick to the south (Alexander et al., 1998; Gray and McKellar, 2002). Coal in the Toolachee Formation is thickest in the Patchawarra and Arrabury troughs, where it reaches a cumulative thickness of up to 40 m. It also occurs in the Nappamerri and Tenappera troughs. Coal reaches cumulative thicknesses of up to 13 m in the Ullenbury Depression, and is also in the Windorah Trough and the Yamma Yamma Depression. It is thought that coals were deposited in raised swamps, with restricted overbank flooding (Gray and McKellar, 2002). The thickness and distribution of the Toolachee Formation in the Cooper subregion is shown in Figure 17.

Nappamerri Group

The late Permian to Middle Triassic Nappamerri Group occurs across the entire Cooper Basin and thickens substantially in the Nappamerri, Patchawarra, Arrabury and Windorah troughs (where it may be up to 550 m thick). The Nappamerri Group thins over structural ridges except the Dunoon and Murteree ridges, and has been eroded around the margins of the Cooper Basin in SA. In Queensland, the Nappamerri Group has a much broader extent than the underlying Gidgealpa Group (Radke, 2009). The Nappamerri Group consists of the Arrabury and Tinchoo formations (Geoscience Australia and Australian Stratigraphy Commission, 2012). The distribution and thickness of the Nappamerri Group is shown in Figure 18.

The basal unit of the Nappamerri Group is the Arrabury Formation. This unit is characterised by thin fine- to medium-grained sandstone interbeds overlain by sandstone with minor siltstone interbeds. The Arrabury Formation is widely distributed throughout the Cooper Basin. The Arrabury Formation unconformably overlies the Toolachee Formation and rocks of the Warburton Basin. It is unconformably overlain by Eromanga Basin rocks in the southern part of the Cooper Basin and conformably overlain by the Tinchoo Formation north of the JNP Trend. Where it overlies the Toolachee Formation, the base of the Arrabury Formation is distinguished by the lack of organic material in comparison to the underlying siltstone and coal.

Three members have been described from within the Arrabury Formation, the Callamurra, Paning and Wimma Sandstone members. The Callamurra and Paning members are mudstone and siltstone with interbedded fine- to medium-grained sandstone, whereas the Wimma Sandstone Member consists of sandstone with minor siltstone interbeds. These units may be indistinguishable in places, although a depositional hiatus of up to 10 million years has been postulated between the Callamurra and Paning members (Alexander et al., 1998). The Arrabury Formation has a maximum thickness of 412 m in the Arrabury Trough, and is also thickest in the Nappamerri and Windorah troughs. The remainder of the Arrabury Formation is between 50 and 100 m thick (Gray and McKellar, 2002).

Deposition of the Arrabury Formation is interpreted as being in vegetated floodplains with ephemeral lakes in lowlands, with pedogenesis in exposed areas. The floodplain was cut by low sinuosity rivers confined to north-east-oriented channel belts in the Patchawarra and Nappamerri troughs (Alexander et al., 1998).

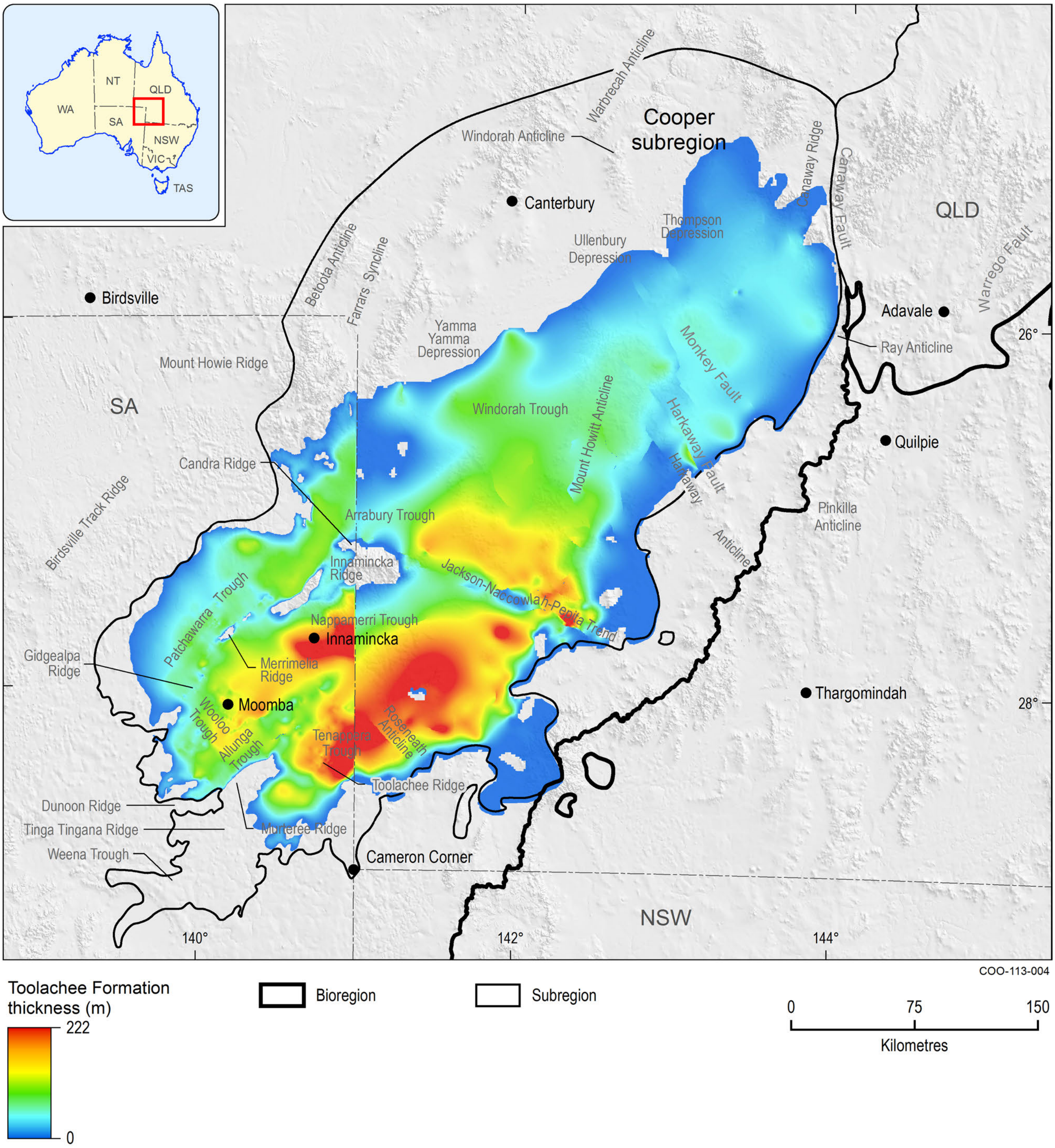

Figure 17 Distribution and thickness of the Toolachee Formation in the Cooper subregion

Data: Draper (2002b); DMITRE (Dataset 7, Dataset 10)

Discontinuities at state boundaries are a result of using different datasets compiled at different times by state agencies.

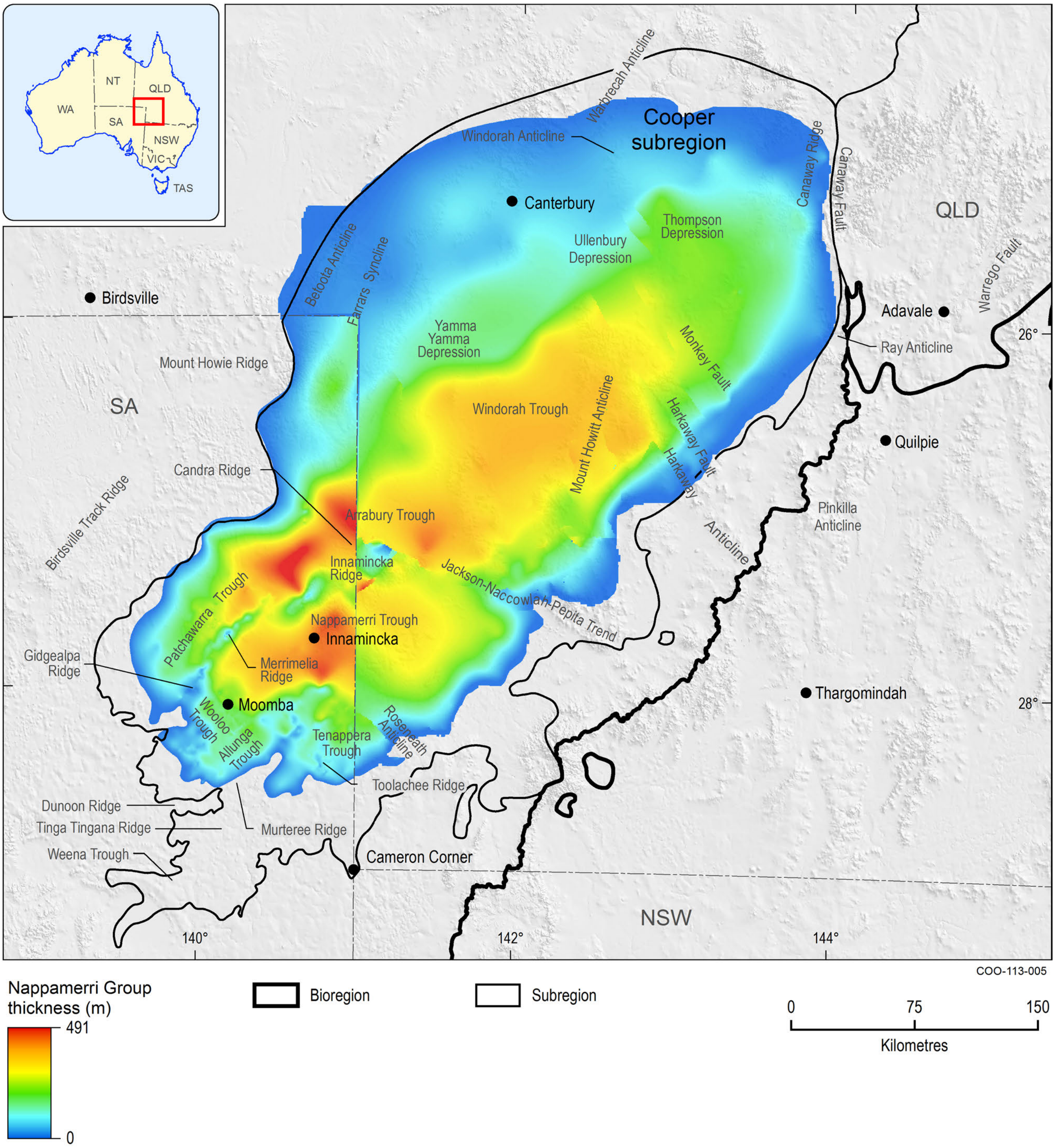

Figure 18 Combined distribution and thickness of the Nappamerri Group in the Cooper subregion

Data: Draper (2002b); DMITRE (Dataset 10)
Discontinuities at state boundaries are a result of using different datasets compiled at different times by state agencies.

The youngest unit in the Cooper Basin (and the top of the Nappamerri Group) is the Tinchoo Formation. The Tinchoo Formation is a fining-upwards fine- to medium-grained sandstone with thin siltstone interbeds which conformably overlies the Arrabury Formation. In Queensland, it is subdivided into the Gilpepee and Doonmulla members, but these members are not readily identifiable to the south-west in SA where the formation has been eroded and is relatively thin (Alexander et al., 1998; Gray and McKellar, 2002). The Tinchoo Formation unconformably overlies the Warburton Basin to the north-west of the Cooper Basin towards the Birdsville Track Ridge. The

Tinchoo Formation is unconformably overlain by the Cuddapan Formation or units of the Eromanga Basin. A maximum thickness of 109 m is preserved in SA where the formation has been eroded from crests of major ridges and towards the edge of the Cooper Basin. In Queensland the formation is mainly 125 to 200 m thick and thickest (to 263 m) adjacent to the Windorah Trough (Alexander et al., 1998; Golder Associates, 2011; Gray and McKellar, 2002).

The Tinchoo Formation is interpreted to have been deposited in a fluvial environment, which graded into a fluvial and lacustrine setting towards the end of deposition (Alexander et al., 1998; Gray and McKellar, 2002).

Cuddapan Formation

The Cuddapan Formation is not assigned to either the Cooper Basin or Eromanga Basin, and may be an outlier of the Simpson Basin to the west (Alexander et al., 1998). The Cuddapan Formation is lithologically similar to the overlying Poolowanna Formation in the Eromanga Basin and their distinction relies on dating. The Cuddapan Formation comprises a basal sandstone package with increasing siltstone and coal interbeds upwards. The Cuddapan Formation disconformably overlies the Tinchoo Formation, and is disconformably overlain by the Poolowanna Formation. This unit reaches a maximum of 67 m (Alexander et al., 1998) and occurs only as eroded remnants in SA, it is not present in Queensland. A fluvial system with some flood basin coal swamps is interpreted as the environment of deposition where the Cuddapan Formation overlies the Cooper Basin (Alexander et al., 1998).

1.1.3.2.3 Eromanga Basin

The Mesozoic Eromanga Basin overlies and extends well beyond the boundary of the Cooper subregion. The Eromanga Basin is thickest where it overlies the Cooper Basin, in the Central Eromanga Depocentre. Structural features of the Eromanga Basin in the Cooper subregion are shown in Figure 19. More detail on the rocks of the Eromanga Basin is provided in Alexander et al. (2006); Cook et al. (2013); Gray et al. (2002); Radke (2009); and Ransley et al. (2012a), which are summarised here.

Early Jurassic to Late Cretaceous deposition within the Eromanga Basin was relatively continuous and widespread. Deposition was controlled by subsidence rates and plate tectonic events on the margins of the Australian Plate to the east. Volcanic activity on the evolving continental boundary to the east influenced sediment provenance and depositional environment. On the southern margin, separation of Australia and Antarctica during the Late Cretaceous also influenced deposition within the Eromanga Basin (Alexander et al., 2006). The stratigraphy of the Eromanga Basin within the Cooper subregion is shown in Figure 15.

The Eromanga Basin rocks were deposited in terrestrial and marine sedimentary environments. There is a basal succession of terrestrial sedimentary rocks, followed by a middle marine succession, and an upper terrestrial succession. In the Early Jurassic to Early Cretaceous lower non-marine succession, large sand-dominated, braided fluvial systems drained into lowland lakes and swamps. The Early Cretaceous marine succession is dominated by thick transgressive shales, with thin sandstone units reflecting regressive cycles. In the Late Cretaceous (upper) non-marine succession, meandering fluvial systems were dominated by coal swamps and lakes (Alexander et al., 2006). The stratigraphy of the Eromanga Basin is summarised in Table 5.

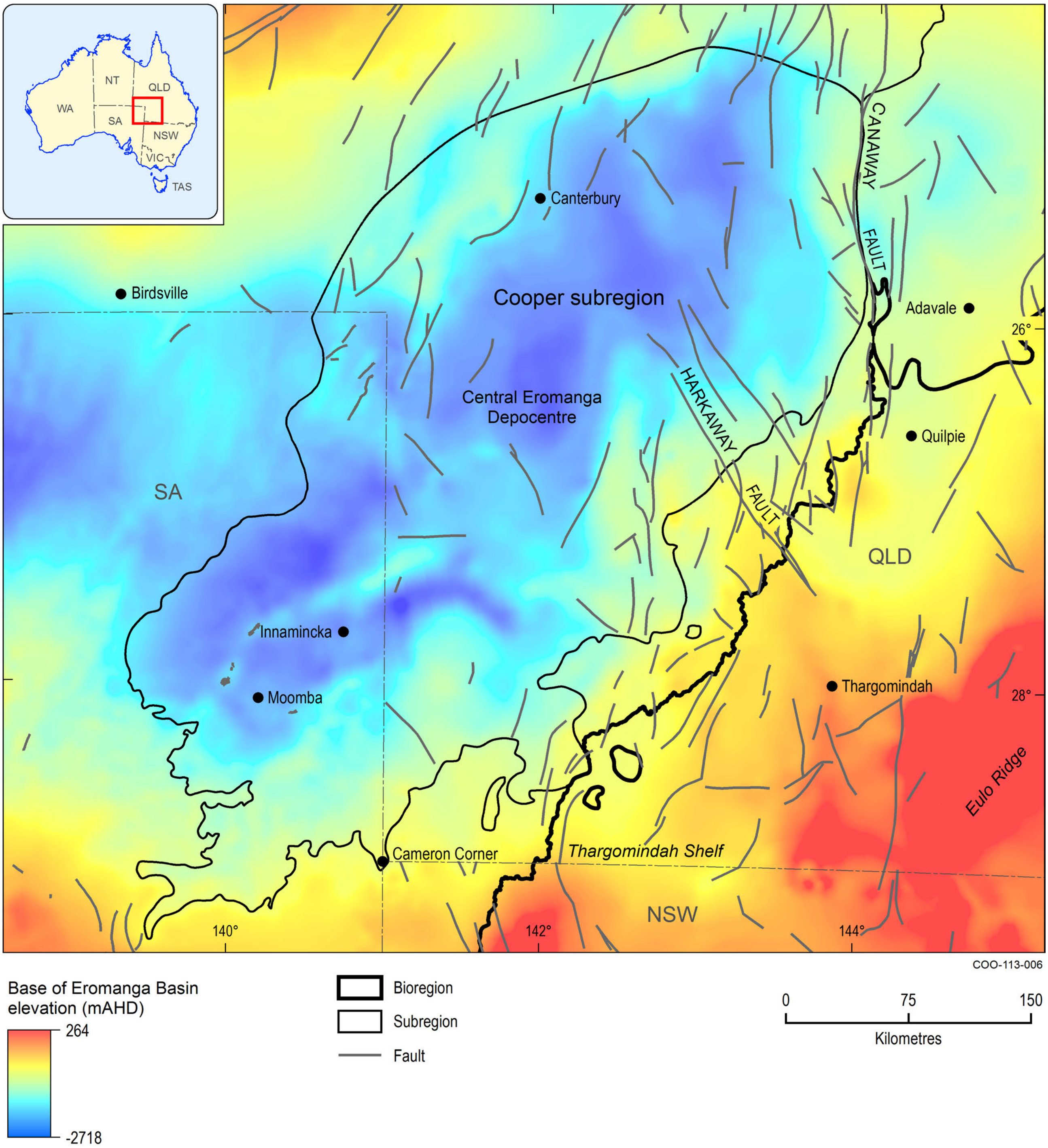

Figure 19 Structural features of the Eromanga Basin in the Cooper subregion

Data: Ransley et al. (2015)

Table 5 Stratigraphy of the Eromanga Basin in the Cooper subregion

Unit name	Age	Lithological description	Thickness	Depositional environments	Stratigraphic relationships
Poolowanna Formation	Early Jurassic	Interbedded carbonaceous siltstone, fine- to medium-grained pebbly sandstone and rare coal with carbonate and clay mineral cements. In Queensland, the lower part is coarser-grained sandstone	up to 205 m	Alternating fluvial floodplain with minor coal swamps and lacustrine	Unconformable on Cooper and Warburton basins and Cuddapan Formation. Interfingers with Algebuckina Sandstone in the south and west and Hutton Sandstone in the north and east
Algebuckina Sandstone	Middle Jurassic to Early Cretaceous	Fine- to coarse-grained sandstone with coarser layers and shale intraclasts. Minor shale and siltstone lenses	up to 800 m	Braided fluvial	Lateral equivalent to Hutton Sandstone, Birkhead Formation, Adori Sandstone, Westbourne Formation, Namur Sandstone and Murta Formation
Hutton Sandstone	Middle Jurassic	Fine- to coarse-grained quartzose sandstone with minor siltstone interbeds. Upper part is generally sandier than the lower part	40 to 360 m	Braided fluvial	Unconformable on Cooper and Warburton basins and Warrabin Trough. Interfingers with Birkhead Formation. Laterally equivalent to Algebuckina Sandstone
Birkhead Formation	Middle Jurassic	Interbedded siltstone, mudstone and fin-to medium-grained sandstone with thin coal seams	40 to 100 m, maximum 150 m	Lacustrine and coal swamp with some meandering channels and deltas	Conformable on and interfingers with Hutton Sandstone, unconformably overlain by Namur and Adori sandstones
Adori Sandstone	Late Jurassic	Upward-fining, very fine- to coarse-grained sandstone with minor siltstone and conglomerate	20 to 130 m	Braided fluvial	Conformable on Birkhead formation and unconformably underlies Westbourne Formation in SA. Unconformable on Birkhead and Conformably underlies Westbourne in Queensland

Unit name	Age	Lithological description	Thickness	Depositional environments	Stratigraphic relationships
Westbourne Formation	Late Jurassic	Shale and siltstone interbedded with minor fine- to very fine-, and some medium- to coarse-grained sandstone	30 to 140 m, maximum 166 m	Transition from fluvial to lacustrine and lake-shore	Conformably overlies Adori Sandstone. Conformably underlies and interfingers with Hooray, Namur and Algebuckina sandstones
Namur Sandstone	Late Jurassic	Fine- to coarse-grained sandstone with minor siltstone and mudstone interbeds and rare conglomerate interbeds with carbonaceous mudclasts	40 to 240 m thick	Fluvial	Conformably overlies Birkhead Formation or interfingers with Westbourne Formation
Murta Formation (includes McKinlay Member)	Late Jurassic	Thin interbeds of shale, very fine- to fine-grained sandstone with minor medium- and coarse-grained sandstone. Base marked by siltstone	30 to 60m, max 90 m	Lacustrine, possible marine transgression at the top	Lateral equivalent to upper part of the Hooray Sandstone. Interfingers with and conformably overlies the Namur Sandstone, gradation with Cadna-owie Formation
Cadna-owie Formation	Early Cretaceous	Silty mudstone, siltstone and very fine- to fine-grained sandstone. Sand increases upwards. Rare coal and carbonaceous fragments, and shale clasts	60 to 115 m	Fluvial, lagoonal, shoreface, beach, offshore marine and lacustrine. Transition between terrestrial and marine environments	Gradational, conformably overlies Murta Formation, or conformably overlies the Algebuckina Sandstone. Unconformably underlies the Bulldog Shale or Wallumbilla Formation
Rolling Downs Group: Bulldog Shale	Early Cretaceous	Fossiliferous mudstone, with minor siltstone and very fine-grained sandstone interbeds. Basal portion is carbonaceous	generally 200 m, maximum greater than 340 m	High latitude marine shelf	Conformably overlies the Cadna-owie Formation, lateral equivalent of the Wallumbilla Formation. Conformably underlies the Coorikiana Sandstone

Unit name	Age	Lithological description	Thickness	Depositional environments	Stratigraphic relationships
Rolling Downs Group: Wallumbilla Formation	Early Cretaceous	Fossiliferous, interbedded mudstone, siltstone, sandy mudstone, sandstone and minor limestone. Coarsening up to sandstone-dominated top	200 to 375 m, maximum 596 m	High latitude marine shelf	Conformably overlies the Cadna-owie Formation, lateral equivalent of Bulldog Shale. Conformably underlies the Toolebuc Formation
Rolling Downs Group: Coorikiana Sandstone	Early Cretaceous	Fine-grained, silty sandstone with minor conglomerate. Siltstone and mudstone interbeds at the base	20 m	Near-shore	Conformably overlies the Bulldog Shale, conformably underlies Oodnadatta Formation
Rolling Downs Group: Oodnadatta Formation	Early Cretaceous	Laminate claystone and siltstone with fine-grained sandstone interbeds. Lower part contains calcareous siltstone and fossil-rich limestone	up to 300 m	Low-energy, shallow marine	Conformably overlies the Coorikiana Sandstone. Interfingers with and conformably underlies the Mackunda Formation. Transitions laterally into the Wallumbilla and Toolebuc formations and Allaru Mudstone
Rolling Downs Group: Toolebuc Formation	Early Cretaceous	Oil shale, kerigenous shale, coquinitic limestone, nodular limestone with minor sandstone	20 to 45 m	Restricted marine at maximum high stand	Conformably overlies the Wallumbilla Formation and conformably underlies the Allaru Mudstone
Rolling Downs Group: Allaru Mudstone	Early Cretaceous	Mudstone, siltstone, calcareous mudstone with minor limestone and very fine-grained sandstone interbeds towards the top	100 to 240 m, maximum greater than 600 m	Quiet shallow marine	Conformably overlies the Toolebuc Formation and conformably underlies the Mackunda Formation
Rolling Downs Group: Mackunda Formation	Early Cretaceous	Interbedded, calcareous, very fine-grained sandstone, siltstone and shale	60 to 120 m	Alternating deep-marine and shoreface	Conformably overlies the Allaru Mudstone, conformably overlies and interfingers with the Oodnadatta Formation. Conformably underlies the Winton Formation

Unit name	Age	Lithological description	Thickness	Depositional environments	Stratigraphic relationships
Rolling Downs Group: Winton Formation	Early to Late Cretaceous	Interbedded fine- to coarse-grained sandstone, carbonaceous shale, siltstone and coal seams with intraclast conglomerates	more than 400 m thick, maximum 1100 m	Fluvial and lacustrine in a coastal plain setting	Conformably overlies the Mackunda Formation. Unconformably overlain by Lake Eyre Basin rocks. Crops out in parts of the subregion

Source: Alexander et al. (2006); Cook et al. (2013); Geoscience Australia and Australian Stratigraphy Commission (2012); Golder Associates (2011); Gray et al. (2002); Radke et al. (2012); Santos (2003)

1.1.3.2.4 Lake Eyre Basin

The geological Lake Eyre Basin is a thick sedimentary succession overlying the Eromanga Basin, covering parts of northern and eastern SA, south-eastern NT, western Queensland and north-western NSW. The basin is up to 400 m thick and contains sediments deposited from the Paleocene (66 Ma) through to the Quaternary (Stewart et al., 2013). The Lake Eyre Basin is further subdivided into three sub-basins, with the Callabonna sub-basin encompassing part of the Cooper subregion (Callen et al., 1995). Three phases of deposition are recognised within the basin, the first from the late Paleocene to the middle Eocene, represented by the Eyre, Glendower and Marion formations; the second from the end of the Oligocene to the Miocene, represented by the Namba, Whitula and Doonbara formations and the Cadalga Limestone; the third phase occurred during the latest Pliocene to the Quaternary (Alley, 1998; Callen et al., 1995).

Eyre, Glendower and Marion formations

The basal unit in the Cenozoic Lake Eyre Basin in SA is the Eyre Formation. This unit consists of carbonaceous sand, silt and gravel, with some lignite and clay beds. The base of the Eyre Formation is marked by polished gravel. Silcrete and other weathering products are common within the Eyre Formation. The Eyre Formation is a lateral equivalent of the Glendower and Marion formations in Queensland. The Eyre Formation unconformably overlies weathered Winton Formation across the subregion, and unconformably underlies the Namba Formation in SA. The Eyre Formation is up to 140 m thick, but is generally 10 to 20 m thick. The Eyre Formation is interpreted as representing deposition in a braided stream fluvial setting (Alexander et al., 2006; Alley, 1998).

The Glendower Formation is a lateral equivalent of the Eyre Formation, which occurs over much of the central Eromanga Basin in Queensland. The unit comprises sandstone, conglomerate and minor siltstone. The base is marked by reworked Winton Formation clasts. The Glendower Formation also contains extensive silcrete and other weathering products. It unconformably overlies the Winton Formation, and is overlain by the Whitula Formation and undifferentiated Quaternary sediments. The Glendower Formation, with a recorded thickness of about 70 m, was deposited in braided stream fluvial settings (Draper, 2002a).

The Marion Formation consists of sandstone and conglomerate, and has been extensively silicified such that it is capped by silcrete. It unconformably overlies the Winton Formation, and is overlain by Austral Downs Limestone and undifferentiated Quaternary sediments. The Marion Formation is up to 8 m thick in the Cooper subregion, and is correlated with the Glendower and Eyre formations. It is recorded as scattered occurrences in the northern and north-western part of the subregion in Queensland (Draper, 2002a).

Namba and Whitula formations

The Namba Formation comprises alternating fine- to medium-grained sand, silt and clay with thin dolomite interbeds (Callen et al., 1995). The Namba Formation reaches a maximum thickness of 210 m in the Cooper subregion (Alexander et al., 2006). It unconformably overlies the Eyre Formation, and is overlain by undifferentiated Quaternary sediments. The Namba Formation is restricted to the Callabonna sub-basin in SA (Callen et al., 1995).

The Whitula Formation is confined to the Windorah Trough, Yamma Yamma Depression, Farrars Syncline and Thomson Depression in the Queensland portion of the Cooper subregion (see Figure 14 for locations). It is an interbedded sandstone, siltstone, mudstone and claystone with minor conglomerate, lignite and gypsum. The unit contains some silica or iron oxide indurated portions. It unconformably overlies the Glendower Formation or weathered Winton Formation and is conformably overlain by undifferentiated Quaternary alluvium. The maximum recorded thickness is 160 m. The Whitula Formation was deposited in a fluvial and lacustrine environment (Draper, 2002a).

Doonbara Formation and Cadelga Limestone

The Doonbara Formation is an iron-rich fine- to medium-grained sand overlying the Eyre Formation. It is generally 7 to 10 m thick, with a maximum thickness of 40 m recorded in places. The Doonbara Formation may represent a lateral fluvial equivalent to the top of the Namba Formation in the north and east of the SA part of the Lake Eyre Basin in the Cooper subregion, and correlate with the Whitula Formation. The Cadelga Limestone is a cherty dolomitic limestone which interfingers with the Doonbara Formation. This unit is up to 5 m thick, and formed in a lacustrine depositional setting (Alley, 1998).

1.1.3.3 Basin history

The geological history of the Cooper subregion extends from the Cambrian through to the present. The Thomson Orogen and Warburton Basin were variably deformed during the Delamerian Orogeny, with metamorphic grade increasing from the relatively unaffected Warburton Basin, to the east and north-east into the Thomson Orogen. This was followed by north-west and south-east oriented compression and uplift in the Devonian to Carboniferous Alice Springs Orogeny, which resulted in the characteristic structural grain of the Cooper Basin. Thrusting of the Warburton Basin sequence formed significant ridges providing up to 600 m relief prior to deposition of the Cooper Basin sequence (Champion et al., 2009).

Basement rocks under the south-western part of the subregion experienced mega bolide impacts, which resulted in shock metamorphism and crustal rebound as well as hydrothermal alteration in rocks of the Warburton Basin (Glikson, 2013; Radke, 2009). Ridges developed as a result of north-west-directed thrust faulting in the Warburton Basin during the Alice Springs and Kanimblan orogenies, creating a high-relief paleotopography that controlled subsequent Cooper Basin sedimentary deposition in the main three troughs (Gravestock and Jensen-Schmidt, 1998; Raymond et al., 2012).

Granite bodies were emplaced in the subregion at two periods prior to deposition of the Cooper Basin rocks. An arcuate granite belt beneath the southern part of the subregion in Queensland and SA was emplaced during the Early Devonian, while granites beneath the Nappamerri Trough, including the Big Lake Suite granodiorite, were emplaced in the middle Carboniferous and earliest Permian (Gatehouse et al., 1995).

The Cooper Basin represents Permian to Triassic deposition which finished at the end of the Early Triassic with regional uplift, tilting and erosion. The basin contains a number of stacked non-marine depositional sequences that are contained within the Late Carboniferous to late Permian Gidgealpa Group and the late Permian to Early Triassic Nappamerri Group (Jensen-Schmidt et al., 2006).

The early depositional history of the Cooper Basin was dominated by glaciers moving across a landscape influenced by major basement ridges. The terminal stages of glaciation were marked by widespread peat swamp deposition (Patchawarra Formation). This was followed by relative tectonic and structural stability through most of the early Permian, which is reflected by lacustrine deposits (Murteree and Roseneath shales) (Draper, 2002b; Gravestock and Jensen-Schmidt, 1998).

Structural growth of the basement ridges commenced in the early Permian, coinciding with deposition of the Epsilon Formation, and culminated in the Daralingie unconformity, a tectonic event that created significant erosion on some ridges (Moussavi-Harami, 1996). The erosional effects of the Daralingie Unconformity are more severe in the north-eastern Cooper Basin in Queensland where the late Permian Toolachee Formation disconformably overlies the early Permian Patchawarra Formation with intervening units absent. Concomitant with this uplift, reverse faulting has been attributed to renewed compression and deformation of the eastern Australian marginal basins (Draper, 2002b; Gravestock and Jensen-Schmidt, 1998).

The Toolachee and Arrabury formations were deposited during a period of tectonic stability. Tectonism recommenced during deposition of the Tinchoo Formation, resulting in north-west tilting of the Cooper Basin, which is reflected in a northerly thickening of the Nappamerri Group, and erosion from the southern areas of the basin (Simon, 2000). Regional uplift and erosion terminate deposition in the Cooper Basin at the end of the Middle Triassic (Jensen-Schmidt et al., 2006).

The Eromanga Basin represents a series of marine transgressions and regressions during the Jurassic and Cretaceous. From the Early Jurassic through to Early Cretaceous periods, the lower non-marine succession accumulated through large sand-dominated braided fluvial systems that drained centripetally into lowland lakes and swamps. This was during a period of tectonic stability with subsidence being the major mechanism accommodating deposition. Sediment coverage was relatively thin, continuous and widespread during this time, and thickest within the Central Eromanga Depocentre (Ransley et al., 2012a).

Subduction and associated volcanism occurred concurrently on the eastern margin of the Australian Plate, on the eastern Australian volcanic arc. Consequently sediment was contributed from two sides of the depocentre. A cratonic source contributed clean quartzose sands from the south-west, whereas volcanogenic detritus came from the volcanic province along the eastern subduction zone (Ransley et al., 2012a).

Several multiple bolide impacts occurred during deposition of the Cadna-owie Formation (Glikson, 2013). Following this, during the Early Cretaceous, there was extensive marine inundation over large areas of the Australian continent. There was a period of rapid subsidence between 112 and 99 Ma. As a result, thick marine shales accumulated with interspersed thin sandstone units during minor regressive cycles (Ransley et al., 2012a).

With uplift of the eastern highlands commencing in the Late Cretaceous, erosion of this uplifted region contributed sediment for the rapid accumulation within the Eromanga Basin that swamped the marine conditions. This led to accumulation of an upper non-marine succession from meandering fluvial systems that crossed a floodbasin dominated by coal swamps and lakes (Winton Formation). The deposition of the upper non-marine sequence contributed almost half the total sediment thickness of the Eromanga Basin. Erosion and deep weathering commenced during the Late Cretaceous and Paleocene (Ransley et al., 2012a).

The Lake Eyre Basin represents terrestrial deposition punctuated by tectonic activity and deep weathering. Major anticlines, including the Innamincka Dome, formed as a result of compression related folding in the Oligocene. This was followed by compressional folding and faulting during the Miocene, reflected in domed and faulted silcrete horizons. Significant uplift of between 350 and 500 m has been reported within the Cooper subregion (Ransley et al., 2012a).

1.1.3.4 Coal and hydrocarbons

The Cooper subregion incorporates the Cooper–Eromanga Basin hydrocarbon system. Gas is the main resource, with some oil production. Gas and dry gas are predominantly in the Cooper Basin sequence, whereas oil is mainly in the sandstone reservoirs of the Eromanga Basin (Radke, 2009). The Cooper Basin contains approximately 190 gas fields and 115 oil fields currently in production. These fields contain approximately 820 producing gas wells and more than 400 producing oil wells which feed into production facilities at Moomba in SA and Ballera in Queensland (Santos, 2014). Gas and oil fields, as well as oil and gas exploration and production tenements, and associated infrastructure are shown in Figure 20.

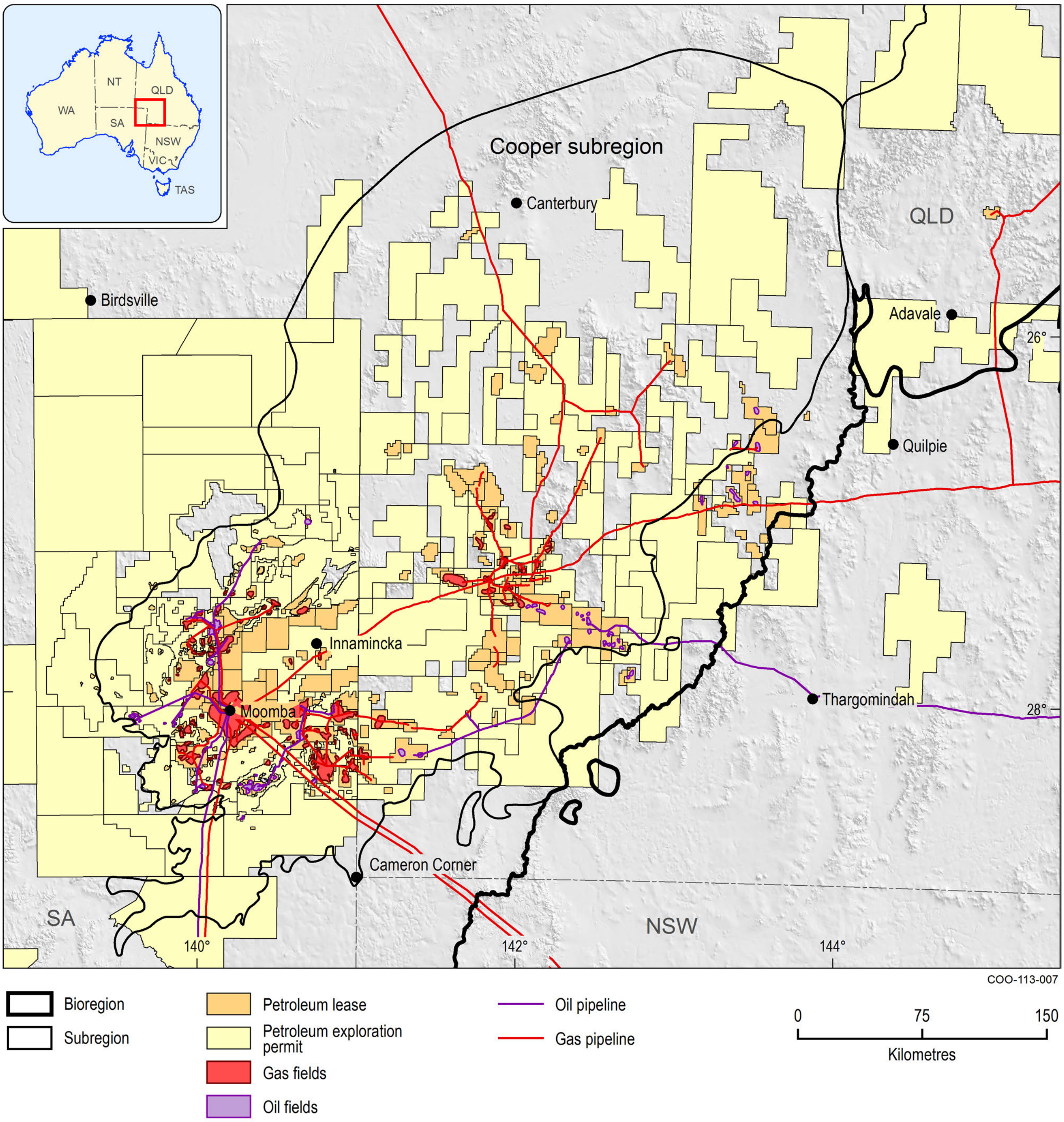

Figure 20 Oil and gas fields in the Cooper subregion, with tenements and infrastructure

Data: Geoscience Australia (Dataset 1, Dataset 2); DNRM (Dataset 5, Dataset 6); DMITRE (Dataset 8, Dataset 9)

The Cooper Basin also hosts significant unconventional hydrocarbon resources, including deep coal seam gas. Assessment of in-place shale gas and oil resources undertaken by the United States Energy Information Administration in 2013 estimated that the Roseneath Shale–Epsilon Formation–Murteree Shale section of the Cooper–Eromanga system contains shale gas in-place resources of 325 trillion cubic feet (Tcf), of which 93 Tcf is classed as technically recoverable. The same assessment estimated that the oil in-place for this section is 29 billion barrels, of which 1.6 billion barrels is deemed technically recoverable (U.S. Energy Information Administration, 2013). Other agencies have highlighted the potential for the Cooper subregion to host significant resources of other unconventional energy commodities, such as tight gas and deep coal seam gas (Goldstein et al., 2012;

Gravestock et al., 1998; GSQ, 2012). For example, GSQ (2012) suggested that the Roseneath Shale–Epsilon Formation–Murteree Shale section and the Patchawarra and Toolachee formations are prospective for shale and tight gas, the Poolowanna, Birkhead and Toolebuc formations are prospective for shale gas, and the Winton Formation may be prospective for coal seam gas. Geoscience Australia and BREE (2014) report total production of 6.4 Tcf (converted from 6926 PJ) and remaining resources of 1.5 Tcf (converted from 1693 PJ) for conventional gas resources from the Cooper-Eromanga Basin system. The remaining resource figure is the Demonstrated Resource under the McKelvey resource classification scheme (Appendix C of Geoscience Australia and BREE, 2014).

The Eromanga Basin is predominantly oil-producing with minor gas. In contrast, the Cooper Basin is gas-dominant with a considerable light liquid component. Production in the Cooper Basin has been from eight formations in a thick sequence containing several coal-bearing units and carbonaceous siltstones, predominantly from the Gidgealpa Group (Radke, 2009). Thick, laterally extensive coal seams have been intersected in the Patchawarra and Toolachee formations. The distribution and cumulative thickness of coal in the Patchawarra Formation is shown in Figure 21, and for the Toolachee Formation in Figure 22.

Patchawarra coal seams average 2.1 m thick but can be 22 to 30 m, with 30% of seams exceeding 2 m thick (Alexander et al., 1998). The thickest laterally extensive coal seam in the Patchawarra Formation is known as the VC50 coal. It ranges in thickness from 13 to 23 m, and is thickest in the Nappamerri and Patchawarra troughs (Figure 21), with coal thickness in the Weena Trough also significant (Simon, 2000). Recent drilling in the Weena Trough has encountered cumulative coal thicknesses of up to 145 m, with the thickest individual seam being 35 m (Strike Energy Limited, 2014). Drilling in the Windorah Trough in Queensland encountered cumulative thicknesses of coal in the Patchawarra Formation of 15 to 20 m (Real Energy Corporation Limited, 2014). The Patchawarra Formation is sufficiently mature to generate gas from coal seams over much of the basin, and high gas readings are recorded when mature Patchawarra Formation coals are intersected in wells (Deighton et al., 2003). Given that depths to the coal-bearing Patchawarra Formation exceeds 1000 m across the subregion, there is no potential for coal to be mined in the subregion (Menpes et al., 2012).

Thick, laterally extensive coal seams are also characteristic of the Toolachee Formation (Figure 22). The average coal seam thickness in the Toolachee Formation is 4.3 m, but individual seams can reach 22 m. Forty-two percent of coal seams are thicker than 2 m (Alexander et al., 1998). Drilling in the Windorah Trough in Queensland encountered cumulative thicknesses of coal in the Toolachee Formation of 10 to 15 m (Real Energy Corporation Limited, 2014). The Toolachee coals are sufficiently mature for thermogenic gas generation in the Nappamerri and Arrabury troughs, and parts of the Patchawarra Trough, high mud gas readings have been recorded during drilling through mature Toolachee coals (Menpes et al., 2012).

Coal seams are also present in the Epsilon Formation with cumulative thickness up to 15 m (equivalent to 13% of the total formation thickness). Coal is also present in the Daralingie Formation with total cumulate thickness of up to 10 m (Sun and Camac, 2004).

The principal coal seam gas play in the Eromanga Basin is the Winton Formation, comprising up to 1200 m of non-marine shale and siltstone with minor coal layers. Individual coal seams are thin (1 to 2 m) and not laterally extensive. The Winton Formation coals are not sufficiently mature to generate thermogenic gas (Goldstein et al., 2012).

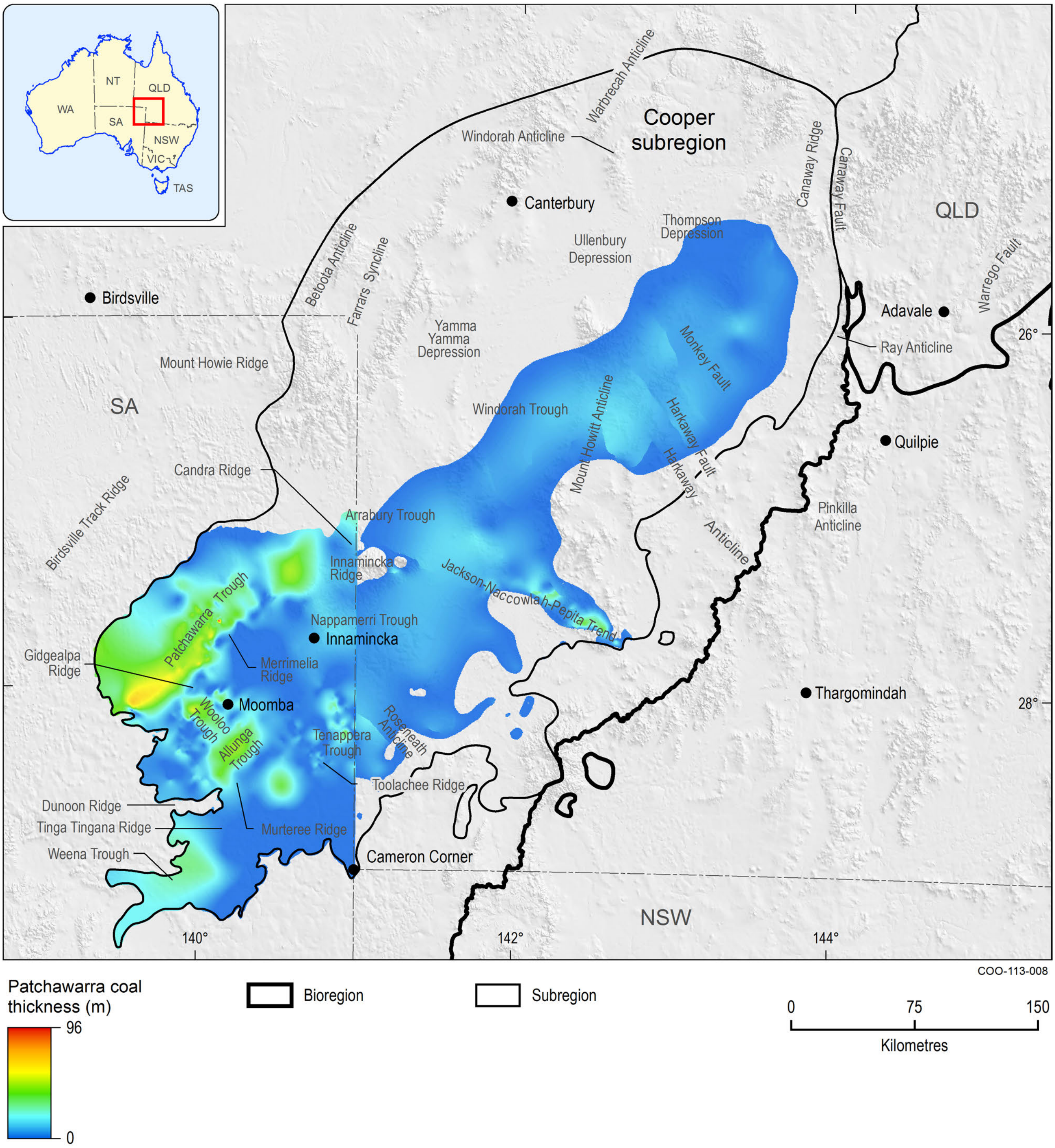

Figure 21 Patchawarra Formation coal distribution and cumulative thickness

Data: Draper (2002b); Sun and Camac (2004)
Discontinuities at state boundaries are a result of using datasets compiled at different times by state agencies.

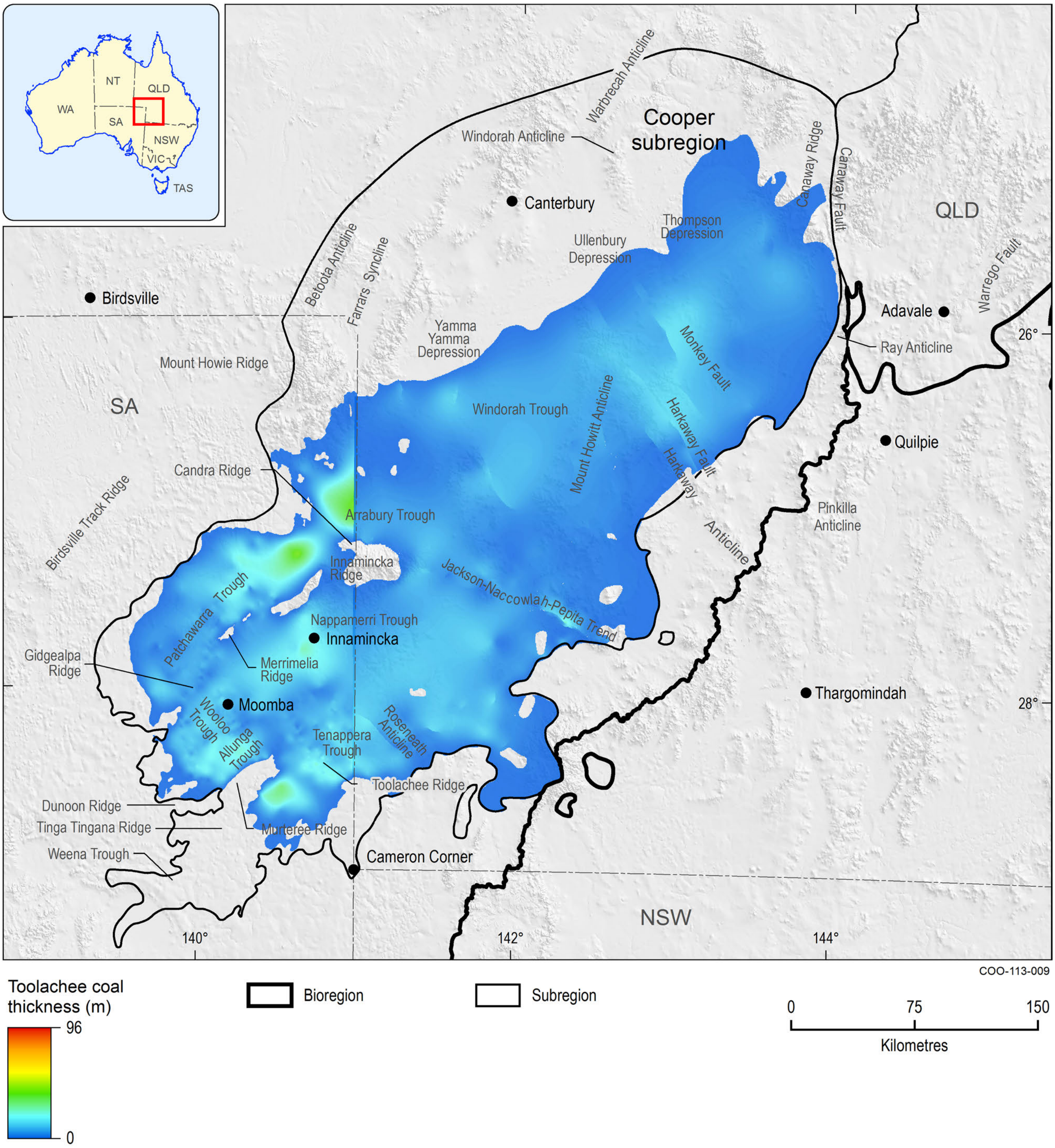

Figure 22 Distribution and cumulative thickness of Toolachee Formation coal in the Cooper subregion

Data: Draper (2002b); Sun and Camac (2004)
Discontinuities at state boundaries are a result of using datasets compiled at different times by state agencies.

1.1.3.5 Potential basin connectivities

The Cooper Basin is potentially connected to the underlying Warburton Basin and Warrabin Trough (Adavale Basin equivalent), and adjacent Galilee Basin, as well as to the overlying Eromanga Basin (Kellett et al., 2012). Most of the surface of the subregion is covered with Lake Eyre Basin sediments, with outcrops of Eromanga Basin rocks in the central part of the subregion. Further discussion of the potential basin connectivities is provided in Section 1.1.4.

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1.1.4 Hydrogeology and groundwater quality

Summary

Within the rocks of the Cooper Basin, coarser sandstone units of the Patchawarra and Toolachee formations represent the highest porosity units. Water quality in the Cooper Basin aquifers is generally brackish to saline.

The main aquifers in the subregion are the Cadna-owie Formation and Algebuckina Sandstone, as well as the Namur and Hutton sandstones. The aquifer system is both artesian and non-artesian. Groundwater in the aquifers of the Eromanga Basin and the Lake Eyre Basin in the Cooper subregion is generally suitable for stock and domestic use. Water quality in the aquifers of the Eromanga Basin deteriorates down flow paths. This is interpreted as the result of mixing of dilute recharge water with more saline groundwater from the deeper parts of the basin. The Lower Cretaceous-Jurassic aquifers are characterised by sodium-bicarbonate-chloride waters, whereas the Cretaceous aquifers are dominated by sodium-chloride waters.

Groundwater from the Lower Cretaceous-Jurassic sequence is of good quality and suitable for domestic, town water supply and stock use, though it is generally unsuitable for irrigation because it is characterised by high alkalinity and sodium contents. Groundwater from the upper, Late Cretaceous, Winton and Mackunda formation aquifers has a higher salinity, but may be acceptable for stock water.

The Eyre Formation aquifer can be a useful aquifer for stock purposes, where water salinity is brackish to saline. Good quality groundwater can be found at shallow depths in alluvial sediments adjacent to the major watercourses.

On a regional scale, groundwater flows from recharge areas along the Great Dividing Range west toward the discharge zones of the Western Eromanga Basin. The watertable throughout the Cooper subregion lies in the Early to Late Cretaceous Winton Formation, and in the underlying Early Cretaceous Mackunda Formation and Cenozoic sediments overlying the Eromanga Basin sequence. The water levels in Quaternary floodplain sediments generally form a continuum with the pressure surface of the underlying rock aquifer.

The south-westerly flow direction is mirrored in deeper hydrostratigraphic units, such as for the Cadna-owie – Algebuckina and Cooper Basin hydrostratigraphic units.

Inter-aquifer connectivity and vertical leakage are important mechanisms in the Cooper subregion. This occurs from the lower, higher pressure aquifers through the overlying leaky aquitards and aquifers into the Cretaceous aquifers of the Mackunda Formation and Winton Formation, or the regional watertable.

Groundwater management within the subregion is undertaken in accordance with water management legislation for SA and Queensland.

1.1.4.1 Groundwater systems

1.1.4.1.1 Cooper Basin

The Cooper Basin consists of alternating sandstone and siltstone units, with varying degrees of interbedded coarser and finer units, and coal seams. This can provide a useful hydrostratigraphic framework with which to begin characterising the groundwater systems. The SA Department for Water provided a hydrostratigraphic framework for the Cooper Basin (Table 6). While geologically distinct from the Cooper Basin sequence, the Cuddapan Formation is included in this framework. Toupin et al. (1997) and Golder Associates (2011) provide slightly different hydrostratigraphic characterisations, which are also summarised in Table 6. Gravestock et al. (1998) characterised the Cooper Basin rocks in terms of their potential as hydrocarbon reservoirs and seals. This classification also provides valuable information on hydrogeological parameters. Gray and Draper (2002) provide a similar summary of the reservoir and seal characteristics for the Cooper Basin in Queensland. These were compiled by Radke (2009) and are presented in Table 6 for comparison. In all classifications, coarser sandstone units of the Patchawarra and Toolachee formations represent the highest porosity units, with workers considering the Tinchoo, Patchawarra, Epsilon, Daralingie and Toolachee formations, along with the Tirrawarra Sandstone and Merrimelia Formation to be reservoir units (Gravestock et al., 1998; Gray and Draper, 2002; Radke, 2009). Table 6 also enables the reservoir and seal framework to be correlated with an aquifer and aquitard framework.

Table 6 Comparison between the various hydrostratigraphic frameworks for the Cooper Basin

	Unit	Hydrogeology (SA Department for Water, 2011)	Hydrostratigraphic Unit Description (Toupin et al., 1997)	Hydrogeological characteristics (Golder Associates, 2011)	Reservoir or seal (Radke, 2009)
Triassic	Cuddapan Formation	Aquifer	Not included	Not characterised	Reservoir
	Tinchoo Formation	Aquifer	Confining bed	Confining bed[a]	Reservoir
	Arrabury Formation	Major aquitard	Confining bed	Confining bed	Seal
Permian	Toolachee Formation	Aquifer	Confining bed Sandstone aquifer	Aquifer	Reservoir
	Daralingie Formation	Aquifer and aquitard	Sandstone aquifer	Confining bed	Reservoir
	Roseneath Shale	Aquitard	Sandstone aquifer	Confining bed	Seal
	Epsilon Formation	Aquifer	Sandstone aquifer	Aquifer	Reservoir
	Murteree Shale	Aquitard	Confining bed	Confining bed	Seal
	Patchawarra Formation	Aquifer	Confining bed Sandstone aquifer	Aquifer	Reservoir
	Tirrawarra Sandstone	Aquifer	Sandstone aquifer	Aquifer	Reservoir
Carboniferous	Merrimelia Formation	Aquifer	Not included	Water bearing	Not Classified

Source: Golder Associates (2011); Radke (2009); SA Department for Water (2011); Toupin et al. (1997)
[a]Golder Associates (2011) split the Tinchoo Formation into the Gilpeppe and Doonmulla members, and the Arrabury Formation into the Wimma Sandstone, Paning and Callamurra members. Of these, only the Wimma Sandstone Member is characterised as an aquifer.

1.1.4.1.2 Eromanga Basin

The Eromanga Basin covers all of the Cooper Basin and is considered as a series of stacked aquifers separated by aquitards. Kellett et al. (2012) proposed a qualitative classification of the hydrogeological units to account for variation in hydraulic properties that may be due to one or a combination of sediment sources, rates of basin subsidence during deposition, and alteration since the time of deposition. It has been subdivided by Kellett et al. (2012) into two hydrogeological systems: a Jurassic to Early Cretaceous hydrogeological system and a Rolling Downs Group hydrogeological system.

The Eromanga sequence reaches over 3000 m thick in the Central Eromanga Depocentre in the subregion (SA Department for Water, 2011). Disruptions to aquifer continuity can occur where displacements across a fault significantly offset an aquifer system. Significant fault offsets are evident at the eastern margin of the Cooper subregion, along the Canaway Fault (see Section 1.1.3.1.2). Another geological feature which may potentially compromise the effectiveness of the Wallumbilla Formation aquitard in the subregion is a pervasively developed polygonal faulting (Kellett et al., 2012) extending across the entire Central Eromanga Depocentre (Figure 2 in Section 1.1.3).

The Cadna-owie Formation and Algebuckina Sandstone together are the main aquifers in the subregion. This aquifer system is both artesian and non-artesian. Kellett et al. (2012) notes a reduction in permeability with increasing depth in the Hutton Sandstone and Cadna-owie Formation within the Central Eromanga Depocentre due to burial diagenetic effects. Similar effects can be seen in the other Eromanga Basin hydrostratigraphic units. Where confined, the Cadna-owie – Algebuckina aquifer system is overlain by the Bulldog Shale.

Along the south-western margin of the Eromanga Basin, the Bulldog Shale is in turn overlain by the Coorikiana Sandstone, which forms a discrete aquifer of high salinity and low yield. Artesian pressures have been recorded in this aquifer. Due to its high salinity and low yield, this aquifer is generally not exploited (SA Department for Water, 2011).

The upper aquifer of the Great Artesian Basin (GAB) occurs in the Winton and Mackunda formations. It is separated from the lower confined Cadna-owie – Algebuckina aquifer system by shale of the Oodnadatta Formation and Bulldog Shale, and is generally overlain by Cenozoic sediments of the geological Lake Eyre Basin. Aquifers in the Winton and Mackunda formations may be confined where overlain by significant thicknesses of the Lake Eyre Basin, but are unconfined where it outcrops (SA Department for Water, 2011).

1.1.4.1.3 Cenozoic

Aquifers occur in the Cenozoic rocks of the geological Lake Eyre Basin in the Cooper subregion. The Eyre and Namba formations are considered to be aquifers, while the other more clay rich units generally form aquitards, or leaky aquitards. The aquifers vary between unconfined and confined (SA Department for Water, 2011).

Water can be obtained from near-surface sedimentary materials, some of which may have been affected by secondary cements. Generally they are unconfined, with the depth to watertable up to 90 m (SA Department for Water, 2011).

1.1.4.2 Groundwater quality

Groundwater quality data are sparse in the Cooper subregion. Data obtained from petroleum well tests drilled up until the late 1990s were compiled and summarised by Dubsky and McPhail (2001). Water samples were collected as part of drill stem tests (DST), production tests, liquid evaluation tests (LET), completion tests and other flow tests in exploration and development wells. As part of the data compilation some quality control processes were applied so as to minimise the inclusion of samples that were contaminated by drilling fluids.

Salinity data from Dubsky and McPhail (2001) are summarised in Table 7. The Eromanga Basin and Cooper Basin Nappamerri Group have salinities ranging from 811 to 8794 ppm sodium chloride equivalent; whereas groundwater in underlying Permian aged Cooper Basin sequences have salinities ranging from 1246 to 18,312 ppm sodium chloride equivalent. The report by Dubsky and McPhail (2001) includes salinity trend maps, which show that for most formations, salinity increases towards the interior of the Cooper subregion, as well as increasing with formation age. Groundwater quality data for the southern Cooper Basin indicates salinities ranging from around 2000 to 7000 mg/L total dissolved solids (TDS). Lower salinity groundwater is found in the Patchawarra Formation where it directly underlies the Hutton Sandstone, and may experience downward leakage from the GAB here (Hydrogeologic Pty Ltd, 2014).

Table 7 Formation water salinities by unit for the SA portion of the Cooper subregion

Formation	Total dissolved solids (mg/L)			sodium chloride equivalent (ppm)		
	Mean	Min	Max	Mean	Min	Max
Murta	3,775	2,549	4,971	3,035	2,129	4,130
Namur-McKinlay	2,766	1,810	4,766	2,338	1,490	4,152
Westbourne-Adori	3,497	NA	NA	3,023	NA	NA
Birkhead-Hutton	2,630	959	5,729	2,253	811	5,241
Poolowanna	4,344	3,085	9,245	3,826	2,674	8,794
Nappamerri	3,763	2,660	4,950	3,276	2,112	4,381
Toolachee-Daralingie	5,714	1,463	12,232	5,178	1,246	11,858
Epsilon	5,473	2,202	9,722	5,062	1,904	9,314
Patchawarra	9,514	2,050	17,420	9,019	1,413	16,756
Tirrawarra-Merrimelia	9,444	5,530	11,656	9,002	4,991	11,202
Basement	4,312	NA	NA	2,755	NA	NA

Source: Dubsky and McPhail (2001)
NA means 'data not available'

Groundwater quality in Eromanga Basin aquifers has also been discussed by various authors including Cresswell et al. (2012), Love et al. (2013) and Radke et al. (2000). Some of the detail of their discussion is summarised below.

Solute concentration in groundwater for all Eromanga Basin aquifers increases down flow paths. This is interpreted as the result of mixing of dilute recharge water with more saline groundwater from the deeper parts of the basin, as well as water – rock interactions that can occur along groundwater flow paths (Cresswell et al., 2012; Love et al., 2013).

Differentiating water sources between the Lower Cretaceous-Jurassic aquifers and the Cretaceous aquifers (see Figure 23) can be done based on hydrogeochemical characteristics. The Lower Cretaceous-Jurassic aquifers are characterised by sodium-bicarbonate-chloride waters, whereas the Cretaceous aquifers are dominated by sodium-chloride water. The chemistry of the groundwater in the upper parts of the Cadna-owie – Hooray Aquifer and its equivalents (such as the upper Algebuckina Sandstone and Namur Sandstone) is influenced by downward diffusion from the marine mudstones of the Rolling Downs Group (Cresswell et al., 2012; Radke et al., 2000).

Groundwater obtained from aquifers in the older part of the Lower Cretaceous-Jurassic and Jurassic sequences is of better quality than that found in the Cretaceous aquifer. That is, water from the Namur and Adori sandstones is generally of better quality than the Cadna-owie Formation. Groundwater from all of the aquifers in the Lower Cretaceous-Jurassic sequence is of good quality and suitable for domestic, town water supply and stock use, though it is generally unsuitable for irrigation because in much of the Eromanga Basin it is characterised by high alkalinity and sodium content. Groundwater from the upper, Late Cretaceous, Winton and Mackunda formation aquifers in the Eromanga Basin in the subregion has higher salinity, but may be acceptable for stock water (Cresswell et al., 2012; Radke et al., 2000).

The Eyre Formation aquifer can be a useful aquifer for stock purposes. Water salinity is brackish to saline, ranging between 3000 and 12,000 mg/L TDS (SA Department for Water, 2011). Water quality in other Cenozoic and Quaternary aquifers is highly variable, from 1000 mg/L to greater than 100,000 mg/L TDS, and quantities are generally low. There is often a layer of fresh groundwater overlying more saline water. In the sandy dune country, good quality groundwater can be found at shallow depths in alluvial sediments adjacent to the major watercourses, such as Cooper Creek (SA Department for Water, 2011). Cenozoic aquifers in the Weena Trough have salinity ranging from 8500 to 21,000 mg/L TDS (Hydrogeologic Pty Ltd, 2014).

1.1.4.3 Groundwater flow

The hydrostratigraphic framework for the Cooper subregion has been developed based on the work of Cresswell et al. (2012), Dubsky and McPhail (2001), Golder Associates (2011), Kellett et al. (2012), Keppel et al. (2013)and Toupin et al. (1997) and shown in Figure 23. This classification recognises the heterogeneous lithological nature of units within the Eromanga Basin, discussed in more detail in Kellett et al. (2012) and the potential interconnectedness between the Nappamerri Group of the Cooper Basin and the Jurassic units of the Eromanga Basin, described further by Kellett et al. (2012) and Keppel et al. (2013).

The main aquifers are the upper part of the Cadna-owie Formation, the Algebuckina Sandstone, Adori Sandstone and Hutton Sandstone, within the Jurassic to Early Cretaceous system.

Partial aquifers include the Winton and Mackunda formations, Coorikiana Sandstone, Murta Formation, Birkhead Formation and Poolawanna Formation.

Leaky aquitards include the Wallumbilla Formation, the Westbourne Formation and the lower part of the Cadna-owie Formation.

Tight aquitards are the Allaru Mudstone and Toolebuc Formation of the Rolling Downs Group, as well as the basal siltstone of the Murta Formation where it is present.

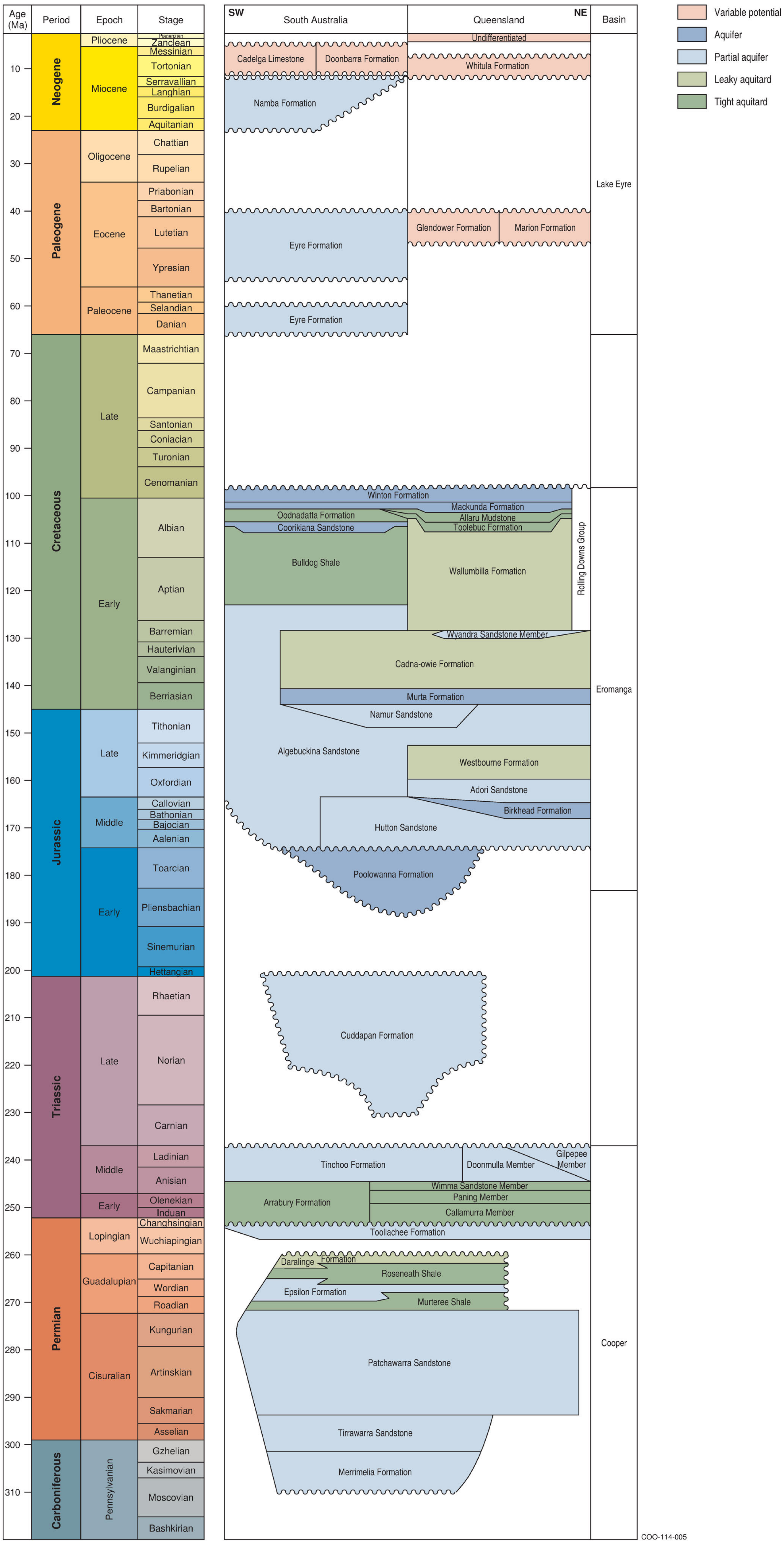

Figure 23 Hydrostratigraphic framework for the Cooper subregion

Source: compiled from Cresswell et al. (2012); Dubsky and McPhail (2001); Golder Associates (2011); Kellett et al. (2012); Keppel et al. (2013) and Toupin et al. (1997)

This figure has been optimised for printing on A3 paper (297 mm x 420 mm).

On a regional scale, groundwater in the Eromanga Basin flows from recharge areas along the Great Dividing Range west toward the discharge zones of the Western Eromanga Basin. Discharge areas include mound springs to the west of Lake Eyre and an arcuate band containing lakes Frome, Callabonna, Blanche and Gregory (Kellett et al., 2012).

1.1.4.3.1 Watertable and potentiometric surfaces

The watertable throughout the Cooper subregion lies in the Early to Late Cretaceous Winton Formation, and less commonly, in the underlying Early Cretaceous Mackunda Formation. The Winton and Mackunda formations form a hydraulically continuous unit, and thus water levels in the Mackunda Formation can also be regarded as equivalent to the regional watertable. The watertable also lies in Cenozoic sediments overlying the Eromanga Basin sequence, such as the Eyre Formation. The water levels in Quaternary floodplain sediments generally form a continuum with the pressure surface and the underlying rock aquifer, however following periods of high river stage temporary head differences of up to 10 to 15 m have been observed in perched alluvial systems (Kellett et al., 2012). A density (salinity) corrected watertable map is provided in Figure 24.

Watertable mapping shows a watertable mound which coincides with the Innamincka Dome. This geological feature is a broad anticline in the vicinity of Innamincka, and exposes Winton Formation material along its axis. The mound is likely to be a local recharge mound, whereby extension fractures formed as a result of unloading and folding provide enhanced infiltration capacity, where they have remained open (Kellett et al., 2012). Groundwater flow bifurcates around this mound, but the regional flow direction to the south-west is generally maintained across the subregion.

The south-westerly flow direction is mirrored in potentiometric surfaces for deeper hydrostratigraphic units, such as for the Cadna-owie – Algebuckina aquifer mapped by Love et al. (2013). This same general flow direction is evident from potentiometric surfaces presented by Dubsky and McPhail (2001) for the Cooper Basin hydrostratigraphic units. Love et al. (2013) note a depression in the Cadna-owie – Algebuckina aquifer potentiometric surface around Moomba of approximately 20 m, stating that it is related to groundwater extraction associated with petroleum and gas industries over several decades. Figure 25 shows an example of the density (temperature) corrected potentiometric surface for the Cadna-owie – Algebuckina aquifer in the Cooper subregion.

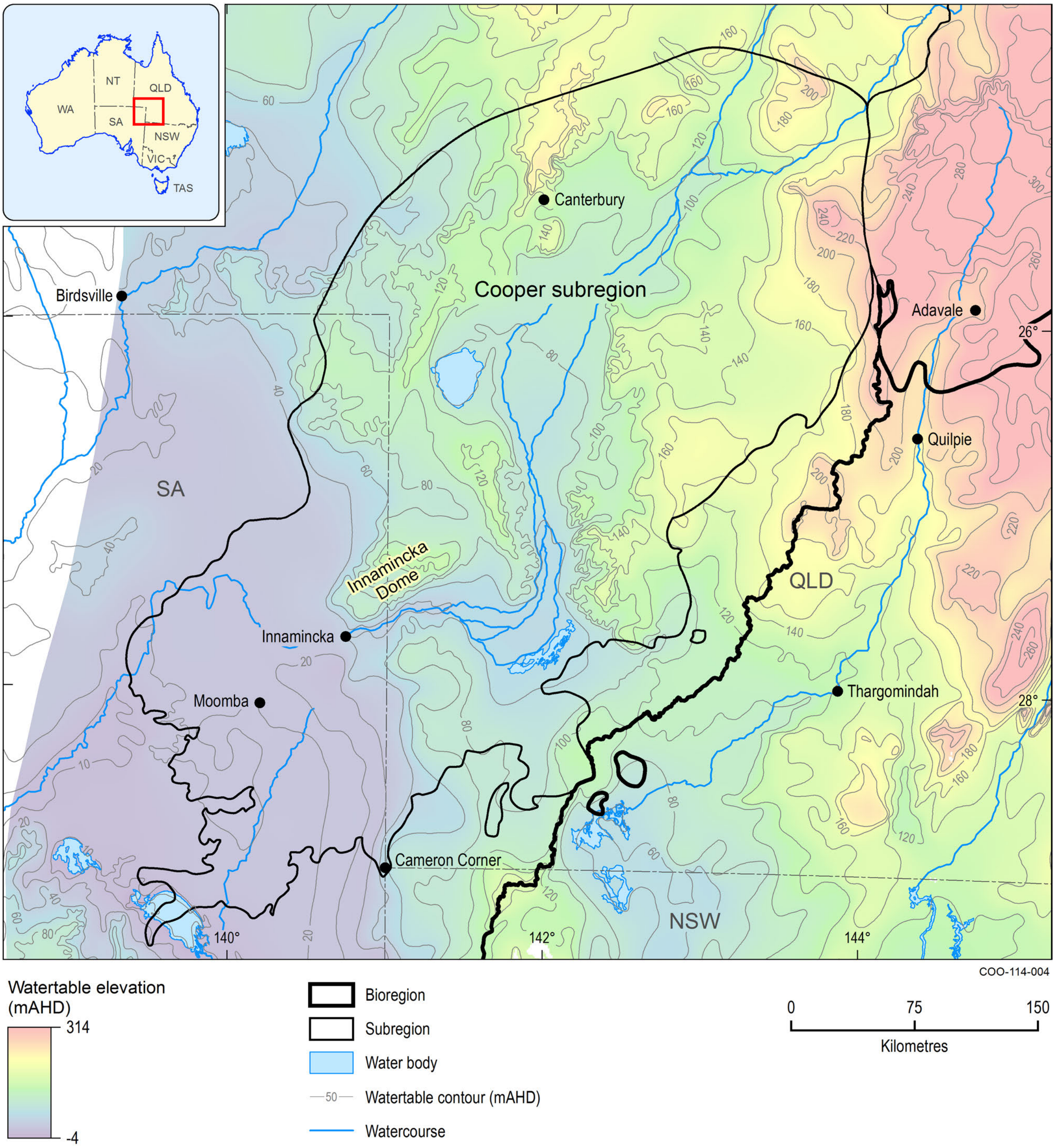

Figure 24 Density (salinity) corrected regional watertable level for the Cooper subregion

Source: after Figure 5.13 from Kellett et al. (2012)

Groundwater flows diminish into areas in the centre of the subregion where the Eromanga Basin aquifers are deeply buried. Within the Central Eromanga Depocentre, flow is hard to quantify, as there are few bores and hydrochemical tracer methods are complicated. Flow rates are inferred to be lower than 0.3 m/year (Cresswell et al., 2012).

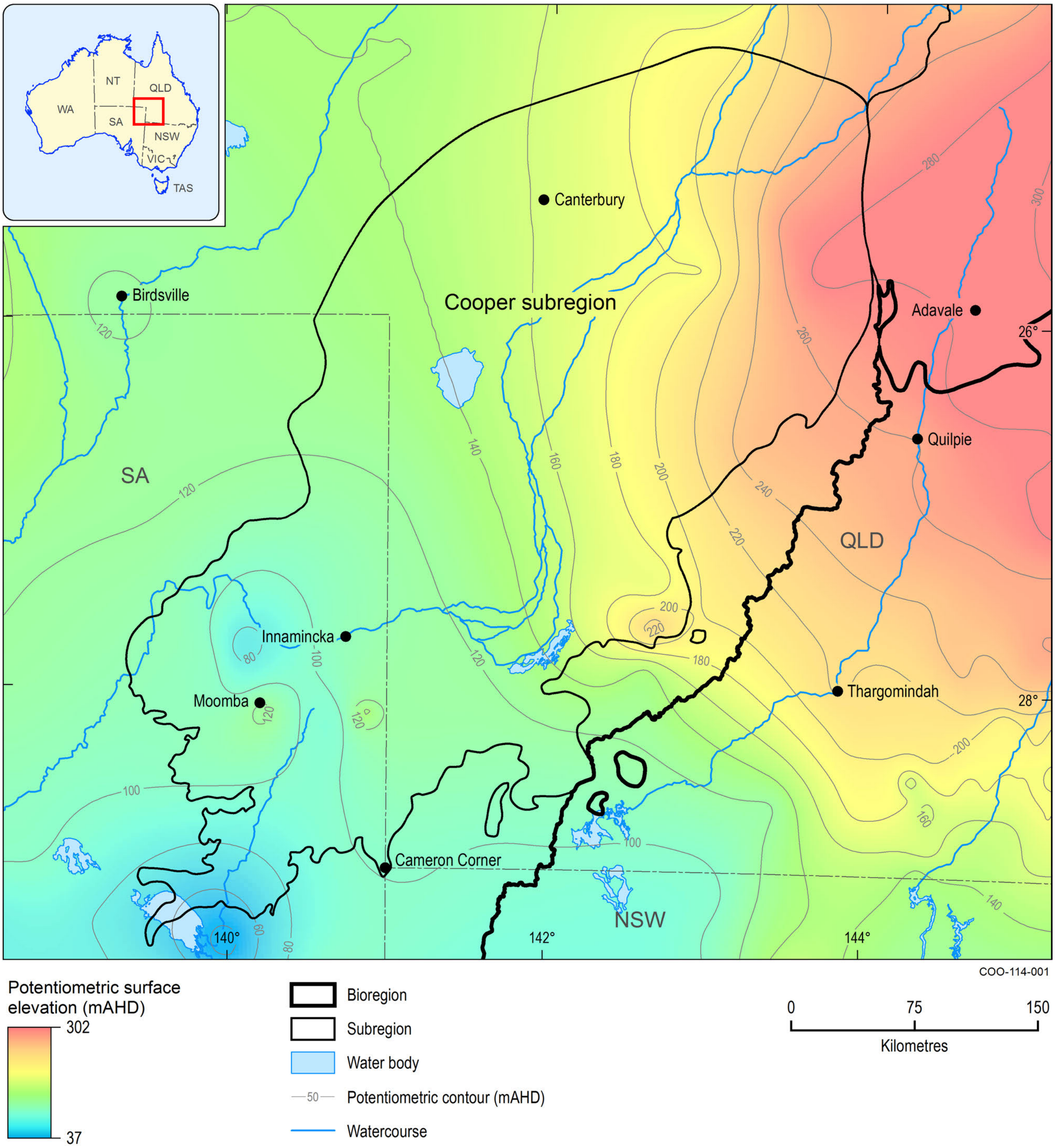

Figure 25 Density (temperature) corrected potentiometric surface of the Cadna-owie – Algebuckina aquifer in the Cooper subregion

Data: Geoscience Australia (Dataset 2)

1.1.4.3.2 Inter-aquifer connectivity

Vertical leakage or cross-formational flow takes place in the Cooper subregion from the lower, higher pressure aquifers in the Nappamerri Group and deeper Jurassic aquifers through the overlying leaky aquitards and aquifers of the Birkhead Formation, Adori Sandstone and Westbourne Formation and subsequent overlying aquifers in the Algebuckina Sandstone and the Cadna-owie Formation, and through the leaky aquitards of the Rolling Downs Group and Bulldog Shale into the Cretaceous aquifers of the Mackunda Formation and Winton Formation, or the regional watertable (Kellett et al., 2012; Keppel et al., 2013; Love et al., 2013; Toupin et al., 1997). Measured pressure differences between aquifers are an indication of the vertical leakage or flow, which is supported by hydrochemical indicators (Cresswell et al., 2012; Dubsky and McPhail, 2001; Love et al., 2013; Toupin et al., 1997).

Based on a regional hydrostratigraphic classification of Eromanga Basin units, potential for connectivity with underlying basins is provided by the overlap of adjacent aquifers and leaky aquitards above and below the basal unconformity of the Eromanga Basin. In Figure 26, the basal hydrostratigraphic units of the Eromanga Basin are shown by patterns and the uppermost stratigraphic units of the Cooper Basin are depicted by colours. This highlights that the upper units of the Cooper Basin are in hydraulic connection with the basal units of the Eromanga Basin.

1.1.4.3.3 Recharge and discharge

The only source of potential rainfall recharge to the Eromanga Basin is via the Innamincka Dome. No other Eromanga Basin units crop out in the Cooper subregion. Some limited recharge via diffuse infiltration of sporadic rain water, flood waters or streamflow through Quaternary and Cenozoic cover sequences may occur, although this is likely to be effectively zero, as a result of extremely low rainfall and high evaporation (Cresswell et al., 2012; Love et al., 2013). The most significant source of groundwater to the Eromanga Basin sequence in the Cooper subregion is inflow from areas outside the subregion.

Recharge to the Cooper Basin can only occur through vertical leakage from underlying or overlying aquifers or cross-formation flow.

Natural leakage or natural discharge to surface takes place at springs and areas of seepage, as well as in lakes, which are abundant around the margins of the Central Eromanga Basin (Love et al., 2013; Radke et al., 2000). Discharge springs in the subregion are discussed in Section 1.1.6.

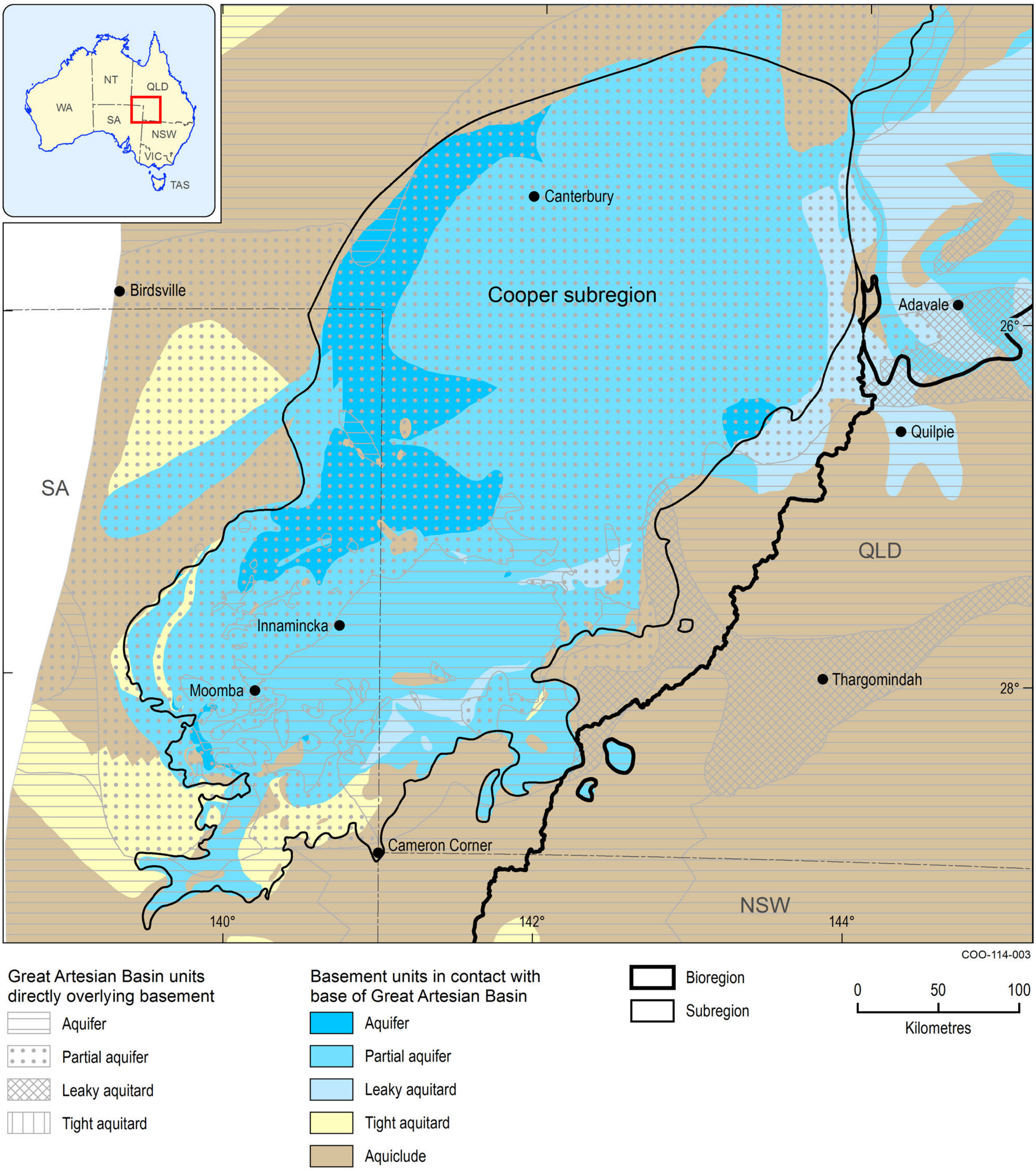

Figure 26 Areas of potential hydraulic interconnection in the Cooper subregion between the Eromanga Basin and underlying Cooper Basin

Data: Kellett et al. (2012)

1.1.4.4 Groundwater planning and use

The Cooper subregion lies in both Queensland and SA. Different approaches to groundwater planning and management operate in the two jurisdictions. Due to the importance of GAB discharge springs listed as endangered under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) the recovery plan for these springs is taken into account by jurisdictions in managing GAB groundwater. The recovery plan for the community of native species dependent on natural discharge of groundwater from the GAB (Fensham et al., 2010) is a joint plan by the SA, Queensland, NSW and Commonwealth governments. The overall objective of the recovery plan is to maintain or enhance groundwater supplies to GAB discharge spring wetlands, maintain or increase habitat area and health, and increase all populations of endemic organisms. Of relevance to groundwater planning is the plan's stated objective to ensure flows from springs do not decrease (lower than natural variability) and are enhanced in some areas.

Groundwater monitoring network bores located in the Cooper subregion are shown in Figure 27. The monitoring network only monitors aquifers in the GAB. There is no groundwater monitoring done by government agencies for aquifers in the geological Cooper Basin.

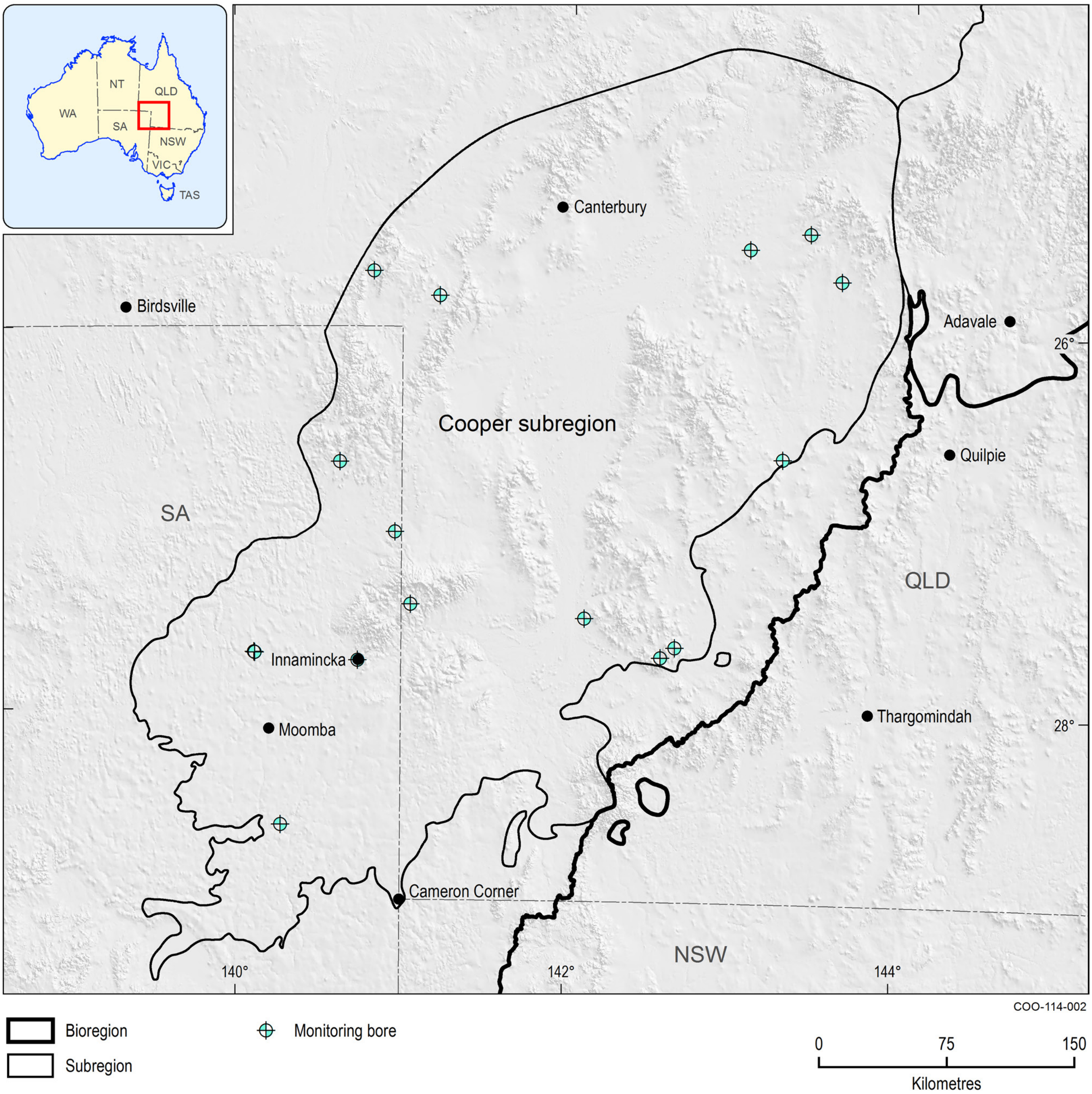

Figure 27 Locations of monitoring bores in the Cooper subregion

Data: Bureau of Meteorology (Dataset 1)

1.1.4.4.1 Queensland groundwater management

Groundwater in Queensland is managed under Queensland's *Water Act 2000* through subsequent water resource plans (WRP) and resource operations plans (ROPs) (Queensland Government, 2014a, 2014b, 2014c), or through declared sub-artesian areas under the *Water Regulation 2002*. ROPs provide the operational details to meet the goals of WRPs, including monitoring and reporting. The applicable WRP or sub-artesian area outlines the licence requirements for the take of water as well as the permit requirements to construct bores.

A licence is generally required for:

- extraction of groundwater for purposes other than stock and domestic use within proclaimed or declared areas (WRP areas, declared sub-artesian areas)
- taking artesian water for any purpose and from any location.

Within the Cooper subregion a licence is required for taking water for stock and domestic purposes from the GAB.

WRPs are generally catchment based and in the Cooper subregion regulate groundwater hydraulically linked to surface water. The Great Artesian Basin WRP differs in that it applies to artesian water and connected sub-artesian water in an area that spans parts of several surface water catchments. The Water Resource Plan (Great Artesian Basin) was published in 2006 (Queensland Government, 2014c). The GAB WRP applies to regional scale aquifers that span a large part of Queensland and many surface water catchments. The management areas of the GAB WRP that cover the Cooper subregion are the Warrego and Central management areas.

The Greater Western sub artesian area established under the Queensland *Water Regulation 2002*, covers the Winton and Mackunda aquifer system, the Lake Eyre Basin and other Cenozoic aquifers, as well as groundwater in the Cooper Basin hydrogeological system. A water entitlement, water permit or seasonal water assignment notice are not required for stock and domestic water, or water for a prescribed activity.

Groundwater management for petroleum activities is dealt with by the underground water management framework under Queensland's *Water Act 2000*. This framework includes a requirement for baseline assessments and preparation of underground water impact reports, as well as the provision of make good obligations. Petroleum and gas operators have the right to take associated water under Queensland's *Petroleum and Gas (Production and Safety) Act 2004* as part of the processing and extraction of petroleum and gas.

Groundwater in the Cooper subregion is managed under the WRPs described in Table 8 along with the general reserves set aside for water management areas relevant to the Cooper subregion. As there is not a single management unit that considers the general reserves for the Cooper subregion, they must be inferred from four plans that overlap with the subregion. Unallocated water volumes in WRPs may already have been partially or fully released or applied for. Those seeking access to unallocated water might also need to wait for an unallocated water release to occur before they are able to apply for the water.

1.1.4.4.2 South Australia groundwater management

In SA groundwater is managed under SA's *Natural Resources Management Act 2004*. Water allocation plans (WAPs) are developed by natural resource management (NRM) boards for each prescribed resource in their region. The Far North Prescribed Wells Area (PWA) covers the part of the Cooper subregion which lies in SA and extends to cover a large portion of the state. The Cooper subregion lies within the Central zone of the Far North PWA.

The Far North PWA WAP (SA Arid Lands Natural Resources Management Board, 2009) is achieved by limiting or excluding new bore development and undertaking to limit drawdown in the vicinity of springs. A management approach based on an acceptable fall in artesian head has been adopted. Under the Far North WAP, a pool of GAB water for consumptive use solely by the petroleum industry has been set aside for use as co-produced water. This allocation is set at 60 ML/day.

Table 8 Queensland water resource plans and groundwater management areas

Water resource plans	Relevant groundwater management area or zone	unallocated water for water licences in the management area or zone[a]
Great Artesian Basin Water Resource Plan (2006) covers artesian water and connected sub-artesian water, while connected springs includes 25 spatial GMAs, each with several stratigraphic GMUs. The Great Artesian Basin Water Resource Plan includes some of the aquifers found in the Cooper subregion, within the Central and Warrego West management areas.	16. Central GMA – 7 GMUs covering Toolebuc Formation – Base of Eromanga Basin 17. Warrego West GMA – 7 GMUs covering Toolebuc Formation – Base of Eromanga Basin	16. Central – 1000 ML 17. Warrego West – 1000 ML
Cooper Creek Water Resource Plan (2011) covers recharge springs, surface water, and sub-artesian groundwater that is hydraulically linked to surface water.	Nil, but Water Resource Plan refers to protected watercourses, waterholes and lakes, which may have implications for hydraulically connected groundwater	NA
Georgina and Diamantina Water Resource Plan (2004) covers surface water and sub-artesian groundwater that is hydraulically linked to surface water.	Nil	NA

Source: Compiled from National Water Commission (2013); Queensland Government (2014a;2014b; 2014c; 2014d)
GMU: Groundwater management unit
GMA: Groundwater management area
NA means 'data not available'
[a]There is a 10,000 ML state reserve shared across all management areas of the GAB that could be applied for in the subregion (Queensland Government, 2014c).

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1.1.5 Surface water hydrology and water quality

Summary

The Cooper subregion of the Lake Eyre Basin bioregion is located predominantly in the state of Queensland and partly in SA, and it intersects the Cooper Creek – Bulloo river basin and the Diamantina–Georgina river basin. The area of the Cooper subregion is 130,060 km^2 of which 118,128 km^2 (91%) is included in the Cooper Creek – Bulloo river basin and 11,932 km^2 (9%) in the Diamantina–Georgina river basin.

Much of the Cooper subregion is part of the Cooper Creek – Bulloo river basin. Cooper Creek and the Thomson, Barcoo and Bulloo rivers are the major streams in this basin. The stream below the junction of Thomson and Barcoo rivers is known as Cooper Creek and is characterised by complex channel networks and numerous wetlands and waterholes. Floods occur infrequently on the floodplain of Cooper Creek. However, during a large flood, the area becomes a huge inland sea broken only by a few ridges and numerous stunted trees. Water quality information such as total phosphorus (TP), total nitrogen (TN), electrical conductivity (EC) and turbidity is scarce for this basin. EC levels are normally low and stable. Turbidity is high and subject to varying trends as a result of local influences.

Only a small proportion of the Cooper subregion is part of the Diamantina–Georgina river basin in the north-west. The Diamantina River originates in the north of Cooper subregion and flows through a series of wetlands, lakes and waterholes along its 1000 km length. The Diamantina River is one of the major watercourses in the Lake Eyre Basin and the major contributor of surface water to Lake Eyre. The flow regimes of the basin are dominated by late summer flow events resulting from highly variable monsoonal rainfall in the upper catchments. The rivers have greatly varying widths of active channel and floodplain. Floods are infrequent but during large events, floodwaters inundate thousands of square kilometres. There are no permanent water quality monitoring stations in the Diamantina–Georgina river basin. However, limited water quality data reported under the Lake Eyre Basin Rivers Assessment (LEBRA) program indicate low EC levels and high turbidity in this region.

1.1.5.1 Surface water systems

For this contextual statement surface water systems were delineated based on Geofabric (Australian Hydrological Geospatial Fabric) maps (Bureau of Meteorology, 2012). The surface water networks in the Cooper subregion are predominantly part of the Cooper Creek – Bulloo river basin and only one named watercourse (Farrars Creek) of the Diamantina – Georgina river basin is within the subregion (Figure 28). The following sections describe the surface water systems in the Cooper subregion and surrounding areas.

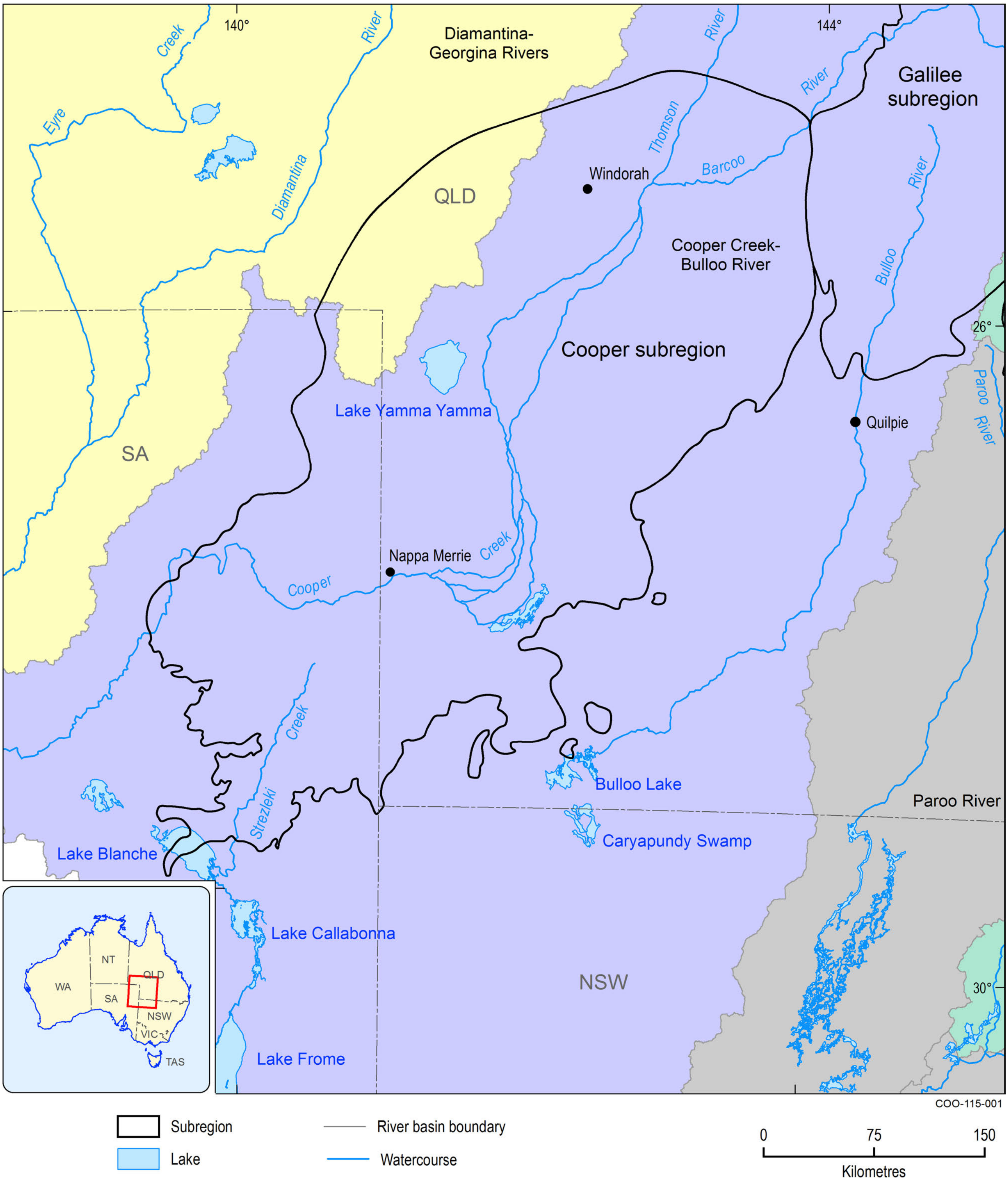

Figure 28 The Cooper subregion and associated nearby river basins

1.1.5.1.1 Cooper Creek – Bulloo river basin

The Cooper Creek – Bulloo river basin is located in the core of the Australian arid region. It has a drainage area of 503,565 km^2 and covers parts of Queensland, SA and NSW (McMahon et al., 2005). The surface water systems include Cooper Creek and the Thomson and Barcoo rivers, as well as numerous wetlands and lakes (Figure 29). A notable feature of the system is the extensive floodplain that dominates the basin south of Windorah and divides into two distinct parts near the Queensland–SA border. The Coongie Lakes Ramsar Wetlands are located in the lower part of the Cooper creek basin, in the far north-east of South Australia. The Ramsar site includes the Cooper Creek system from the Queensland–SA border downstream to Lake Hope, the north-west branch of the Cooper Creek. About 118,128 km^2 (or 91%) of the Cooper subregion is part of the Cooper Creek – Bulloo river basin and this comprises 23% of the basin.

The stream below the junction of the Thomson and Barcoo rivers is known as Cooper Creek and is characterised by complex anastomosing channels and numerous wetlands and waterholes. Headwater streams originate from the Great Dividing Range of Queensland and feed Cooper Creek through the Thomson and Barcoo rivers. Cooper Creek flows towards the south-west to its final terminus in Lake Eyre after passing more than 1500 km of different geographical features. The area of the Cooper creek floodplain is approximately 15,300 km^2 and the width can exceed 60 km at many locations near Currareva. In the dry season, the channels are restricted to numerous lagoons and claypans but during high flow the actual main channel becomes hard to define. When a flood event occurs, the area becomes a huge inland sea broken only by a few ridges and numerous stunted trees (Knighton and Nanson, 2001). Records of large floods in the area extend back as far as the late 19th century, with the most significant episodes of flooding occurring in 1893, 1906, 1949, 1955, 1963, 1974, 1990 and 2000 (Bureau of Meteorology, 2010).

Flow in Cooper Creek has not yet been affected by diversion of water for irrigated agriculture or major dams or weirs (McMahon et al., 2005). In a recent water resource plan for the Cooper Creek, the Queensland Government reserved 2000 ML of unallocated water (200 ML for general reserve, 1300 ML for strategic reserve and 500 ML for the town and community reserve) to meet future demand (DERM, 2011a). There is no major public water storage within the basin.

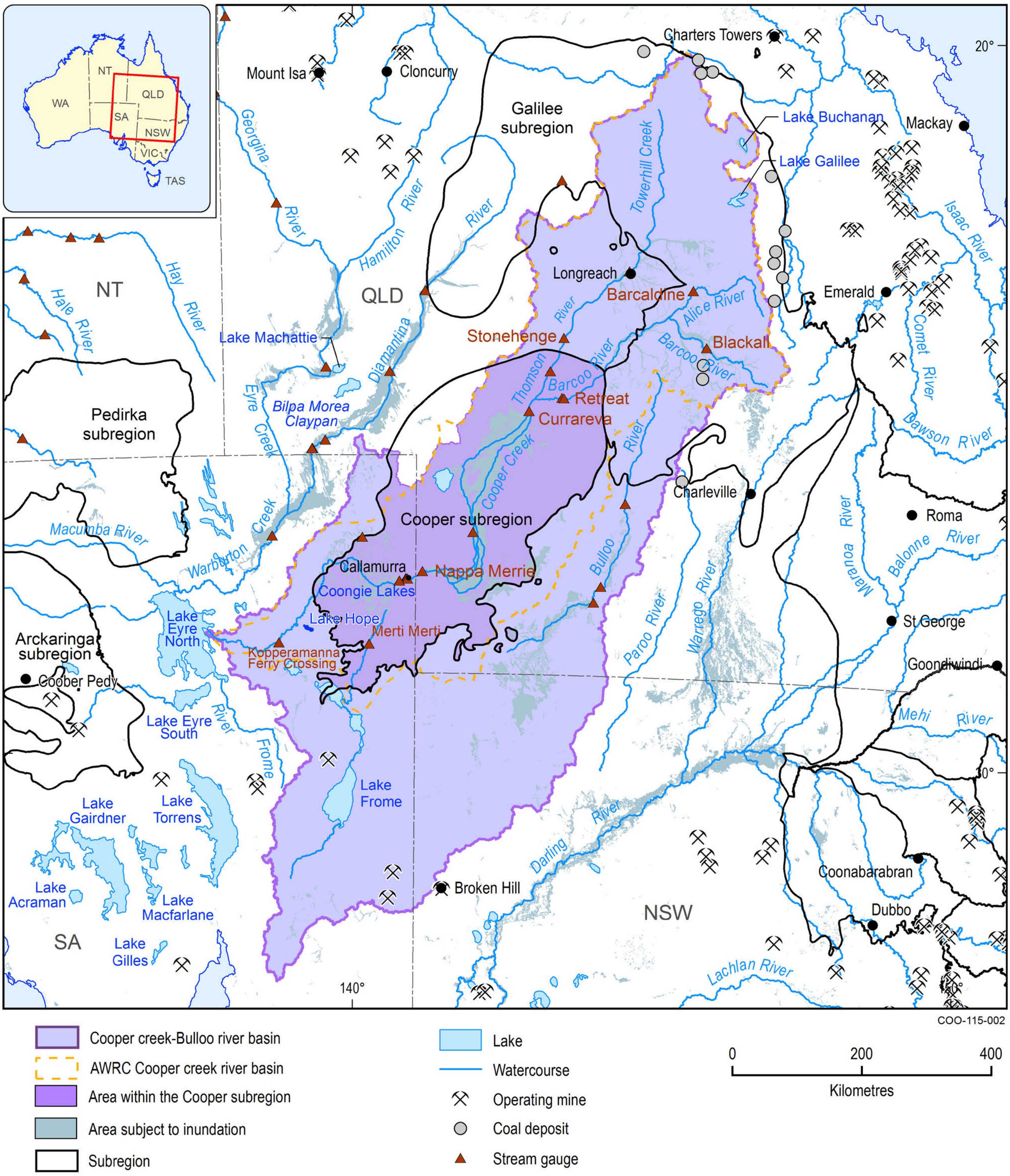

Figure 29 Cooper Creek – Bulloo river basin showing major stream network, water assets and location of mining development in the Cooper subregion

Data: Mining data were obtained from the OZMIN Mineral deposit database (Geoscience Australia, Dataset 1)

1.1.5.1.2 Diamantina–Georgina river basin

The Diamantina–Georgina river basin is located in the central part of Australia and is one of the largest river basins of the Lake Eyre Basin. It has a combined drainage area of 699,162 km^2, which is about half of the Lake Eyre Basin including areas of Queensland and SA (McMahon et al., 2005). The major surface water resources in the basin are Mayne, Diamantina, Georgina, Hay and Alberga rivers and Farrars and Walker creeks as well as numerous wetlands and lakes. Other minor stream channels include Western River and Mill Creek as well as a series of small unnamed tributaries and swamps. A notable feature of the system is the extensive floodplain that dominates the catchment above Birdsville. About 11,932 km^2 (9%) of the Cooper subregion is part of the Diamantina–Georgina river basin and this comprises 2% of the total basin area.

The Diamantina River originates in the north-west of Longreach and flows in a south-westerly direction through central Queensland and the Channel Country to form the Warburton River at its confluence with the Georgina River. The entire river length is about 1000 km to its terminus at Lake Eyre. The Western and Mayne rivers join the Diamantina River above Diamantina Lakes and Farrars Creek joins below Monkira (Figure 30). The rivers are characterised by complex anastomosing channels, wide floodplains and numerous waterholes and wetlands. Overall, the Diamantina–Georgina river basin is very flat and the rivers have greatly varying widths of active channels and floodplains. During large flood events, floodwaters can inundate thousands of square kilometres due to the low relief throughout the area. Floods normally develop in the headwaters of the Diamantina River and its major tributaries, however, flooding may result from heavy rainfall falling in the middle-to-lower reaches around Diamantina Lakes. Since 1965, large floods have occurred in 1974, 1991, 2004 and 2010 (Bureau of Meteorology, 2010).

The Georgina and Diamantina Water Resource Plan 2004 provides for 1000 ML as general reserve in the Lower Diamantina management area, which overlies a small part of the Cooper Basin. Additionally, 1500 ML is available across the whole catchment area for projects of state significance. The Plan also provides for limitation of in-stream storages. Currently, there are no large storages on the Diamantina River and it retains a near-natural flow regime.

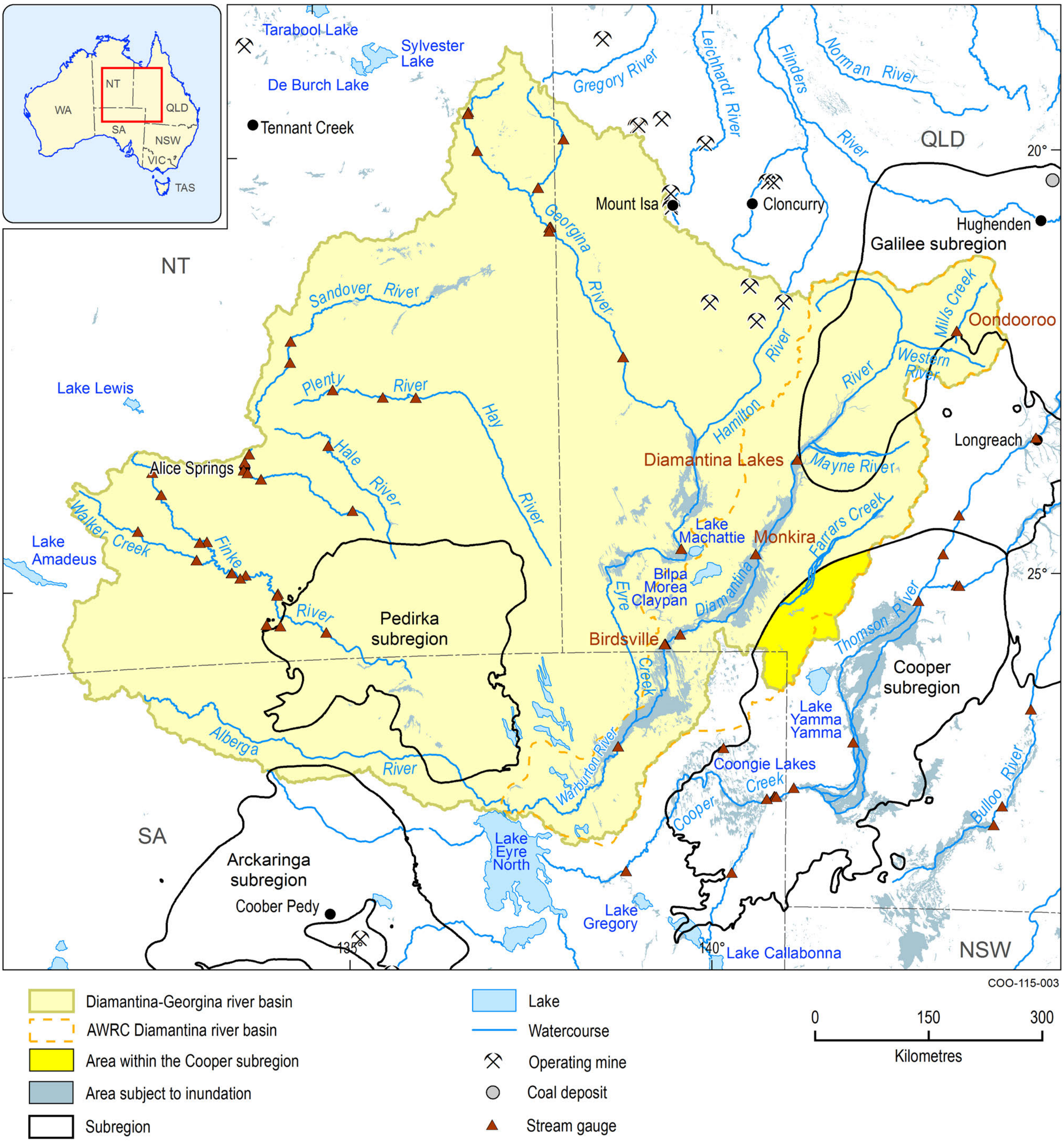

Figure 30 Diamantina–Georgina river basin showing major stream network, water assets and location of mining development in the Cooper subregion

Data: Mining data were obtained from the OZMIN Mineral deposit database (Geoscience Australia, Dataset 1)

1.1.5.2 Surface water quality

The Queensland Government operates a number of water quality measuring sites (including automated and manual sampling) under its nine Aquatic Ecosystem Provinces (AEPs) across the state (DERM, 2011b). The Cooper creek and Diamantina river basins are part of the Lake Eyre AEP. The frequency of sampling varies depending on operational conditions. These measurements generally include EC, temperature, pH, turbidity, nutrients, dissolved oxygen and total alkalinity (DNRM, 2012).

The availability of water quality data for the Cooper creek and Diamantina river basins is extremely poor due to logistic and accessibility difficulties associated with monitoring such a vast and sparsely populated area. There are six permanent monitoring sites for water quality data in the Cooper creek and Diamantina river basins of which only one (at Nappa Merrie) is located within the Cooper subregion. Among the sites, continuous auto-sensor data are available for Longreach station on the Thomson River. For the remaining stations, including the Nappa Merrie, no more than five sampled data points are available. In addition, there are 20 water quality monitoring sites (data loggers) in the Lake Eyre Basin including two in the Cooper subregion that have been operated by the Lake Eyre Basin Rivers Assessment (LEBRA) programme since 2011 (Cockayne et al., 2013). The LEBRA programme also operates occasional in situ measurements all across the sites.

As reported by DERM (2011b), EC levels are low and stable at each of the gauging stations but subject to occasional high pulses at some sites. At Longreach, the median EC is about 200 µS/cm at baseflow and 100 µS/cm at high flow, however, occasional high EC values occur anomalously at mid-flow ranges, particularly flows of between 0.1 and 10 m^3/s (DERM, 2011b). Data from the LEBRA logger sites also showed a general pattern of increasing EC throughout the low or no flow periods, followed by sharp lowering during high-flow events. At some sites there is a distinct initial rise in EC when the first flood water arrives (Cockayne et al., 2013).

Turbidity is high and subject to varying trends as a result of local influences. It appears turbidity decreases from upstream to downstream and then increases again before the Cooper Creek crosses the Queensland–SA border. Due to the isolated water holes forming during the extended dry seasons in this basin, differing turbidity trends may be more representative of local influences than generally deteriorating water quality further downstream (DERM, 2011b). In situ measurements at 17 sites (during spring 2011 and autumn 2012) show the turbidity varies from 4 to 354 NTU, with a mean of 124 NTU across the Cooper creek basin (Cockayne et al., 2013).

1.1.5.3 Surface water flow

The Cooper subregion contributes surface water predominantly to Cooper creek basin and a small proportion to Diamantina river basin by its floodplain pathways and numerous creeks. Both of these river basins are characterised by large variations in discharge and flow duration. Streamflow monitoring stations are relatively sparse in the Cooper subregion. A list of available stream gauges within and adjacent to the Cooper subregion along with their length of record is given in Table 9 (DNRM, 2013). Detail of streamflow characteristics of the Cooper creek basin, part of the Cooper Creek – Bulloo river basin, and Diamantina river basin, part of the Diamantina–Georgina river basin, are described in the subsequent sections.

Table 9 List of stream gauges in the Cooper subregion and surrounding areas located in the Cooper creek basin and Diamantina river basin

Gauge number	Stream gauge name	Catchment area (km^2)	Mean annual flow (GL/y)	Drainage basin	Data period
003101A	Cooper Creek at Currareva	150,220	3642	Cooper	1966–1988
003103A	Cooper Creek at Nappa Merrie	237,000	1607	Cooper	1949–present
AW003501	Cooper Creek at Callamurra	230,000	1430	Cooper	1973–2004
003202A	Thomson River at Longreach	57,590	1228	Cooper	1969–present
003203A	Thomson River at Stonehenge	87,810	2361	Cooper	1966–present
003204A	Cornish Creek at Bowen Downs	22,830	338	Cooper	1968–present
003205A	Darr River at Darr	2,700	49	Cooper	1969–present
003301A,B	Barcoo River at Retreat	51,663	1193	Cooper	1999–present
003302A	Alice River at Barcaldine	7,918	55	Cooper	1968–present
003303A	Barcoo River at Blackall	8,782	102	Cooper	1969–present
002101A,B	Diamantina River at Birdsville	115,200	1261	Diamantina	1949–1988
002104A	Diamantina River at Diamantina Lakes	54,130	1835	Diamantina	1966–present
002105A	Mills Creek at Oondooroo	2,642	0.3	Diamantina	2007–present

Data: DNRM (2013)

Water in the Cooper creek basin is predominantly derived from runoff from headwater catchments. The Thomson and Barcoo rivers, which originate outside the Cooper subregion, play an important role in flow into Cooper Creek. Transmission losses are generally very high. The long-term (1901–2003) average modelled runoff coefficient in the Cooper creek basin varies from a low of 1.2% for the Alice River at Barcaldine to a high of 6.6% for the Thomson River at Stonehenge. The runoff coefficients are 5.8% at Currareva and 1.6% at Nappa Merrie (McMahon et al., 2005).

Streamflow in Cooper Creek and its tributaries varies greatly between years from almost no flow to significant flooding, and between months with no flow for some months. Figure 31 shows an example of yearly and monthly flow distribution based on measured data (1966–2012) at Nappa Merrie (DNRM, 2013). Watercourses in this basin are ephemeral and carry water mostly between January and July. The maximum monthly flow varies depending on the location of the gauging site and contributing catchment area, with some sites having very high flows (up to 15,900 GL/month for Cooper Creek at Currareva). Both annual and monthly flows generally increase down the catchment, although there are exceptions to this trend. On average there is flow in Cooper Creek at Nappa Merrie about 60% of the time. The flow duration curves are steep for all gauging sites in the Cooper creek basin, confirming the observation that streamflow is highly variable and that there is little groundwater contribution to the overall flow (McMahon et al., 2005).

Due to its low gradient, water flows very slowly on the floodplain. For a large flood, it takes around 16 days for the water to pass through the floodplain with a wave speed of 0.3 m/s, while for a small flood the speed can be as low as 0.1 m/s (Costelloe et al., 2003). The long travel time allows the air and earth to absorb much of the water on the flat floodplain. On average the water of the

Cooper Creek reaches Lake Eyre only once in every six years (Kingsford et al., 1999). For the biggest flood in the recorded history of Cooper Creek (1974), around 25,000 GL of water inundated the creek and 40% of the water was lost by the time the flood peak arrived in Callamurra near the Queensland–SA border. For flow events below 5000 GL, the transmission loss is often above 80% (McMahon et al., 2005).

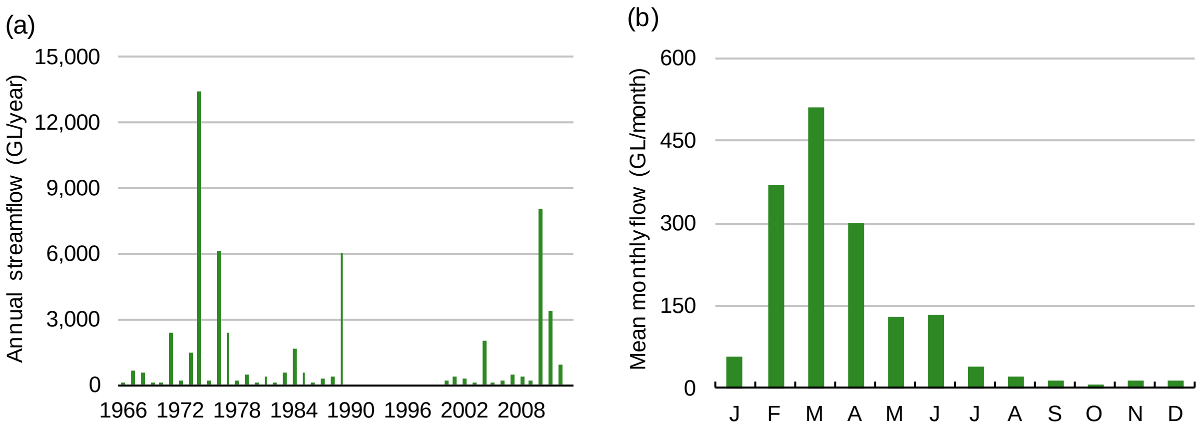

Figure 31 Annual and mean monthly flow distribution at Nappa Merrie on the Cooper Creek (003103A) in the Cooper subregion: (a) annual and (b) mean monthly flow

Data: DNRM (2013)

1.1.5.3.1 Diamantina river basin

The flow regimes of the Diamantina River are dominated by late summer flow events resulting from highly variable monsoonal rainfall in the upper catchments. Due to the location of the catchment, which includes semi-arid and arid regions, the streams are ephemeral (Knighton and Nanson, 2001). Like many arid zone rivers, the Diamantina river basin has few gauging stations to record streamflow, with two stations currently operating: one at Oondooroo on the Mills Creek and the other at Diamantina Lakes on the Diamantina River (Figure 30). Streamflow varies greatly between years and months from almost no flow to significant flooding. Figure 32 shows an example of yearly and monthly flow distribution based on measured data (1966–2012) at Diamantina Lakes on the Diamantina River (DNRM, 2013). The maximum monthly flows vary depending on the location and contributing catchment area, with some stations having high maximum mean monthly flows of up to 574 GL/year at Diamantina Lakes and 926 GL/year at Birdsville. On average, this catchment contributes some inflow to Lake Eyre North every two years (Kotwicki, 2005). At Diamantina Lakes, cease-to-flow conditions occur approximately 53% of the time (Costelloe et al., 2003).

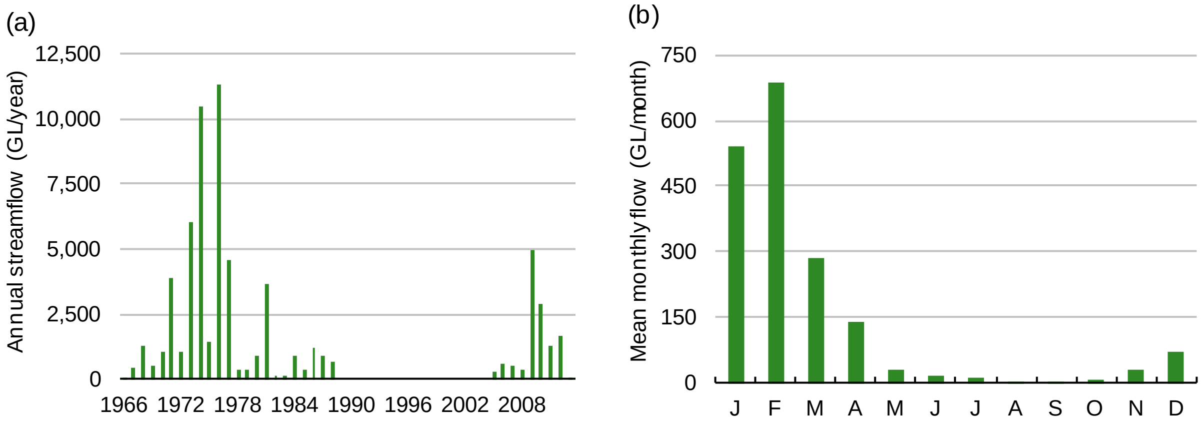

Figure 32 Annual and mean monthly flow distribution at Diamantina Lakes on the Diamantina River (002104A) in the Cooper subregion: (a) annual flow and (b) mean monthly flow

Data: DNRM (2013)

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1.1.6 Surface water – groundwater interactions

Summary

Little information is available with which to characterise the surface water – groundwater interactions within the Cooper subregion. Flowing artesian springs are found at the margins of the Great Artesian Basin (GAB) including just outside the subregion boundary, and are associated with structural geological features. These spring waters have a hydrochemical character which indicates mixing of different GAB water sources, and potentially deeper water sources.

The watertable in the Cooper subregion may interact with parts of the Cooper Creek surface water system. There is the potential for the shallow groundwater system to discharge to surface drainage. Groundwater may also be an important source of water for lakes in the subregion, such as Lake Blanche.

Large flooding events which occur within the subregion are unlikely to contribute significantly to groundwater recharge due to high evaporation rates.

Flowing artesian springs occur adjacent to the Cooper subregion (Figure 33), within the discharge margins of the GAB, and are generally associated with structural features, such as faults, folds, monoclines and intersecting lineaments. Upward artesian groundwater flow along faults is the source of many springs, as well as the abutment of aquifers against impervious bedrock and pressure water breaking through thin confining beds near the discharge margins of the geological Eromanga Basin.

The hydrochemistry of western margin GAB springs indicates the occurrence of GAB groundwater mixing of several large-volume, chemically distinct recharge sources and potential fluid inputs from deeper strata that move along fault zones. Major and trace elements, isotope concentrations and ratios indicate distinct regional flow systems with geochemical evolution and complex mixing along flow paths. The regional flow paths are consistent with the regional flow systems inferred from the potentiometric surface, and trace gas data from the GAB springs indicates mixing of deeply sourced fluids moving upwards along faults (Love et al., 2013).

Kellett et al. (2012a) describe features that indicate that the shallow watertable may be interacting with surface water along significant reaches of the Cooper Creek. They propose that some reaches of these drainage systems may be receiving baseflow from shallow aquifer systems, that is, there is potential for the shallow groundwater system to discharge to surface drainage, which may occur within the Cooper subregion.

Watertable mapping presented in Section 1.1.4 coupled with vegetation mapping and remote sensing shows the potential for surface water – groundwater interaction along many reaches of streams in the Cooper subregion (Kellett et al., 2012a). This potential is likely to be diminished where streams open out onto broad alluvial plains or terminal wetlands, such as for broad braided sections of Cooper Creek, and the terminal reaches of Strzelecki Creek at Lake Blanche (Kellett et al., 2012a). The *Atlas of Groundwater Dependent Ecosystems* (GDE Atlas; Bureau of Meteorology,

2012) identifies few areas within the subregion that may have a potential for reliance upon the surface expression of groundwater (Figure 33). Ecosystems reliant on surface expressions of groundwater rely on groundwater to meet some or all of their water requirements and to be present at the ground surface. This includes some terrestrial vegetation, subsurface fauna communities, and some vegetation which is associated with a surface water body. The GDE Atlas does not show any ecosystems identified in previous studies (either desktop or field-based) as being reliant upon groundwater (Bureau of Meteorology, 2012). Lake Blanche hosts several GAB discharge springs, shown in Figure 33, which lie just outside the subregion, but are included here as they may be connected to the hydrogeological system. These springs are in the Lake Frome spring supergroup, which is part of the 'community of native species dependent on natural discharge of groundwater from the Great Artesian Basin', a community listed as 'Endangered' under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (Fensham et al., 2010).

Groundwater discharge via salt lakes, such as Lake Blanche within the Cooper subregion, has been recognised, particularly in areas where aquifers interact with faults and are juxtaposed against geological units with lower porosity and permeability (Love et al., 2013). Polygonal faulting has been proposed as a potential pathway for fluid migration (Kellett et al., 2012b). In the north-east of SA, polygonal faulting is recorded at the surface and at depths of hundreds of metres, throughout the Cretaceous Eromanga Basin sequence (Watterson et al., 2000).

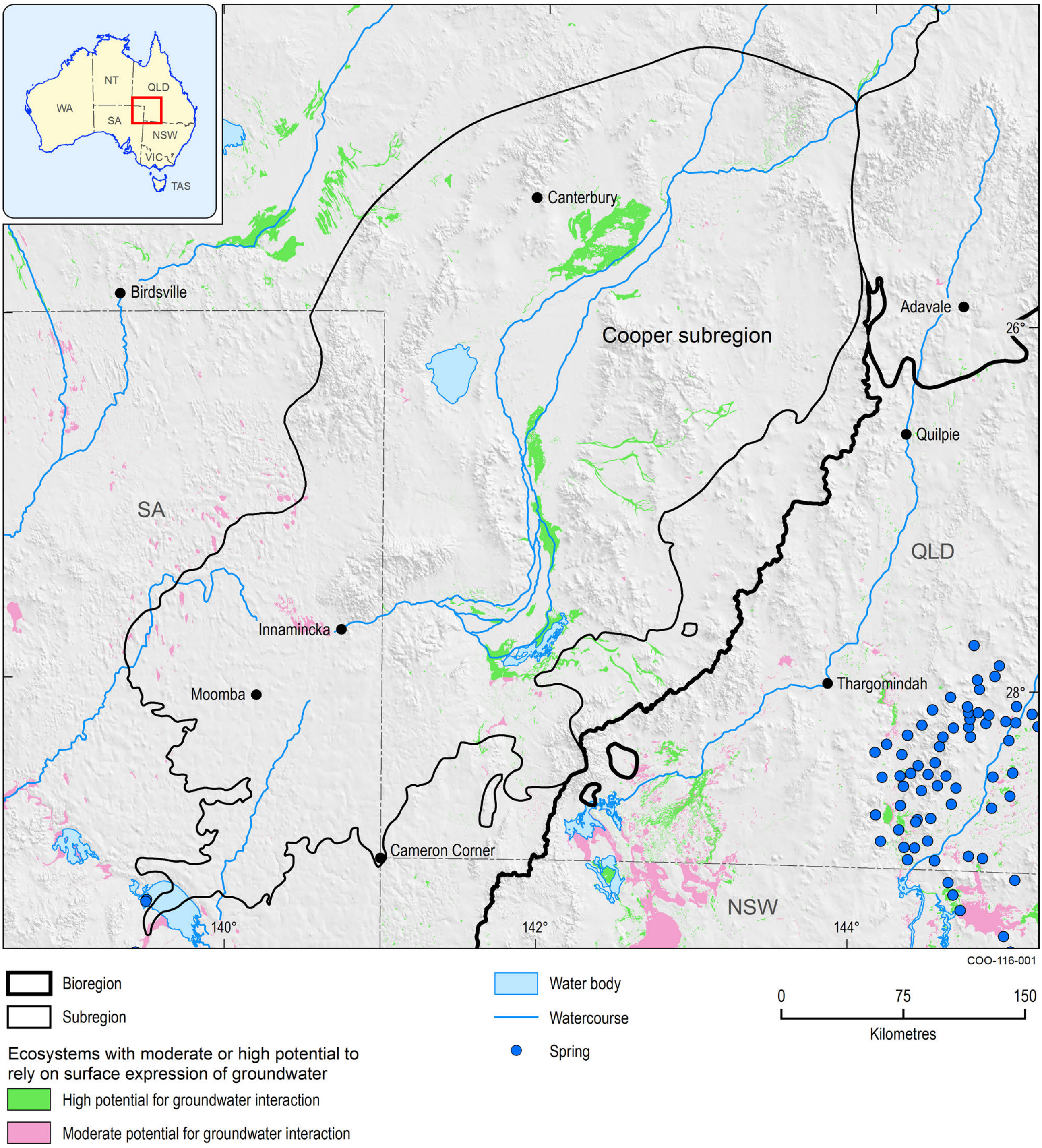

Figure 33 Map showing Great Artesian Basin discharge springs and ecosystems with a high or moderate potential to be reliant on the surface expression of groundwater in the Cooper subregion

Data: Bureau of Meteorology (Dataset 1); Queensland Herbarium, Environmental Protection Agency (Dataset 2)

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1.1.7 Ecology

Summary

The Cooper subregion has a high diversity of ecological communities and species as a consequence of the interactions between its large area, its diversity of surface geological types and soils, a gradient of rainfall seasonality, and the importance of landscape form driving water and soil redistribution in semi-arid environments of inland Australia. This diversity is expressed through the presence of 14 subregions of the Interim Biogeographic Regionalisation for Australia (IBRA; Department of the Environment, 2014a; SEWPaC, Dataset 1) and 27 major vegetation subgroups of the National Vegetation Information System (NVIS; Department of the Environment, 2014b; Australian Government Department of the Environment, Dataset 3). Pastoral grazing is by far the most frequent land use (>80%) and conservation reserves occupy around 9%.

The most common terrestrial vegetation NVIS subgroups are (i) Saltbush and/or bluebush shrublands, (ii) Mitchell grass (*Astrebla*) tussock grasslands, (iii) Hummock grasslands, and (iv) Mulga (*Acacia aneura*) open woodlands and shrublands. Other vegetation subgroups occur with lower frequency and form a mosaic that gradually changes from north-east to south-west across the subregion. However, there has been a lack of cross-border harmonisation of NVIS vegetation subgroups between states, meaning that it is difficult to interpret vegetation patterns for the subregion as a whole. The area has been subject to almost no clearance of vegetation. Pasture components are reported to have stable condition.

Wetlands listed formally in *A directory of important wetlands in Australia* (DIWA; Department of the Environment, 2014c; Australian Government Department of the Environment, Dataset 9) occupy 12.8% of the area of the Cooper subregion, and riverine floodplains that are also potentially water dependent occupy 12.2% of the area.

As rivers and lakes are all intermittent, the durations of flow and non-flow periods, as well as the depth of water, together are important determinants of the number of species locally per unit area and degree of species sharing amongst lakes, rivers and residual waterholes. The ecology of rock holes (shallow depressions that collect local rainwater) and outcrop springs (springs of water that has percolated through rock layers in the immediately surrounding area) is poorly studied, as is the ecology of the species that occur within aquifers below ground level (stygobiota). Discharge springs (springs of water that had percolated through rock layers over long distances and from which water emanates under pressure) are better studied, and numerous locally endemic species have been identified. While there are no discharge springs within the Cooper subregion, there are such springs in the immediately adjacent parts of the Great Artesian Basin which may be hydrologically connected to the Cooper subregion. The ecology of both discharge springs and stygobiota is understood to depend on relatively stable water regimes, compared with the highly intermittent character of other aquatic habitats in the region. Discharge springs are highly sensitive to changes in groundwater; over the last century, water drawdown for pastoralism has resulted in significant degradation such that as few as one-third of discharge springs identified in the

western Great Artesian Basin in 1900 are still active and leading to the bore-capping programme. There are no data on impacts of agricultural drawdown on stygobiota. Riverbanks and waterholes are generally assessed to be in better condition.

In the Cooper subregion, 18 species are listed nationally under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999*, of which only one species is water dependent beyond incident rainfall. While the community of native species dependent on natural discharge of groundwater from the Great Artesian Basin is also EPBC-listed, it is not found directly within the subregion. A further 45 species are listed under Queensland's *Nature Conservation Act 1992*, 48 species under NSW's *Threatened Species Conservation Act 1995*, and 82 species under SA's *National Parks and Wildlife Act 1972.*

1.1.7.1 Ecological systems

The Cooper subregion includes considerable ecological spatial variability as a consequence of its large area (130,000 km^2) which includes important interactions between the following environmental factors:

- a variety of surface geological features and associated soil types, including low ranges and breakaways, cracking clay plains, gibber plains, desert dune fields and alluvial floodplains
- a gradient in amount and seasonality of rainfall from the north-east corner, where rainfall is somewhat summer-dominated, to the south-west corner, where rainfall is weakly winter-dominated
- the strong influences of surface water redistribution after rain, even in landscapes with modest degrees of topographic relief, and of access to near-surface groundwater, as is typical of Australian arid and semi-arid landscapes (e.g. Stafford Smith and Morton, 1990).

As an indication of the variability within the Cooper subregion, 14 IBRA subregions (Figure 34; SEWPac, Dataset 1; Bioregional Assessment Programme, Dataset 2) and 27 major vegetation subgroups defined in the NVIS v4.1 classification (Figure 34, Table 10; Australian Government Department of the Environment, Dataset 3) are represented. The north-eastern half of the subregion, where mean annual rainfall is in the range 300 to 600 mm, is dominated by Mitchell grass (*Astrebla*) tussock grasslands and Mulga open woodlands and sparse shrublands. The south-western half, where rainfall is less than 300 mm, is dominated by Hummock grasslands and saltbush and/or bluebush shrublands, including the sparse forms occurring on gibber plains.

Wetlands listed in DIWA (Department of the Environment, 2014c; Australian Government Department of the Environment, Dataset 9) occupy 12.8% of the area of the subregion and include representation of 21 NVIS v4.1 major vegetation subgroups (Table 10). The Coongie Lakes reserve in the western part of the subregion (Reid and Gillen, 1988; Butcher and Hale, 2011) constitutes a large proportion of the DIWA-listed area. At more than 2 million ha, the Coongie Lakes and their surroundings constitute Australia's largest area designated as a wetland of international importance under the Ramsar Convention. A smaller Ramsar wetland, Lake Pinaroo, lies immediately south of the subregion, in NSW. Nationally mapped riverine floodplains that are also potentially water dependent, at least in part on a seasonal or multi-year basis through flooding and/or elevated watertable, occupy 12.2% and also include 21 of the vegetation subgroups found within the Cooper subregion (Table 10 and Figure 36). For both the DIWA wetlands and the riverine floodplains, the mapped areas include areas of vegetation subgroups that have low likelihood of being dependent on water in excess of local incident rainfall and sourced from subterranean and/or surface water flows (hereafter termed *water dependent* as per *Methodology for bioregional assessments of the impacts of coal seam gas and coal mining development on water resources* (BA methodology; Barrett et al., 2013)). The inclusion of non-water-dependent ecosystems in DIWA wetlands and riverine floodplains is due to the coarse resolution of existing map polygons which include some areas that are sufficiently distant from water bodies and/or sit well above ecologically accessible groundwater. The remaining 84.2% of the area is of terrestrial vegetation subgroups with limited likelihood of being water dependent.

Land use includes 12 of the 37 Australian Land Use and Management (ALUM) classification scheme secondary classes, but their occurrence is highly non-uniform (see Figure 9). Pastoral cattle grazing of native and semi-natural pasture, almost exclusively on leasehold lands (Figure 37), is by far the greatest land use (81.3% of the area), which is consistent with the predominance of semi-arid and arid climates, landscapes and vegetation community types. Conservation is the principal land use for 8.6% of the area, which is equal to the national average of 8.6% in the Australian National Reserve System (excluding lands of private and Indigenous landholders who have conservation amongst multiple land use objectives), above the Queensland average of 7.5% (Department of the Environment, 2012), and below the SA average of 13.7% (excluding regional reserves and Indigenous Protected Areas; 29.8% including these two categories) (Department of the Environment, 2012).

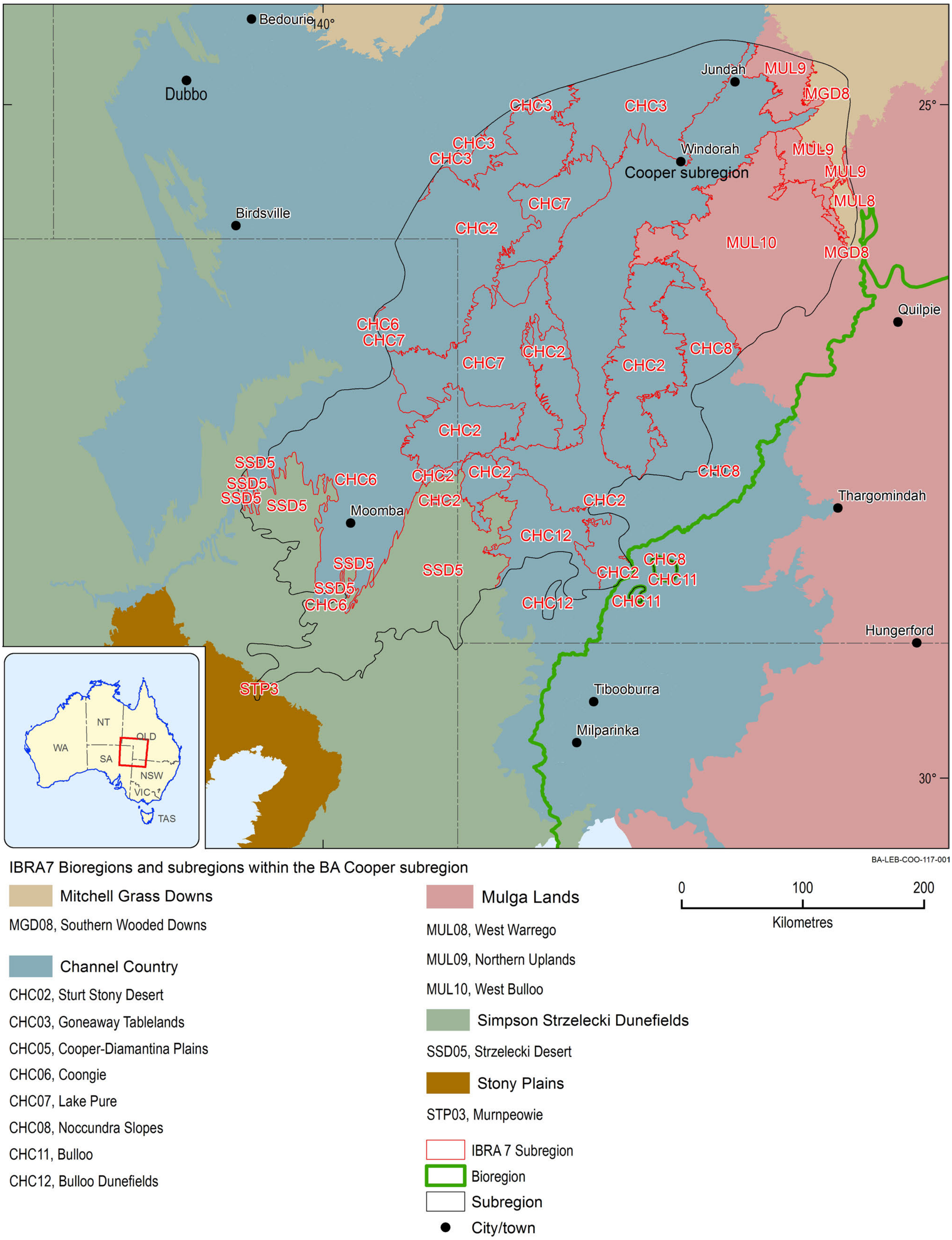

Figure 34 Interim Biogeographic Regionalisation for Australia subregions within the Cooper subregion

Data: SEWPaC (Dataset 1); Bioregional Assessment Programme (Dataset 2)

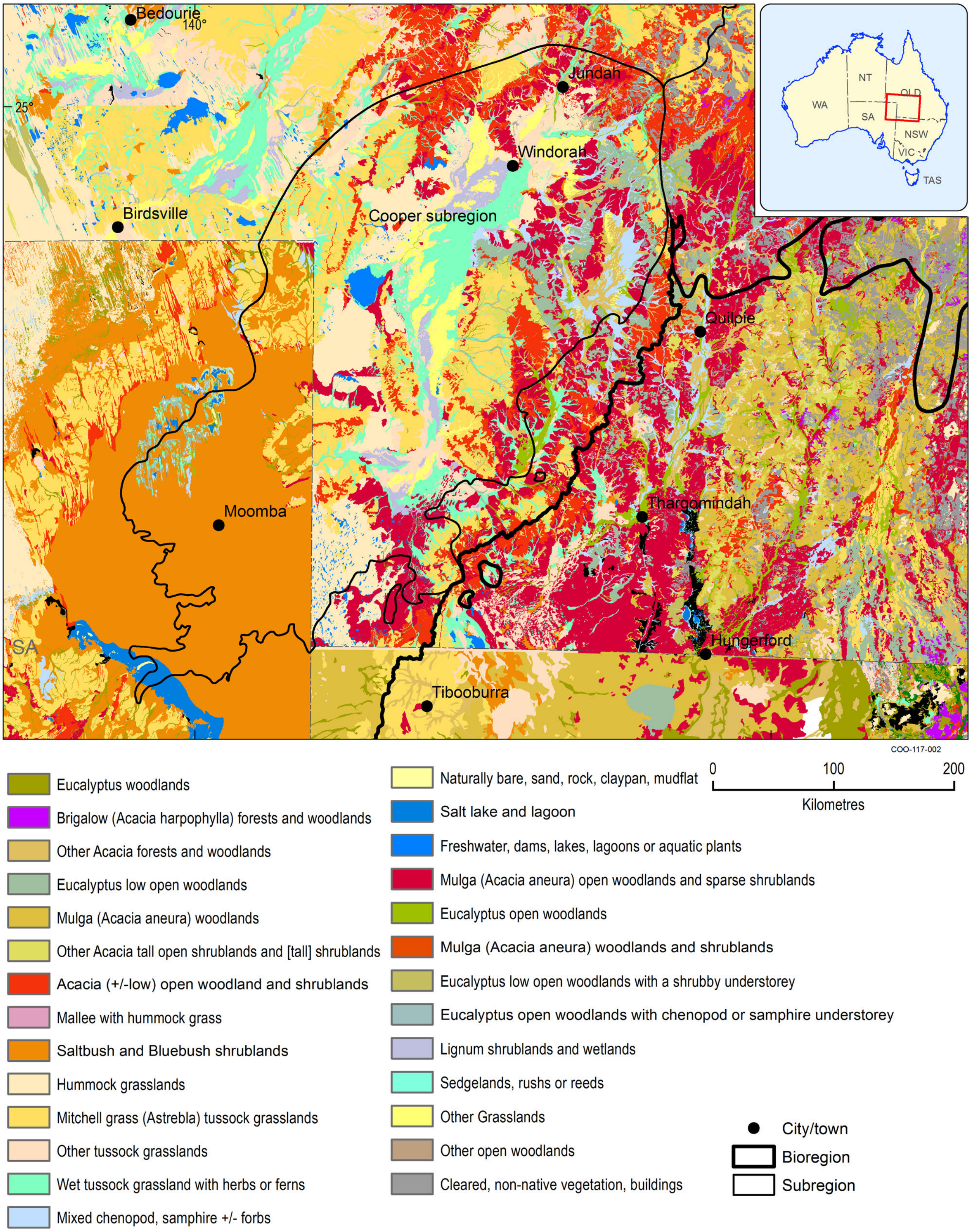

Figure 35 National Vegetation Information System major vegetation subgroups for the Cooper subregion

Data: Australian Government Department of the Environment (Dataset 3)

Table 10 National Vegetation Information System (v4.1) major vegetation subgroups in the Cooper subregion

Vegetation subgroups (in descending order of area)	Area of subgroup in subregion (ha)	Area of subgroup in subregion, as percentage of total area of subgroups (%)	Area of DIWA wetlands in the subgroup (ha)	Area of DIWA wetlands in the subgroup, as percentage of total area of subgroups (%)	Area of watercourses and floodplains in subgroup (ha)	Area of watercourses and floodplains in subgroup, as percentage of total area of subgroups (%)
Saltbush and/or bluebush shrublands	2,895,096	22.27%	1,064,180	64.16%	286,785	18.05%
Mitchell grass (*Astrebla*) tussock grasslands	2,002,662	15.41%	45,703	2.76%	4,528	0.28%
Hummock grasslands	1,474,259	11.34%	2,650	0.16%	4,522	0.28%
Mulga (*Acacia aneura*) open woodlands and sparse shrublands +/– tussock grass	1,381,198	10.63%	9,585	0.58%	10,952	0.69%
Wet tussock grassland with herbs, sedges or rushes, herblands or ferns	1,137,495	8.75%	116,449	7.02%	580,947	36.56%
Other tussock grasslands	589,746	4.54%	75,173	4.53%	192,393	12.11%
Acacia (+/– low) open woodlands and sparse shrublands +/– tussock grass	578,449	4.45%	84	0.01%	583	0.04%
Other grasslands	562,621	4.33%	27,524	1.66%	172,415	10.85%
Eucalyptus low open woodlands with tussock grass	451,653	3.47%	37	0.00%	5,043	0.32%
Mixed chenopod, samphire +/– forbs	345,079	2.65%	21,343	1.29%	26,014	1.64%
Other Acacia tall open shrublands and shrublands	254,801	1.96%	11,567	0.70%	1,194	0.08%
Other Acacia forests and woodlands	239,818	1.84%	0	0.00%	4,914	0.31%
Lignum shrublands and wetlands	233,256	1.79%	111,559	6.73%	219236	13.80%
Acacia (+/– low) open woodlands and sparse shrublands with hummock grass	178,675	1.37%	2,263	0.14%	453	0.03%
Freshwater, dams, lakes, lagoons or aquatic plants	133,003	1.02%	62,975	3.80%	5,138	0.32%
Eucalyptus open woodlands with a grassy understorey	81,374	0.63%	280	0.02%	26,213	1.65%

Vegetation subgroups (in descending order of area)	Area of subgroup in subregion (ha)	Area of subgroup in subregion, as percentage of total area of subgroups (%)	Area of DIWA wetlands in the subgroup (ha)	Area of DIWA wetlands in the subgroup, as percentage of total area of subgroups (%)	Area of watercourses and floodplains in subgroup (ha)	Area of watercourses and floodplains in subgroup, as percentage of total area of subgroups (%)
Acacia (+/– low) open woodlands and sparse shrublands with chenopods	78,322	0.60%	0	0.00%	1	<0.01%
Acacia (+/– low) open woodlands and sparse shrublands with a shrubby understorey	65,586	0.50%	0	0.00%	1	<0.01%
Eucalyptus woodlands with a shrubby understorey	64,726	0.50%	28,867	1.74%	12,994	0.82%
Cleared, non-native vegetation, buildings	61,652	0.47%	0	0.00%	319	0.02%
Salt lakes and lagoons	41,465	0.32%	31,142	1.88%	5,190	0.33%
Mulga (*Acacia aneura*) woodlands and shrublands +/- tussock grass +/– forbs	37,025	0.28%	0	0.00%	1,042	0.07%
Eucalyptus (+/– low) open woodlands with a chenopod or samphire understorey	36,358	0.28%	36,358	2.19%	23,880	1.50%
Eucalyptus open woodlands with shrubby understorey	21,376	0.16%	4,669	0.28%	2,415	0.15%
Other open woodlands	11,006	0.08%	0	0.00%	0	0.00%
Mallee with hummock grass	10,269	0.08%	0	0.00%	0	0.00%
Eucalyptus woodlands with a tussock grass understorey	10,084	0.08%	0	0.00%	2	<0.01%
Eucalyptus low open woodlands with a shrubby understorey	8,667	0.07%	2,079	0.13%	1,518	0.10%
Unknown/No data	4,528	0.03%	450	0.03%	438	0.03%
Naturally bare, sand, rock, claypan, mudflat	3,786	0.03%	3,766	0.23%	36	<0.01%
Eucalyptus low open woodlands with hummock grass	2,458	0.02%	0	0.00%	0	0.00%
Mulga (*Acacia aneura*) woodlands and shrublands with hummock grass	1,583	0.01%	0	0.00%	0	0.00%

Vegetation subgroups (in descending order of area)	Area of subgroup in subregion (ha)	Area of subgroup in subregion, as percentage of total area of subgroups (%)	Area of DIWA wetlands in the subgroup (ha)	Area of DIWA wetlands in the subgroup, as percentage of total area of subgroups (%)	Area of watercourses and floodplains in subgroup (ha)	Area of watercourses and floodplains in subgroup, as percentage of total area of subgroups (%)
Brigalow (*Acacia harpophylla*) forests and woodlands	825	0.01%	0	0.00%	0	0.00%
Sedgelands, rushes or reeds	360	<0.01%	0	0.00%	0	0.00%
Unclassified native vegetation	17	<0.01%	17	<0.01%	17	<0.01%
Total	**12,999,278**	**100.00%**	**1,658,720**	**100.00%**	**1,589,183**	**100.00%**

Data: Australian Government Department of the Environment (Dataset 3, Dataset 9); Geoscience Australia (Dataset 14)
Watercourses and floodplains from the combination of all other datasets listed as sources for Figure 36

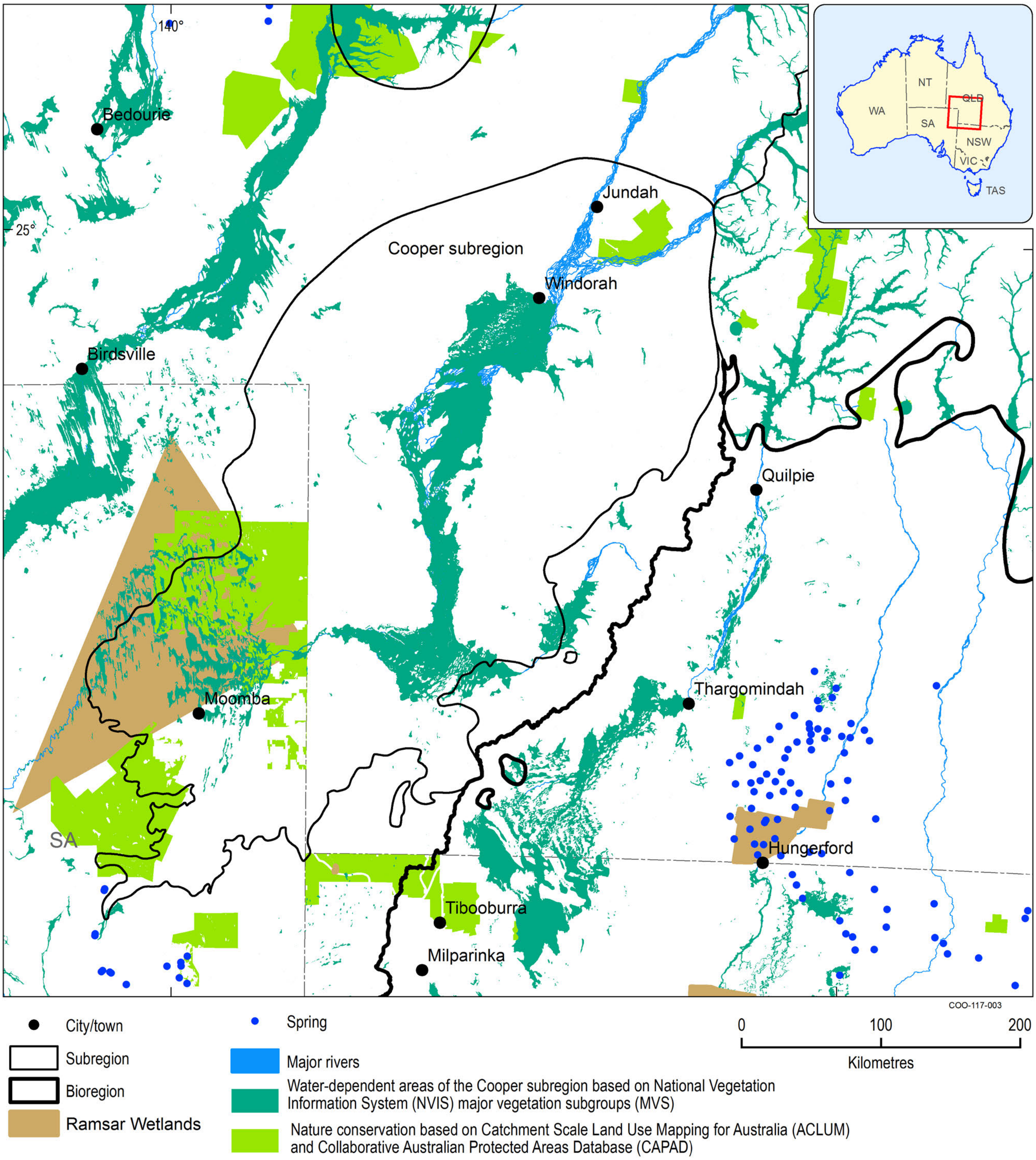

Figure 36 Conservation areas (including wetlands listed in *A directory of important wetlands in Australia*), springs and riverine floodplains with potential for water dependence for the Cooper subregion

Data: Bioregional Assessment Programme (Dataset 4); Queensland Herbarium, Environmental Protection Agency (Dataset 5); Australian Government Department of the Environment (Dataset 3); Geoscience Australia (Dataset 6, Dataset 7, Dataset 8); Australian Government Department of the Environment (Dataset 9, Dataset 10)

Table 11 Australian Land Use and Management Classification (version 7) land use classes in the Cooper subregion

ALUM secondary land use class	Area in subregion (ha)	Area in subregion, as percentage of total (%)
Grazing natural vegetation	10,568,872	81.30%
Nature conservation	1,113,135	8.56%
Mining	814,609	6.27%
Marsh/wetland	401,843	3.09%
Lake	96,063	0.74%
River	2,298	0.02%
Utilities	1,500	0.01%
Transport and communication	346	<0.01%
Reservoir/dam	160	<0.01%
Services	179	<0.01%
Residential and farm infrastructure	178	<0.01%
Manufacturing and industrial	95	<0.01%
Total	**12,999,278**	

Data: ABARE-BRS (Dataset 15)

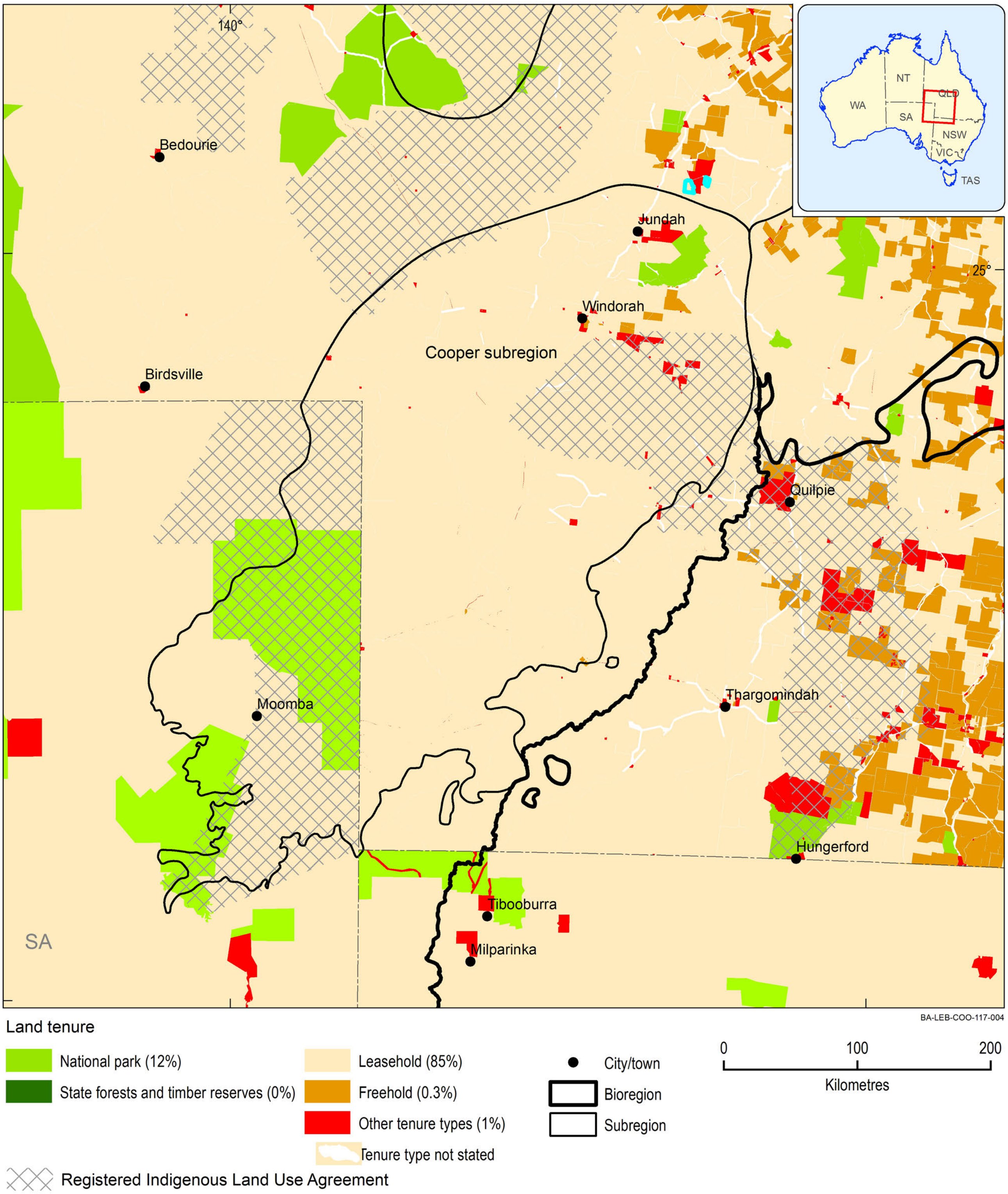

Figure 37 Land tenure as at 2009 for the Cooper subregion

Data: Geoscience Australia (Dataset 11, Dataset 12, Dataset 13)

1.1.7.2 Terrestrial species and communities

1.1.7.2.1 Principal vegetation types and distribution patterns

According to the NVIS v4.1 data (Australian Government Department of the Environment, Dataset 3), saltbush and/or bluebush shrublands is the most widespread terrestrial NVIS v4.1 major vegetation subgroup in the Cooper subregion (22.3% by area, occurring primarily in the western half of the subregion), followed by Mitchell grass (*Astrebla*) tussock grasslands (15.4%, primarily in the central and northern parts of the subregion), Hummock grasslands (11.3%) and Mulga (*Acacia aneura*) open woodlands and sparse shrublands (10.6%). Eleven other vegetation subgroups each cover 1 to 10% of the subregion (130,000 to 1,300,000 ha each) and 19 vegetation subgroups (excluding 'No data') each cover less than 1% of the subregion (<130,000 ha each) (Table 10).

At smaller-scale mapping, these vegetation subgroups have been delineated as discrete communities that respond to drainage patterns, topographic and edaphic variation. However, in larger-scale mapping, vegetation type mosaics have been identified, causing more homogeneous interpretation of the NVIS classification and thus causing difficulty in harmonising the vegetation mapping across state borders (Figure 34). The consequence of this scale issue is that major boundaries between vegetation subgroups occur along state borders, when there are no corresponding boundaries in terms of surface geology, soils or drainage patterns. For example, east of Moomba, saltbush and/or bluebush shrublands in SA (the most common NVIS vegetation subgroup in the subregion) abut Hummock grasslands in Queensland (the third most common NVIS in the subregion). Furthermore, a complex of vegetation subgroups along Cooper Creek and its floodplains in Queensland are not mapped across the border into SA. Due to this difference in the scale of mapping across state borders it not possible to develop relative abundance of NVIS major vegetation subgroups as terrestrial ecological context for the Cooper subregion as a whole.

1.1.7.2.2 Recent change and trend

Very early in the Euro-Australian settlement of central and western Queensland, the Eucalyptus open woodlands with a grassy understorey (along Cooper Creek and major tributaries), the Mitchell grass (*Astrebla*) tussock grasslands (on cracking clay soils) and all other tussock grasslands and wetlands were recognised as vegetation types with a combination of plant growth and palatability characteristics that would yield high livestock productivity under pastoral grazing systems (Orr and Holmes, 1984; Burrows et al., 1988). After more than a century of extensive cattle grazing, the bulk of these vegetation types in the Cooper subregion are now classed as 'modified' or 'transformed', according to the Vegetation Assets, States and Transitions (VAST) classification of Thackway and Lesslie (2005). In this classification, 'modified' and 'transformed' mean that the dominant structuring native species are present, but their levels of dominance have been significantly altered, and their natural regenerative capacity is limited or at risk under past and/or current land use or land management practice. Adventive, exotic plant species may be present or common, but are only co-dominant in the understorey where the vegetation is 'transformed'. Remote and unpalatable vegetation types, such as Hummock grasslands (on desert dune fields), are the only vegetation types in the Cooper subregion that retain their original or 'residual' status according to the VAST classification.

As part of Queensland activities for the Australian Collaborative Rangeland Information System (ACRIS), Bastin et al. (2014) have recently completed an analysis of trend in condition of the non-woody component of the native terrestrial vegetation across Queensland's rangelands, including the north-eastern part of the Cooper subregion. Using multi-temporal remote sensing data and analyses based on landscape heterogeneity and functionality, Bastin et al. report that the three IBRA subregions that partly lie within the Cooper subregion showed approximately stable to slightly improving range condition over the period 1988 to either 2003 or 2005 (depending on drought sequences).

1.1.7.2.3 Species and ecological communities of national significance

Table 12 lists species of national significance listed under the Commonwealth's *Environmental Protection and Biodiversity Conservation Act 1999* (the EPBC Act) that are known to occur in the Cooper subregion through specimens or human observations, or for which their occurrence is likely based upon analysis of the distribution of suitable habitat. All but one of those species can be identified as having low or no water dependence in the sense of the BA methodology (Barrett et al., 2013) and thus can be considered terrestrial.

There are no EPBC-listed terrestrial ecological communities within, or near, the Cooper subregion.

1.1.7.2.4 Species of regional significance

Table 13 lists taxa of regional significance under Queensland's *Nature Conservation Act 1992*. There are 45 taxa that occur in the Cooper subregion but are not also listed nationally.

Table 14 lists the 48 taxa of regional significance under NSW's *Threatened Species Conservation Act 1995*.

Table 15 lists the taxa (including some subspecies) of regional significance under SA's *National Parks and Wildlife Act 1972.* There are 82 taxa that occur in the Cooper subregion but are not also listed nationally. Fifty-three of those species can be identified as having low or no water dependence in the sense of the BA methodology (Barrett et al., 2013) and thus can be considered terrestrial.

Table 12 Species and ecological communities in the Cooper subregion that are listed as threatened nationally under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)

Biodiversity asset group	Scientific name	Common name	Status under the EPBC Act	Occurrence in subregion	Endemicity in subregion	Water dependence	Comments on water dependence
Plants	*Acacia peuce*	Waddy, Waddi, Waddy-wood, Birdsville wattle	Vulnerable	Likely	Low	Low	No specific mention of water dependence
	Frankenia plicata		Endangered	Known	Low	Moderate	Drainage lines
	Grevillea kennedyana	Flame spiderflower	Vulnerable	Likely	High	Moderate	No specific mention of water dependence
	Hakea maconochieana		Vulnerable	Likely	Low	Low	No specific mention of water dependence
	Xerothamnella parvifolia		Vulnerable	Likely	High	Low	No specific mention of water dependence
Reptiles	*Acanthophis hawkei*	Plains Death Adder	Vulnerable	Known	Low	Low	Treeless floodplain, habitat that is favoured by its prey (frogs)
	Egernia rugosa	Yakka skink	Vulnerable	Maybe	Low	Low	No specific mention of water dependence
Birds	*Amytornis barbatus barbatus*	Grey grasswren (bulloo)	Vulnerable	Known	High	High	Swampy floodplains
	Amytornis modestus	Thickbilled grasswren	Vulnerable	Likely	Low	Low	May favour drainage lines, but not exclusively
	Erythrotriorchis radiatus	Red goshawk	Vulnerable	Maybe	Low	Moderate	
	Neochmia ruficauda ruficauda	Star finch (eastern), star finch (southern)	Endangered	Likely	Low	Moderate	Grasslands and grassy woodlands that are located close to bodies of fresh water
	Pedionomus torquatus	Plains-wanderer	Vulnerable	Likely	Moderate	Low	No specific mention of water dependence
	Rostratula benghalensis (sensu lato)	Painted snipe	Endangered, migratory	Likely	Low	High	Shallow terrestrial freshwater (occasionally brackish) wetlands

Biodiversity asset group	Scientific name	Common name	Status under the EPBC Act	Occur-rence in subregion	Endemi-city in subregion	Water depend-ence	Comments on water dependence
Mammals	*Dasyuroides byrnei*	Kowari	Vulnerable	Likely	Low	Low	No specific mention of water dependence
	Macrotis lagotis	Greater bilby	Vulnerable	Likely	Low	Low	No specific mention of water dependence
	Notomys fuscus	Dusky Hopping-mouse, Wilkiniti	Vulnerable	Likely	Low	Low	No specific mention of water dependence
	Pseudomys australis	Plains rat, Palyoora	Vulnerable	May	Low	Low	Gypseous cracking clay areas associated with minor drainage features
	Sminthopsis douglasi	Julia Creek dunnart	Endangered	Known	Low	Low	No specific mention of water dependence

Data: Department of the Environment (2014d)
Source database includes comments on water dependence

Table 13 Species in the Queensland part of the Cooper subregion (Shires of Barcoo, Bulloo and Quilpie, and parts of Shires of Diamantina and Longreach) that are listed as threatened under Queensland's *Nature Conservation Act 1992* and *Nature Conservation (Wildlife) Regulation 2006* (updated to 27 September 2013), and under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)

Biodiversity asset type	Family	Scientific name	Common name	Status under Queensland's legislation	Status under the EPBC Act	Water dependent (aquatic)
Plants	Acanthaceae	*Rhaphidospora bonneyana*		Vulnerable	Vulnerable	
	Acanthaceae	*Xerothamnella parvifolia*		Vulnerable	Vulnerable	
	Amaranthaceae	*Ptilotus brachyanthus*		Endangered		
	Amaranthaceae	*Ptilotus maconochiei*		Near threatened		
	Amaranthaceae	*Ptilotus pseudohelipteroides*		Near threatened		
	Araliaceae	*Hydrocotyle dipleura*		Vulnerable		Yes
	Asteraceae	*Calocephalus* sp. *(Eulo M.E.Ballingall MEB2590)*		Near threatened		
	Asteraceae	*Calotis suffruticosa*		Near threatened		
	Asteraceae	*Rhodanthe rufescens*		Near threatened		
	Byttneriaceae	*Commersonia salviifolia*		Near threatened		
	Chenopodiaceae	*Atriplex lobativalvis*		Near threatened		
	Chenopodiaceae	*Atriplex morrisii*		Vulnerable		
	Chenopodiaceae	*Sclerolaena blackiana*	Black's copperburr	Near threatened		
	Chenopodiaceae	*Sclerolaena walkeri*		Vulnerable	Vulnerable	
	Cucurbitaceae	*Austrobryonia argillicola*		Endangered		
	Euphorbiaceae	*Euphorbia sarcostemmoides*	Climbing caustic	Vulnerable		
	Fabaceae	*Indigofera oxyrachis*		Vulnerable		
	Goodeniaceae	*Goodenia angustifolia*		Near threatened		
	Mimosaceae	*Acacia ammophila*		Vulnerable	Vulnerable	
	Mimosaceae	*Acacia peuce*	Waddy	Vulnerable	Vulnerable	
	Mimosaceae	*Acacia spania*		Near threatened		
	Myoporaceae	*Eremophila tetraptera*		Vulnerable		

Biodiversity asset type	Family	Scientific name	Common name	Status under Queensland's legislation	Status under the EPBC Act	Water dependent (aquatic)
	Myrtaceae	*Melaleuca kunzeoides*		Vulnerable	Vulnerable	
	Myrtaceae	*Micromyrtus rotundifolia*		Vulnerable		
	Myrtaceae	*Thryptomene hexandra*		Near threatened		
	Proteaceae	*Grevillea kennedyana*		Vulnerable	Vulnerable	
	Proteaceae	*Hakea maconochieana*		Vulnerable	Vulnerable	
	Scrophulariaceae	*Elacholoma hornii*		Near threatened		
	Scrophulariaceae	*Rhamphicarpa australiensis*		Near threatened		
Amphibians	Hylidae	*Cyclorana verrucosa*	Rough-collared frog	Near threatened		Yes
Reptiles	Boidae	*Aspidites ramsayi*	Woma	Near threatened		
	Diplodactylidae	*Strophurus taenicauda*	Golden-tailed gecko	Near threatened		
	Elapidae	*Acanthophis antarcticus*	Common death adder	Near threatened		
	Elapidae	*Oxyuranus microlepidotus*	Western taipan	Near threatened		
	Pygopodidae	*Paradelma orientalis*	Brigalow scaly-foot	Vulnerable		
	Scincidae	*Ctenotus ariadnae*		Near threatened		
	Scincidae	*Ctenotus septenarius*		Near threatened		
	Scincidae	*Ctenotus serotinus*		Near threatened		
	Scincidae	*Egernia rugosa*	Yakka skink	Vulnerable	Vulnerable	
Birds	Acanthizidae	*Pyrrholaemus brunneus*	Redthroat	Near threatened		
	Accipitridae	*Accipiter novaehollandiae*	Grey goshawk	Near threatened		
	Accipitridae	*Erythrotriorchis radiatus*	Red goshawk	Endangered	Vulnerable	
	Accipitridae	*Lophoictinia isura*	Square-tailed kite	Near threatened		
	Anatidae	*Stictonetta naevosa*	Freckled duck	Near threatened		
	Cacatuidae	*Calyptorhynchus lathami*	Glossy black-cockatoo	Vulnerable		

Biodiversity asset type	Family	Scientific name	Common name	Status under Queensland's legislation	Status under the EPBC Act	Water dependent (aquatic)
	Cacatuidae	*Lophochroa leadbeateri*	Major Mitchell's cockatoo	Vulnerable		
	Ciconiidae	*Ephippiorhynchus asiaticus*	Black-necked stork	Near threatened		
	Columbidae	*Geophaps scripta scripta*	Squatter pigeon (southern subspecies)	Vulnerable	Vulnerable	Yes
	Falconidae	*Falco hypoleucos*	Grey falcon	Near threatened		
	Maluridae	*Amytornis barbatus*	Grey grasswren	Near threatened		
	Maluridae	*Amytornis striatus*	Striated grasswren	Near threatened		
	Meliphagidae	*Epthianura crocea*	Yellow chat	Vulnerable		
	Meliphagidae	*Grantiella picta*	Painted honeyeater	Vulnerable		
	Meliphagidae	*Melithreptus gularis*	Black-chinned honeyeater	Near threatened		
	Pedionomidae	*Pedionomus torquatus*	Plains-wanderer	Vulnerable	Vulnerable	
	Psittacidae	*Pezoporus occidentalis*	Night parrot	Endangered	Endangered	
	Rostratulidae	*Rostratula australis*	Australian painted snipe	Vulnerable	Endangered	Yes
Mammals	Dasyuridae	*Dasycercus blythi*	Brush-tailed mulgara	Vulnerable	Vulnerable	
	Dasyuridae	*Dasycercus cristicauda*	Crest-tailed mulgara	Vulnerable	Endangered	
	Dasyuridae	*Dasyuroides byrnei*	Kowari	Vulnerable	Vulnerable	
	Macropodidae	*Onychogalea fraenata*	Bridled nailtail wallaby	Endangered	Endangered	
	Megadermatidae	*Macroderma gigas*	Ghost bat	Vulnerable		
	Muridae	*Notomys fuscus*	Dusky hopping-mouse	Endangered	Vulnerable	
	Muridae	*Pseudomys australis*	Plains rat	Endangered	Vulnerable	
	Peramelidae	*Macrotis lagotis*	Greater bilby	Endangered	Vulnerable	
	Vespertilionidae	*Chalinolobus picatus*	Little pied bat	Near threatened		

Data: DSITIA (Dataset 16, Dataset 17)
Source database does not include comments on water dependence, but a preliminary comment on water dependence is included here for consistency with Table 12.

Table 14 Species in the NSW part of the Cooper subregion (Strzelecki Desert subregion of the West Dunefields Catchment Management Authority) that are listed as threatened under NSW's *Threatened Species Conservation Act 1995*

Biodiversity asset type	Scientific name	Common name	Status under NSW legislation	Distribution in Strzelecki Desert subregion	Water dependent (aquatic)
Plants	*Acacia carneorum*	Purple-wood wattle	Vulnerable	Known	
	Atriplex infrequens	A saltbush	Vulnerable	Predicted	
	Crotalaria cunninghamii	Green bird flower	Endangered	Known	
	Dipteracanthus australasicus orynothecus		Endangered	Known	
	Dysphania platycarpa		Endangered	Predicted	
	Glinus orygioides		Presumed extinct	Known	
	Grevillea kennedyana	Flame spider flower	Vulnerable	Known	
	Ipomoea polymorpha	Silky cow-vine	Endangered	Known	
	Kippistia suaedifolia	Fleshy minuria	Endangered	Known	
	Osteocarpum pentapterum		Presumed extinct	Known	
	Polycarpaea spirostylis glabra		Endangered	Predicted	
	Scaevola collaris	Fan flower	Endangered	Predicted	
	Stackhousia clementii		Endangered	Known	
Reptiles	*Aspidites ramsayi*	Woma	Vulnerable	Predicted	
	Ctenophorus decresii	Tawny crevice-dragon	Endangered	Predicted	
	Ctenotus brooksi	Wedge-snout ctenotus	Vulnerable	Known	
	Ctenotus pantherinus ocellifer	Leopard ctenotus	Endangered	Predicted	
	Cyclodomorphus venustus		Endangered	Predicted	
	Demansia torquata	Collared whip snake	Vulnerable	Known	
	Diplodactylus conspicillatus	Fat-tailed diplodactylus	Endangered	Predicted	
	Lerista xanthura	Yellow-tailed plain slider	Vulnerable	Known	
	Lucasium stenodactylum	Crowned gecko	Vulnerable	Known	
	Ramphotyphlops endoterus	Interior blind snake	Endangered	Known	
	Simoselaps fasciolatus	Narrow-banded snake	Vulnerable	Known	
	Tiliqua multifasciata	Centralian blue-tongued lizard	Vulnerable	Known	

Biodiversity asset type	Scientific name	Common name	Status under NSW legislation	Distribution in Strzelecki Desert subregion	Water dependent (aquatic)
Birds	*Ardeotis australis*	Australian bustard	Endangered	Known	
	Certhionyx variegatus	Pied honeyeater	Vulnerable	Known	
	Circus assimilis	Spotted harrier	Vulnerable	Known	
	Climacteris picumnus victoriae	Brown treecreeper (eastern subspecies)	Vulnerable	Known	
	Epthianura albifrons	White-fronted chat	Vulnerable	Known	
	Falco hypoleucos	Grey falcon	Endangered	Known	
	Falco subniger	Black falcon	Vulnerable	Known	
	Grantiella picta	Painted honeyeater	Vulnerable	Predicted	
	Grus rubicunda	Brolga	Vulnerable	Known	
	Hamirostra melanosternon	Black-breasted buzzard	Vulnerable	Known	
	Hieraaetus morphnoides	Little eagle	Vulnerable	Known	
	Limosa limosa	Black-tailed godwit	Vulnerable	Known	Yes
	Melanodryas cucullata cucullata	Hooded robin (south-eastern form)	Vulnerable	Known	
	Oxyura australis	Blue-billed duck	Vulnerable	Known	Yes
	Pedionomus torquatus	Plains-wanderer	Endangered	Predicted	
	Pomatostomus halli	Hall's babbler	Vulnerable	Predicted	
	Pyrrholaemus brunneus	Redthroat	Vulnerable	Known	
	Stictonetta naevosa	Freckled duck	Vulnerable	Known	Yes
Mammals	*Antechinomys laniger*	Kultarr	Endangered	Known	
	Chaeropus ecaudatus	Pig-footed bandicoot	Presumed extinct	Known	
	Chalinolobus picatus	Little pied bat	Vulnerable	Predicted	
	Saccolaimus flaviventris	Yellow-bellied sheathtail-bat	Vulnerable	Known	
	Sminthopsis macroura	Stripe-faced dunnart	Vulnerable	Known	

Data: NSW Office of Environment and Heritage (Dataset 18). Source database does not include comments on water dependence, but a preliminary comment on water dependence is included here for consistency with Table 12.

Table 15 Species in the South Australian part of the Cooper subregion (Coongie, Sturt Stony Desert, Lake Pure and Strzelecki Desert IBRA subregions) that are listed as threatened under SA's *National Parks and Wildlife Act 1972*, including their threat status in the South Australian Outback region as assessed by Gillam and Urban (2013)

Biodiversity asset type	Scientific name	Common name	Status under the EPBC Act	Status under South Australian legislation	Status in the Outback region of SA	Trend in the Outback region of SA	Water dependent (aquatic)
Plants	*Acacia carneorum*	Needle wattle	Vulnerable	Vulnerable	Vulnerable	No trend detected	
	Acacia georginae	Georgina gidgee		Rare	Rare	No trend detected	
	Acacia pickardii	Pickard's wattle	Vulnerable	Rare	Rare	No trend detected	
	Acacia tenuissima	Slender wattle		Rare	Rare	-	
	Atriplex eichleri	Eichler's saltbush		Rare	Near threatened	No trend detected	
	Atriplex papillata	Coral saltbush		Endangered	Vulnerable	-	
	Bergia occultipetala			Vulnerable	Near threatened	No trend detected	
	Calandrinia stagnensis			Rare	Rare	-	
	Callitriche sonderi	Matted water starwort		Rare	Near threatened	No trend detected	Yes
	Cyperus bifax	Downs flat-sedge		Rare	Rare	-	Yes
	Cyperus concinnus			Rare	Rare	No trend detected	Yes
	Cyperus dactylotes			Vulnerable	Vulnerable	No trend detected	Yes
	Cyperus nervulosus			Rare	Near threatened	-	Yes
	Eleocharis plana	Flat spike-rush		Rare	Rare	No trend detected	Yes
	Eragrostis lacunaria	Purple love-grass		Rare	Rare	No trend detected	
	Eremophila polyclada	Twiggy emubush		Rare	Vulnerable	-	
	Frankenia cupularis			Rare	Near threatened	No trend detected	
	Frankenia plicata		Endangered	Vulnerable		-	
	Gilesia biniflora	Western tar-vine		Rare	Near threatened	No trend detected	
	Malacocera gracilis	Slender soft-horns		Vulnerable	Rare	No trend detected	

Biodiversity asset type	Scientific name	Common name	Status under the EPBC Act	Status under South Australian legislation	Status in the Outback region of SA	Trend in the Outback region of SA	Water dependent (aquatic)
	Mimulus prostratus	Small monkey-flower		Rare	Near threatened	No trend detected	Yes
	Neurachne lanigera	Woolly mulga-grass		Rare	Vulnerable	Decline	
	Nymphoides crenata	Wavy marshwort		Rare	Endangered	Decline	Yes
	Ophioglossum polyphyllum	Large adder's-tongue		Rare	Rare	-	Maybe
	Orobanche cernua var. australiana	Australian broomrape		Rare	Near threatened	No trend detected	
	Osteocarpum acropterum var. deminutum	Wingless bonefruit		Rare	Rare	-	
	Osteocarpum pentapterum	Five-wing bonefruit		Endangered	Vulnerable	Decline	
	Phlegmatospermum eremaeum	Spreading cress		Rare		-	
	Pimelea penicillaris	Sandhill riceflower		Rare	Vulnerable	No trend detected	
	Sauropus ramosissimus			Vulnerable	Vulnerable	No trend detected	
	Sclerolaena blackiana	Black's bindyi		Rare	Near threatened	No trend detected	
	Stylidium desertorum			Vulnerable	Vulnerable	No trend detected	
	Swainsona oligophylla			Rare	Near threatened	No trend detected	
	Zygophyllum humillimum	Small-fruit twinleaf		Rare	Near threatened	No trend detected	
Amphibians	*Cyclorana cultripes*	Knife-footed frog		Rare	Rare	-	Yes
	Uperoleia capitulata	Small-headed toadlet		Rare	Rare	-	Yes
Reptiles	*Aspidites ramsayi*	Woma		Rare	Near threatened	No trend detected	
	Ctenotus astarte	Ashy downs ctenotus		Rare	Rare	No trend detected	
	Ctenotus joanae	Blacksoil ctenotus		Rare	Rare	No trend detected	

Biodiversity asset type	Scientific name	Common name	Status under the EPBC Act	Status under South Australian legislation	Status in the Outback region of SA	Trend in the Outback region of SA	Water dependent (aquatic)
	Demansia rimicola	Channel country whipsnake		Rare	Rare	No trend detected	
	Emydura macquarii	Macquarie tortoise		Vulnerable	Vulnerable	No trend detected	Yes
	Morelia spilota	Carpet python		Rare	Rare	Decline	
	Proablepharus kinghorni	Blacksoil skink		Rare	Rare	-	
Birds	*Actitis hypoleucos*	Common sandpiper		Rare	Rare	No trend detected	Yes
	Amytornis barbatus	Grey grasswren	Vulnerable	Rare	Vulnerable	No trend detected	
	Anas rhynchotis	Australasian shoveler		Rare	Rare	No trend detected	Yes
	Anhinga novaehollandiae	Australasian darter		Rare	Rare	No trend detected	Yes
	Anseranas semipalmata	Magpie goose		Endangered	Endangered	-	Yes
	Aprosmictus erythropterus	Red-winged parrot		Rare	Vulnerable	No trend detected	
	Ardea intermedia	Intermediate egret		Rare	Rare	No trend detected	Yes
	Ardeotis australis	Australian bustard		Vulnerable	Vulnerable	No trend detected	
	Biziura lobata	Musk duck		Rare	Rare	No trend detected	Yes
	Burhinus grallarius	Bush stone-curlew		Rare	Critically endangered	Decline	
	Cacatua leadbeateri	Major Mitchell's cockatoo		Rare	Endangered	Decline	
	Calidris subminuta	Long-toed stint		Rare	Rare	No trend detected	Yes
	Cladorhynchus leucocephalus	Banded stilt		Vulnerable	Rare	No trend detected	Yes
	Conopophila whitei	Grey honeyeater		Rare	Endangered	-	
	Egretta garzetta	Little egret		Rare	Rare	No trend detected	Yes
	Elanus scriptus	Letter-winged kite		Rare	Vulnerable	Decline	

Biodiversity asset type	Scientific name	Common name	Status under the EPBC Act	Status under South Australian legislation	Status in the Outback region of SA	Trend in the Outback region of SA	Water dependent (aquatic)
	Epthianura crocea	Yellow chat		Endangered	Endangered	Decline	
	Falco hypoleucos	Grey falcon		Rare	Endangered	Decline	
	Falco peregrinus	Peregrine falcon		Rare	Vulnerable	No trend detected	
	Gallinago hardwickii	Latham's snipe		Rare	Rare	No trend detected	Yes
	Geophaps plumifera	Spinifex pigeon		Rare	Vulnerable	Decline	
	Grantiella picta	Painted honeyeater		Rare	Endangered	-	
	Grus rubicunda	Brolga		Vulnerable	Vulnerable	No trend detected	
	Hamirostra melanosternon	Black-breasted buzzard		Rare	Rare	Decline	
	Limosa limosa	Black-tailed godwit		Rare	Rare	No trend detected	Yes
	Lophoictinia isura	Square-tailed kite		Endangered	Endangered	-	
	Melithreptus gularis laetior	Golden-backed honeyeater		Rare	Endangered	-	
	Myiagra inquieta	Restless flycatcher		Rare	Rare	No trend detected	
	Neophema chrysostoma	Blue-winged parrot		Vulnerable	Vulnerable	No trend detected	
	Ninox connivens	Barking owl		Rare	Endangered	No trend detected	
	Oxyura australis	Blue-billed duck		Rare	Rare	No trend detected	Yes
	Pedionomus torquatus	Plains-wanderer	Vulnerable	Endangered	Endangered	-	
	Pezoporus occidentalis	Night parrot	Endangered	Endangered	Critically endangered	-	
	Phaps histrionica	Flock bronzewing		Rare	Rare	Increase	
	Plegadis falcinellus	Glossy ibis		Rare	Rare	No trend detected	Yes
	Podiceps cristatus	Great crested grebe		Rare	Rare	No trend detected	Yes

Biodiversity asset type	Scientific name	Common name	Status under the EPBC Act	Status under South Australian legislation	Status in the Outback region of SA	Trend in the Outback region of SA	Water dependent (aquatic)
	Porzana tabuensis	Spotless crake		Rare	Rare	No trend detected	Yes
	Stictonetta naevosa	Freckled duck		Vulnerable	Rare	No trend detected	Yes
	Tringa glareola	Wood sandpiper		Rare	Rare	No trend detected	Yes
	Tyto longimembris	Eastern grass owl		Rare	Critically endangered	No trend detected	
	Tyto novaehollandiae	Australian masked owl		Endangered	Critically endangered	-	
Mammals	*Caloprymnus campestris*	Desert rat-kangaroo	Extinct	Endangered	Regionally extinct	No trend detected	
	Chalinolobus picatus	Little pied bat		Endangered	Insufficient data	-	
	Dasycercus byrnei	Kowari	Vulnerable	Vulnerable	Vulnerable	Decline	
	Isoodon auratus	Golden bandicoot	Vulnerable	Endangered	Regionally extinct	No trend detected	
	Macropus giganteus	Eastern grey kangaroo		Rare	Rare	-	
	Macrotis lagotis	Bilby (Greater bilby)	Vulnerable	Vulnerable	Vulnerable	No trend detected	
	Macrotis leucura	Lesser bilby	Extinct	Endangered	Regionally extinct	No trend detected	
	Notomys cervinus	Fawn hopping-mouse		Vulnerable	Vulnerable	No trend detected	
	Notomys fuscus	Dusky hopping-mouse	Vulnerable	Vulnerable	Least concern	-	
	Pseudomys australis	Plains mouse (plains rat)	Vulnerable	Vulnerable	Rare	Decline	
	Saccolaimus flaviventris	Yellow-bellied sheathtail-bat		Rare	Insufficient data	-	

Data: Gillam and Urban (2013). Source database does not include comments on water dependence, but a preliminary comment on water dependence is included here for consistency with Table 12.
'-' means insufficient data

1.1.7.3 Aquatic species and communities

1.1.7.3.1 Classification of aquatic habitats

The aquatic habitats in the Cooper subregion can be classified using the work of Jaensch (1999), Eamus et al. (2006), Kennard et al. (2010) and Fensham et al. (2011). None of these four classifications alone describes the range of water-dependent ecosystems at a consistent resolution sufficient for the BA methodology (Barrett et al., 2013), but in combination they provide robust coverage of the range of water-dependent ecosystem types.

Jaensch (1999) developed a classification of the wetlands of the south-western quadrant of Queensland, which included the Queensland parts of the Cooper subregion (Table 16). While originally developed only for the parts of the Lake Eyre drainage catchment that falls within Queensland, the classification applies equally well to the wetlands of the Lake Eyre drainage catchment in SA, that is, in the western half of the Cooper subregion. Nineteen of the wetland classes occur within the Cooper subregion (Queensland and SA combined). Artesian springs occur to the west, north and east of the Cooper subregion. Permanent freshwater lakes are restricted to the uplands of the Great Dividing Range, in the headwaters of the Lake Eyre Basin and distant from the boundary of the subregion.

Eamus et al. (2006) proposed three simple primary classes of groundwater-dependent ecosystems:

- ecosystems dependent on the surface expression of groundwater, including baseflow rivers and streams, wetlands, some floodplains and mound springs. This class of groundwater-dependent ecosystems requires a surface expression of groundwater, which may, in many cases, then soak below the soil surface and thereby become available to plant roots
- ecosystems dependent on the subsurface presence of groundwater, often accessed via the capillary fringe (non-saturated zone above the saturated zone of the watertable) when roots penetrate this zone. No surface expression of groundwater is required in this class of groundwater-dependent ecosystems
- aquifer and cave ecosystems. These ecosystems include karstic, fractured rock and alluvial aquifers. The hyporheic zones of rivers and floodplains is considered in this category because these ecotones often support species that are obligate groundwater inhabitants.

The Cooper subregion lacks any ecosystems dependent on flows of groundwater at the level of the soil surface, although artesian springs occur nearby, to the west, north and east. The other two classes occur within the subregion and are associated with the major drainage lines, especially Cooper Creek. Aquifer ecosystems were not recognised in the classification of Jaensch (1999, see above) and thus there would be merit in extension of that classification to include a new class for aquifer ecosystems.

Table 16 Wetland types of south-western Queensland, as defined by Jaensch (1999)

Wetland type		Presence in subregion: Yes = present Near = present in Lake Eyre Basin, to the west or north
Waterholes and watercourses		
1	Permanent river reaches and waterholes	Yes
2	Wooded watercourses	Yes
3	Shrubby floodplain watercourses	Yes
4	Watercourses without trees and shrubs	Yes
Freshwater lakes		
5	Permanent, isolated freshwater lakes	No
6	Oxbows (cut-off river bends)	Yes
7	Temporary freshwater lakes without grassland	Yes
8	Temporary freshwater lakes with couch grassland	Yes
Saline lakes		
9	Semi-permanent saline lakes	Yes
10	Temporary saline lakes	Yes
Swamps		
11	Gibber and interdunal claypan aggregations	Yes
12	Isolated claypans and canegrass swamps	Yes
13	Sedge swamps	Yes
14	Forb meadows on floodplains	Yes
15	Lignum swamps	Yes
16	Bluebush swamps	Yes
17	Cooba shrubby swamps	Yes
18	Eucalypt wooded swamps	Yes
19	Acacia/belah wooded swamps	Yes
Springs		
20	Artesian springs	Near
Rock holes		
21	Rock holes in arid uplands	Yes

Through an analysis of stream gauge data from across Australia, Kennard et al. (2010) developed a classification of surface water flow regimes for creeks, rivers and river segments. Four of twelve flow regime classes are likely to occur in watercourses in the Cooper subregion:

- predictable winter highly intermittent
- predictable summer highly intermittent
- unpredictable summer intermittent
- variable summer intermittent.

Each of the four flow regime classes was found at least once in different stretches of Cooper Creek and its tributaries. There is some indication of systematic longitudinal variation of flow patterns along Cooper Creek, with south-western, downstream gauging stations indicating predictable winter intermittent flows, and north-eastern, upstream gauging stations indicating predictable or unpredictable summer intermittent flow regimes. However analytical difficulty may have led to somewhat similar flow patterns being assigned to different regime classes. With different seasonality and degrees of predictability, all observed river flow regimes are intermittent, meaning that the rivers largely dry up and retreat to waterholes between major flow events (Kennard et al., 2010). This is consistent with the findings of the Australia-wide analysis of low-flow rivers by Mackay et al. (2012); all stretches of rivers in and around the Cooper subregion were classified as highly or moderately ephemeral.

Fensham et al. (2011) developed a classification of permanent water bodies and natural wetlands, along rivers and elsewhere, for an area that substantially overlaps the subregion:

- waterholes – enlarged segments of an ephemeral or seasonal river or watercourse which hold water after streamflow has ceased
- rock holes – natural hollows in rocky landscapes, formed from fracturing and weathering, which store water from local runoff
- outcrop springs (referred to as *recharge springs* in the earlier terminology of Fensham and Fairfax (2003)) – dependent on groundwater and occurring where sediments that form the aquifer are outcropping
- discharge springs – dependent on groundwater that emanates through confining beds (aquitards) in areas remote from where the aquifer receives its inputs.

The ecological principles inherent in each of the regional classifications above have been incorporated into classifications of wetlands at state (Queensland) and national (across Queensland, NSW and SA) scales (Queensland WetlandInfo mapping – see Environmental Protection Agency, 2005; Interim Australian National Aquatic Ecosystem Classification Framework – see Aquatic Ecosystems Task Group, 2012). Both classifications have the advantage of completeness, with the Australian National Aquatic Ecosystem (ANAE) classification framework, in particular, including subterranean ecosystems.

1.1.7.3.2 Diversity and ecological drivers in aquatic habitats

There is a growing, but not yet comprehensive, literature on the key ecological drivers of aquatic communities of the Cooper subregion from which important principles are summarised in this section.

Rivers and waterholes

As foreshadowed in the above description of the Cooper subregion flow regime classification of Kennard et al. (2010), temporal patterns of water and of depth of water are the primary drivers of ecological characteristics of aquatic community type, species diversity and species abundance in rivers (Silcock, 2009) – with spatial connectivity and water salinity as secondary (and often related) drivers.

In Cooper Creek and other rivers of the Lake Eyre Basin, diversity of invertebrates, fish and birds at a broad (temporal) scale follows a boom-and-bust cycle. Booms are associated with high-flow periods and better water quality (Shiel et al., 2006; Kingsford et al., 2010; Sheldon and Fellows, 2010). Recent research suggests that the full range of booms are important, including both the spectacular sequences of flows that are able to fill all ‘hydrological sponges’ in a river system and its floodplains (Leigh et al., 2010b) as well as those that flow down river channels but do not spill across floodplains nor fill all billabongs and lakes associated with a river (Balcombe and Arthington, 2009; Kerezsy et al., 2011). For invertebrates and fish, booms result from population dynamics entirely within the river systems, but for nomadic waterbirds – which Kingsford et al. (2010) describe as ‘time and space travellers’ – diversity is not determined locally or by any one river system, but instead by the probability of viable resource patches across all river systems in inland Australia.

In the inland rivers, as floods recede and water flow is no longer continuous, waterholes and riverine wetlands take on the role of refuges, habitats to which a species population retreats and persists during times of environmental stress (Marshall et al., 2006; Silcock, 2009; Sheldon et al., 2010; Puckridge et al., 2010; Davis et al., 2013). Refuges during the dry period are important areas for the survival of species and persistence of water-dependent communities. Their physical habitat characteristics (e.g. surface area, depth, underwater benches, eroding banks and snags) influence aquatic species diversity and evenness. For example, fish community and macroinvertebrate composition changes with the size, depth and structural diversity of the refuges (Balcombe et al., 2006; Arthington et al., 2010; Puckridge et al., 2010).

Connectivity within and between inland river systems is the spatial analogue of temporal variation in flow rate, and the two are interlinked as larger floods or flood sequences permit spatial connection between locations that are geographically and hydrologically more distant within a river basin. Balcombe et al. (2006), Leigh and Sheldon (2009), Fensham et al. (2011) and Kerezsy et al. (2013) have all emphasised the role of connectivity between, or conversely isolation of, waterholes and wetland refuges. Kerezsy et al. (2013) demonstrated that in the Georgina–Mulligan river basin, to the north of the Cooper subregion, connectivity interacts with life history strategies of fish, so that species can be identified as either extreme or conservative dispersers. Connectivity within river systems during times of flood has also been identified as the most probable reason for the high level of similarity between the ecological communities of the many waterholes within inland river systems (Fensham et al., 2011).

Connectivity has its limits, as determined by the maximum extent of the biggest flood events, and lack of connectivity – especially isolation between river systems – also is an important factor in patterns of endemism. For example, Australian smelt, carp gudgeon and Cooper Creek catfish occur only in the Cooper river system, while golden goby and banded grunter that occur in other Lake Eyre Basin rivers are not in the Cooper river system (Fensham et al., 2011; Kerezsy et al., 2013).

The biological consequences of the interactions between connectivity during flood periods and isolation of waterholes during low-flow periods are illustrated well by the fish communities recorded in Lake Eyre Basin waterholes during non-flood conditions in 2012 and 2013 (Cockayne et al., 2013; Sternberg et al., 2014). Twenty-one native species of fish were recorded across the entire drainage basin, but only 3 to 13 fish species were detected at any one waterhole. Just four species (bony herring (*Nematalosa erebi*), desert rainbow fish (*Melanotaenia splendida tatei*), Hyrtl's tandan (*Neosilurus hyrtlii*) and Silver tandan (*Porochilus argenteus*)) represented more than 70% of the catch during three sampling campaigns, and were present at more than 50% of sites. The spangled perch (*Leiopotherapon unicolor*) was also present at more than 50% of sites, but at low abundance. The other 16 species were observed at few waterholes and in low numbers.

Despite the documented importance of connectivity along river systems, evidence for connectivity between aquatic and adjacent terrestrial ecosystems is relatively weak. Using stable isotope techniques to examine ecosystems along Cooper Creek, Bunn et al. (2003) and Fellows et al. (2007) have found that aquatic food webs in waterholes during non-flow periods depend almost exclusively on autochthonous carbon sources from within the waterhole or falling into the waterhole from the littoral zone, and very little from surrounding terrestrial sources. Likewise Arthington et al. (2010) could find little influence of medium-scale 'watershed' characteristics on fish assemblage structure in waterholes. Whilst major flood events might be expected to generate windows of connectivity between aquatic and floodplain ecosystems, there are as yet no data on the magnitudes of resource flows or population movements along floodplain gradients during floods.

Shiel et al. (2006) has shown the significance of water salinity in determination of zooplankton diversity and assemblage composition in the Lake Eyre Basin rivers and associated ephemeral waterbodies. The study observed generally lower species richness in sites of higher salinity, but concluded that the effects of salinity were site-specific and involved thresholds of change. The authors suggested that the threshold level for salinity at a site was probably dependent on the time span between flushing events of fresher water relative to the life history characteristics and physiological tolerances of individual species.

Lakes

Cooper Creek and its major tributaries have impermanent or near-permanent lakes associated with major floods overflowing into low-lying areas of floodplains (Jaensch, 1999). The Coongie Lakes, in the western part of the Cooper subregion, is probably the best studied example (Reid and Gillen, 1988; Puckridge et al., 2010).

The lakes associated with rivers experience the same boom-and-bust dynamics, and the same sensitivity to salinity, as described above for rivers and waterholes; indeed, the lakes are frequently the largest fillable pores within the hydrological sponges of the river system (Leigh et al., 2010b). Puckridge et al. (2010) demonstrated that with increasing of permanence of lake water, fish species diversity (richness, evenness) and disease incidence increased, but fish species dominance and macroinvertebrate abundance decreased. Only the more mobile species of fish were able to utilise food resources provided by lakes that were filled for only brief periods before drying out again. The more permanent lakes also have the greatest diversity of bird species (Kingsford et al., 2010), and for this reason many have received national or international conservation protection status.

Sheldon and Puckridge (1998), Puckridge et al. (1999, 2000) and Sheldon et al. (2002) go on to observe that flooding regime alone is not sufficient to explain the characteristics of overflow lakes in the Lake Eyre Basin catchments. Lakes associated with river systems should be seen as parts of complexes rather than individual habitats, complexes that include not only the rivers that deliver the inputs of water, but also the floodplains and swamps surrounding the rivers and lakes, since locations may alternate between ecosystem or habitat type during flood-drought cycles, and local mobility of species between habitats and locations may drive species diversity.

Swamps

Jaensch (1999) details a variety of types of swamps that are associated with the margins of rivers, oxbows, waterholes, lakes and springs, or the lower-lying parts of river floodplains. The dynamics and ecology of these wetlands is most likely determined primarily by surface water hydrology and seasonal or infrequent flooding from rivers and lakes, although in the wetland classes containing trees (e.g. Eucalypt wooded swamps and Acacia/belah wooded swamps), the trees are likely to be accessing groundwater. With the exclusion of the dependence of the trees on groundwater, the biodiversity and ecology of swamps are poorly studied in comparison with other wetland habitat types. Swamps are often mapped as terrestrial ecological communities and form part of the subregion’s complex mosaic of vegetation shown in Figure 34.

Rock holes

Fensham et al. (2011) observed that rock holes are poorly known in the Lake Eyre Basin. They document 18 permanent rock holes in three clusters in Paleogene sandstone ranges, including a group to the north-east of Windorah, on the north-eastern fringes of the Cooper subregion. Data were available on the biota of only five rock holes. All major groups of aquatic organisms had low diversity and abundance, and there was no evidence of endemism.

Outcrop springs

Fensham et al. (2011) mapped outcrop springs in two groups on the north-eastern fringes of the Cooper subregion: to the north-east and to the east of Windorah. More species were observed in outcrop springs than in rock holes, but all species observed were widespread. Geographically isolated populations of three species of plant, one species of mollusc (*Sermyla* sp.) and one species of fish (*Mogurnda clivicola*, the Flinders Ranges mogurnda) were observed, but no endemism was evident.

Discharge springs

Discharge springs have been studied to a much greater extent than outcrop springs. Fensham and Fairfax (2003) estimated that before 1900 there were 300 discharge spring complexes, or local clusters of springs, in the Great Artesian Basin (excluding Cape York Peninsula), of which only 36% (108 complexes) are still active. Most of these spring complexes lie around the margins of the Great Artesian Basin, including a group of spring complexes in the Bulloo catchment to the south-east of the Cooper subregion (the Eulo supergroup), a small group of springs near Lake Blanche immediately south-west of the subregion, and a substantial number of spring complexes in SA, to the west and south of Kati Thanda – Lake Eyre (see Greenslade et al., 1985; Zeidler and Ponder, 1989; Tyler et al., 1990; Harris, 1992, Lewis et al., 2013; Gotch, 2013). No discharge springs are known within the Cooper subregion, but discussion of them is included here on the basis of the precautionary principle, given possible connectivity of Great Artesian Basin aquifers beyond the bounds of the subregion.

Because the groundwater has a very long residence time in the Great Artesian Basin, discharge springs show minimal fluctuations in flow rates, and their biota are adapted to relatively stable environmental conditions (i.e. there is low resilience and low resistance to environmental change in the biota). Nevertheless these discharge springs communities do show distinct seasonal fluctuations associated with the seasonally variable balance between flow and evaporation (Lewis et al., 2013).

Isolation of discharge springs complexes means that they have the highest rates of endemism and genetic differentiation of any surface aquatic habitat type (Fensham and Price, 2004; Fensham et al., 2011; Gotch, 2013). Almost half of all species recorded from discharge springs in the Great Artesian Basin are endemic to the area. *Jardinella*, a genus of snail, is represented by 12 locally endemic species. Each of the three species of fish that are listed under the EPBC Act is restricted to a single springs complex. The significance of endemism led Fensham and Price (2004) to rank the discharge springs on degree of species endemism, as a basis for conservation prioritisation. The highest priority springs are not those closest to the Cooper subregion's boundaries.

Subsurface aquatic habitats

In the Cooper subregion, there is no information on the diversity and ecology of stygobiota, the suite of organisms that inhabit subterranean groundwater habitats. Humphreys (2006) and Tomlinson and Boulton (2010) report that the biodiversity of Australia's subsurface groundwater-dependent ecosystems is inconsistently characterised. Invertebrates (especially crustaceans) are well characterised only in the major artesian basins of WA, while microbial, fungal and protozoan diversity is virtually unexplored throughout Australia.

From the analysis of the ecological characteristics of groundwater environments by Tomlinson and Boulton (2010), it is, however, possible to identify, in principle, two sets of key drivers for subsurface ecosystems:

- The stygobiota is adapted to relatively stable environmental conditions compared with surface aquatic environments (except Great Artesian Basin discharge springs), and thus is likely to depend strongly on the stability of the groundwater regime and other abiotic environmental factors (i.e. there is low resilience and resistance amongst stygobiota).

- Because detritivorous microbes, rather than plants, are the basis of the food chain, ecosystem structure depends on carbon and nutrient inputs through vertical ecotones – the vadose zone in soil under terrestrial vegetation, and the hyporheic and littoral zones of springs, rivers and wetlands – and changes in resource fluxes through these ecotones could lead to change in stygobiota diversity and abundance.

1.1.7.3.3 Recent change and threatening processes

Ecological changes to –and potentially threatening processes for – rivers, waterholes, rock holes and outcrop springs are poorly documented for the Cooper subregion. Choy et al. (2002) undertook a survey of the ecological condition of reaches of Cooper Creek (as well as the Georgina and Diamantina rivers) and concluded that they were in generally good condition except for bank damage by cattle. However, Silcock (2009) indicated that river waterholes are being slowly degraded by the cumulative impacts of cattle, feral animals, native herbivores and their consequent total grazing pressure during dry periods. Increased grazing may lead to increased rates of soil erosion and deposition in the surrounding landscape, due to the combined effects of decreased vegetation cover, increased exposure of soil surfaces and surface destabilisation by trampling – resulting in sedimentation posing a potential threat to waterholes and associated biota.

Non-native fish seem to be a lesser threat in the rivers of the subregion than in other parts of Australia. Costelloe et al. (2010) concluded that non-native fish may be disadvantaged by, and their invasions have been hampered by, the extremely variable flow regimes in Lake Eyre Basin rivers and wetlands. However, there are small populations of exotic species in these river systems. In a multi-year survey of fish in waterholes throughout the Lake Eyre Basin, Cockayne et al. (2013) and Sternberg et al. (2014) reported low catches of exotic species (<1%).

The sleepy cod (*Oxyeleotris lineolatus*), a species native to tropical fresh waters in northern Australia, was first reported in the Thomson River in 2008 (Kerezsy, 2010). This species has potential to colonise channels throughout the Cooper Creek river system, but little is known of its interactions with native ecological communities. Cockayne et al. (2013) and Sternberg et al. (2014) also detected sleepy cod in Cooper Creek in 2012 and 2013. Cooper Creek also supports a population of goldfish (*Carassius auratus*), with their abundances and spatial distribution being highly variable but strongly linked to consecutive years of high flows (Cockayne et al., 2013). The eastern mosquito fish (*Gambusia holbrooki*) occurs in the lower parts of Cooper Creek, in the Warburton River and in the Neales River (Cockayne et al., 2013; Sternberg et al., 2014).

Change in discharge springs have been the subject of much closer scrutiny, because of both the large number of springs that have become inactive and the sensitivity of the remaining active springs to ecological impact. The past and current threatening processes are (Fensham and Fairfax, 2003; Fensham et al., 2011; Gotch, 2013; Kerezsy and Fensham, 2013):

- drawdown of groundwater for stock, irrigated agriculture and mining – a significant driver of inactivity and diminishment of springs
- excavation, including dredging, conversion to dams, wells, draining, and construction of raised concrete structures that limit surface flows away from the point of discharge. At least one form of excavation affects 26% of active springs (Fensham and Fairfax, 2003)

- impoundments
- exotic plants (23 species recorded by Fensham and Fairfax (2003)), including date palms (*Phoenix dactylifera*) and *Phragmites australis* (Gotch 2013), as well as plant species for ponded pastures (e.g. *Brachiara mutica, Echinochloa polystachya* and *Hymenachne acutiglumis*)
- pests, especially the eastern mosquito fish (*Gambusia holbrooki*; see Kerezsy and Fensham (2013) for more details) and the cane toad (*Rhinella marina*)
- feral animals, such as pigs, horses and donkeys (throughout the Great Artesian Basin area of Queensland), and camels (in western desert areas)
- sheep grazing of aquatic and littoral vegetation, and subsequent erosion of exposed soils (in southern areas).

Fensham and Fairfax (2003) record only three discharge spring complexes in national or conservation parks throughout the Great Artesian Basin, although some additional spring complexes have been afforded conservation status since 2003. Subject to effective management plans, park status affords those spring complexes protection against some of the threatening processes above, but aquifer drawdown is a more diffuse process that would also require coordinated management actions in surrounding lands regardless of designation.

1.1.7.3.4 Species and ecological communities of national significance

Only one unequivocally aquatic species is listed under the EPBC Act and is known to occur, or are likely to occur, in the Cooper subregion: the painted snipe (Table 12). Five other species are associated to a lesser degree with watercourses or floodplains.

The community of native species dependent on discharge springs in the Great Artesian Basin is listed under the EPBC Act for the subregion (Table 12), but occurs near the Cooper subregion rather than within the subregion. This community has become the focus of intense management concern as a result of its high levels of endemicity and the many potentially threatening processes that have been identified (e.g. Wilson, 1995; Fensham and Price, 2004; Queensland Environmental Protection Agency, 2005; Fensham et al., 2010; Fensham et al., 2011; Kerezsy and Fensham, 2013).

1.1.7.3.5 Species of regional significance

For the 45 taxa (including some subspecies) listed under Queensland's *Nature Conservation Act 1992* but not also listed under the EPBC Act (Table 13), there has been no formal assessment of which are associated with aquatic habitat types. However, it is possible to identify two taxa with clear water dependence using record and habitat data from the *Atlas of Living Australia* (Atlas of Living Australia, 2014):

- plant: *Hydrocotyle dipleura* (no common name)
- amphibian: *Cyclorana verrucosa* (rough-collared frog).

For the 48 species listed under NSW's *Threatened Species Conservation Act 1995* (Table 14), only two species of bird could be identified as having clear water dependence using record and habitat data from the *Atlas of living Australia* (Atlas of Living Australia, 2014):

- *Oxyura australis* (blue-billed duck)
- *Stictonella naevosa* (freckled duck).

For the 82 taxa (including some subspecies) listed under SA's *National Parks and Wildlife Act 1972* but not also listed under the EPBC Act (Table 15), nine plants, two amphibians, one reptile (*Emydura macquarii*, the Macquarie tortoise), and 17 birds (a range of ducks and waders) have demonstrable water dependence according to record and habitat data from the *Atlas of living Australia* (Atlas of Living Australia, 2014).

The Cooper Creek catfish (*Neosiluroides cooperensis*) is endemic to the Cooper Creek catchment, and has been recorded from locations within the subregion, but it is not listed as threatened under the EPBC Act, Queensland's *Nature Conservation Act 1992* nor SA's *National Parks and Wildlife Act 1972*.

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