Australian Government

BIOREGIONAL ASSESSMENTS

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

Context statement for the Maranoa-Balonne-Condamine subregion

Product 1.1 for the Maranoa-Balonne-Condamine subregion from the Northern Inland Catchments Bioregional Assessment

21 July 2014

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>.

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Authorship is listed in relative order of contribution.

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Condamine river weir on Darling Downs in Queensland
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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 publicly available, providing the opportunity for all other interested parties, including community, industry and government regulators, 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 experts, such as from state governments or universities, are 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 Hawkesbury-Nepean, Georges River and Wollongong Coast subregions, within the Southern Sydney Basin bioregion
- the Gippsland Basin bioregion.

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

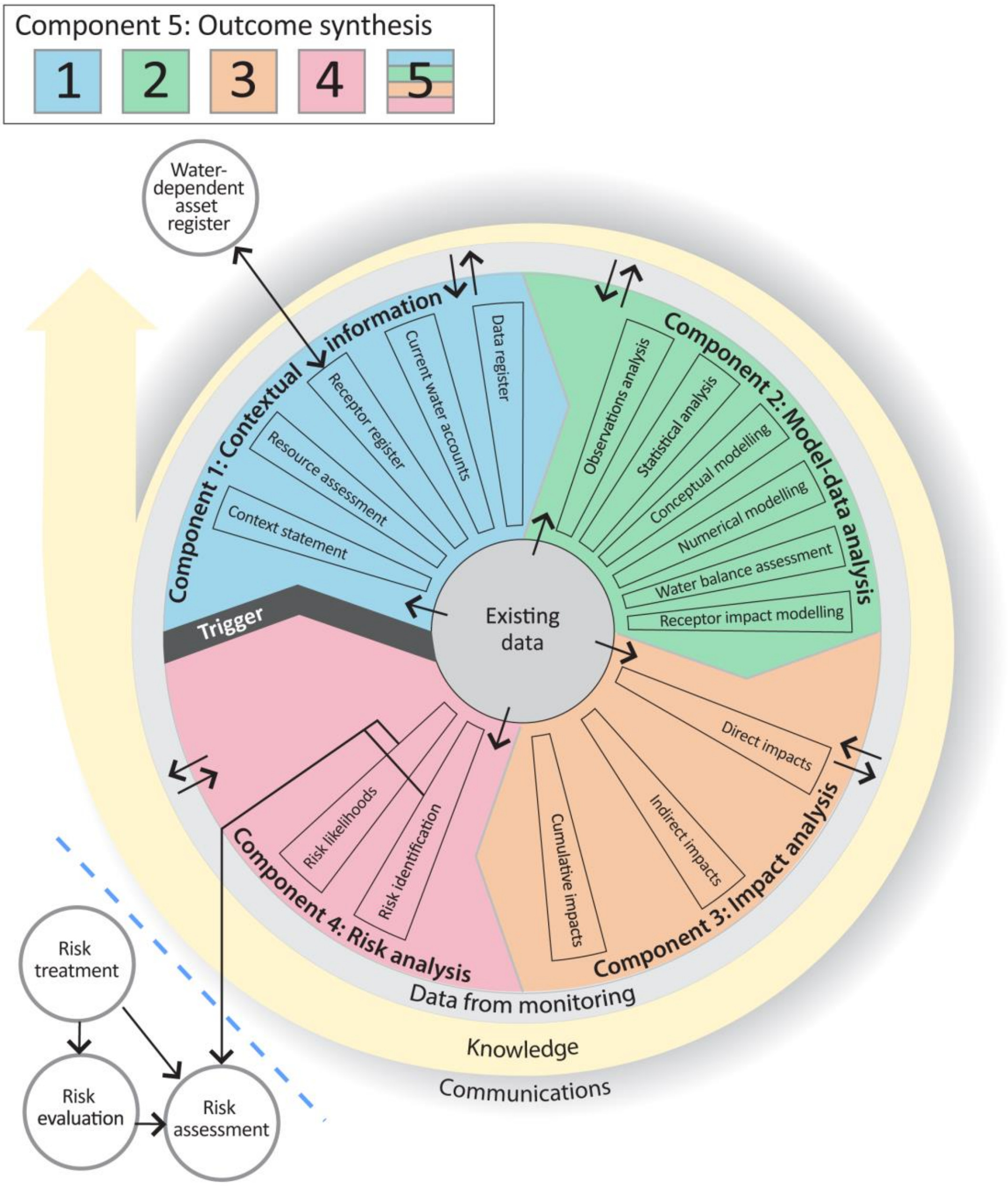

Figure 1 Schematic diagram of the bioregional assessment methodology

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 risk identification and risk likelihood components are conducted within a bioregional assessment and may contribute to risk evaluation, risk assessment and risk treatment undertaken externally.

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 large coal mining developments on water resources, both above and below ground. Importantly, these technical products are publicly available, 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 the BA methodology[1]. Figure 2 shows the information flow within a BA. Table 1 lists the content provided in the technical products, with cross-references to the part of the BA methodology that specifies it. The red ovals in both Figure 2 and Table 1 indicate the information presented for 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 the following website: <http://www.bioregionalassessments.gov.au>.

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.
- In January 2014, catchment management authorities were amalgamated into local land services <http://www.lls.nsw.gov.au>. This report was written before this change, so refers to catchment management authorities rather than local land services.
- All reasonable efforts were made to provide all material under a Creative Commons Attribution 3.0 Australia Licence. The copyright owners of the following figures, however, did not grant permission to do so: Figure 17 and Figure 24. It should be assumed that third parties are not entitled to use this material without permission from the copyright owner.
- All maps created as part of this BA for inclusion in this product used the Albers equal area projection with a central meridian of 151.0° East for the Northern Inland Catchments bioregion and two standard parallels of –18.0° and –36.0°.

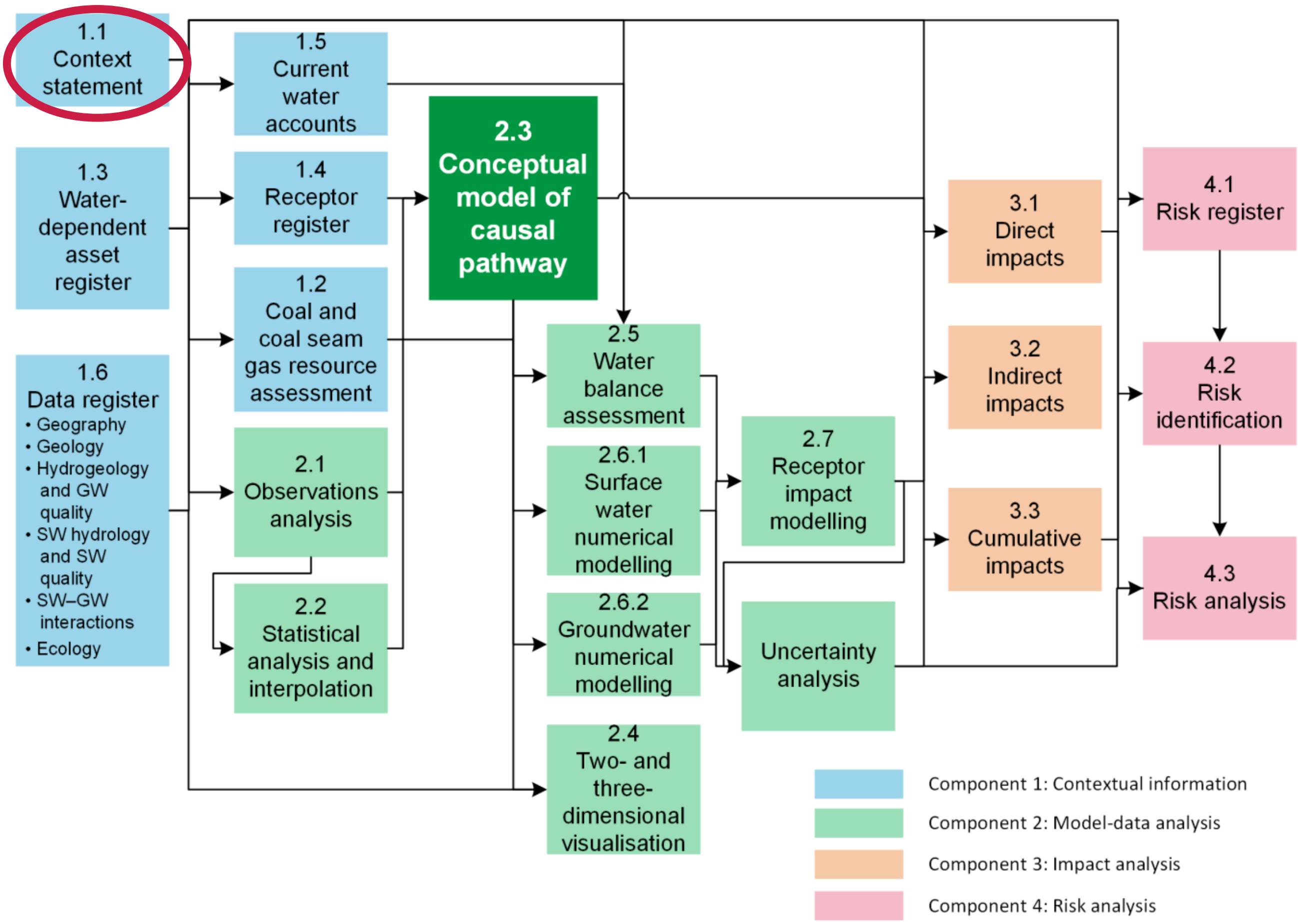

Figure 2 The simple decision tree indicates the flow of information through a bioregional assessment

The red oval indicates the information covered in this report.

Table 1 Technical reports being delivered as part of the Northern Inland Catchments Bioregional Assessment

For each subregion in the Northern Inland Catchments Bioregional Assessment, technical products will be delivered as data, summaries and reports (PDFs) as indicated by ■ in the last column of Table 1. Merged cells indicate that more than one product is reported in one report. The red oval indicates the information covered in this report. A suite of other technical and communication products – such as maps, registers and factsheets – will also be developed through the bioregional assessments.

	Product code	Information	Section in the BA methodology[a]	Report
Component 1: Contextual information for the Maranoa-Balonne-Condamine subregion	1.1	Context statement	2.5.1.1, 3.2	■
	1.2	Coal and coal seam gas resource assessment	2.5.1.2, 3.3	■
	1.3	Description of the water-dependent asset register	2.5.1.3, 3.4	■
	1.4	Description of the receptor register	2.5.1.4, 3.5	■
	1.5	Current water accounts and water quality	2.5.1.5	[b]
	1.6	Description of the data register	2.5.1.6	■
Component 2: Model-data analysis for the Maranoa-Balonne-Condamine subregion	2.1	Observations analysis	2.5.2.1	
	2.2	Statistical analysis and interpolation	2.5.2.2	
	2.3	Conceptual modelling	2.5.2.3, 4.3	■
	2.4	Two- and three-dimensional representations	4.2	[c]
	2.5	Water balance assessment	2.5.2.4	■[b]
	2.6.1	Surface water numerical modelling	4.4	■
	2.6.2	Groundwater numerical modelling	4.4	■
	2.7	Receptor impact modelling	2.5.2.6, 4.5	■
Component 3: Impact analysis for the Maranoa-Balonne-Condamine subregion	3.1	Direct impacts	5.2.1	■
	3.2	Indirect impacts	5.2.2	
	3.3	Cumulative impacts of mining	5.2.3	
	3.4	Baseline for other sectors	5.2.4	
Component 4: Risk analysis for the Maranoa-Balonne-Condamie subregion	4.1	Risk register	2.5.4, 5.3	■
	4.2	Risk identification	2.5.4, 5.3	
	4.3	Risk analysis	2.5.4, 5.3	
Component 5: Outcome synthesis for the Northern Inland Catchments bioregion	5.1	Synthesis of contextual information	2.5.5	■
	5.2	Synthesis of model-data analysis	2.5.5	
	5.3	Synthesis of impact analysis	2.5.5	
	5.4	Synthesis of risk analysis	2.5.5	

[a]Barrett et al. (2013)
[b]Product 1.5 (Current water accounts and water quality) will be included in the report for product 2.5 (Water balance assessment).
[c]The two- and three-dimensional representations will be delivered in products such as 2.3, 2.6.1 and 2.6.2.

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 18 July 2014, <http://www.environment.gov.au/coal-seam-gas-mining/pubs/methodology-bioregional-assessments.pdf>.

1.1 Context statement for the Maranoa-Balonne-Condamine subregion

The context statement summarises the current extent of knowledge on the ecology, hydrology, geology and hydrogeology of a bioregion. It provides baseline information that is relevant to understanding the regional context of water resources within which coal seam gas and coal mining development is occurring. 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 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; it is essentially a literature review of existing information. Thus, some figures are reproduced from other sources and the look and feel is not consistent with those produced in the Assessment. Likewise, results from different sources may use different methods or inconsistent units.

1.1.1 Bioregion

The Maranoa-Balonne-Condamine subregion is part of the Northern Inland Catchments bioregion (Figure 3). The Northern Inland Catchments bioregion is located west of the Great Dividing Range in eastern Australia. It includes parts of the northern Murray–Darling Basin in northern NSW and southern Queensland. Parts of the northern Murray–Darling Basin that are not underlain by coal are not included. The Northern Inland Catchments bioregion adjoins the Clarence-Moreton bioregion in the north-east, and the Northern Sydney Basin bioregion in the south. It covers an area of about 248,000 km^2.

The Maranoa-Balonne-Condamine subregion includes the Border Rivers, Maranoa-Balonne and Condamine natural resource management regions over the extent of the coal-bearing Surat and Clarence-Moreton geological basins. The subregion also extends west to include part of the eastern edge of the Queensland South West natural resource management region, and south to include part of the NSW North West Local Land Services region. The Maranoa-Balonne-Condamine subregion covers a smaller area than the combined Border Rivers, Moonie and Condamine-Balonne river basins; it does not extend beyond the coal-bearing geological basins.

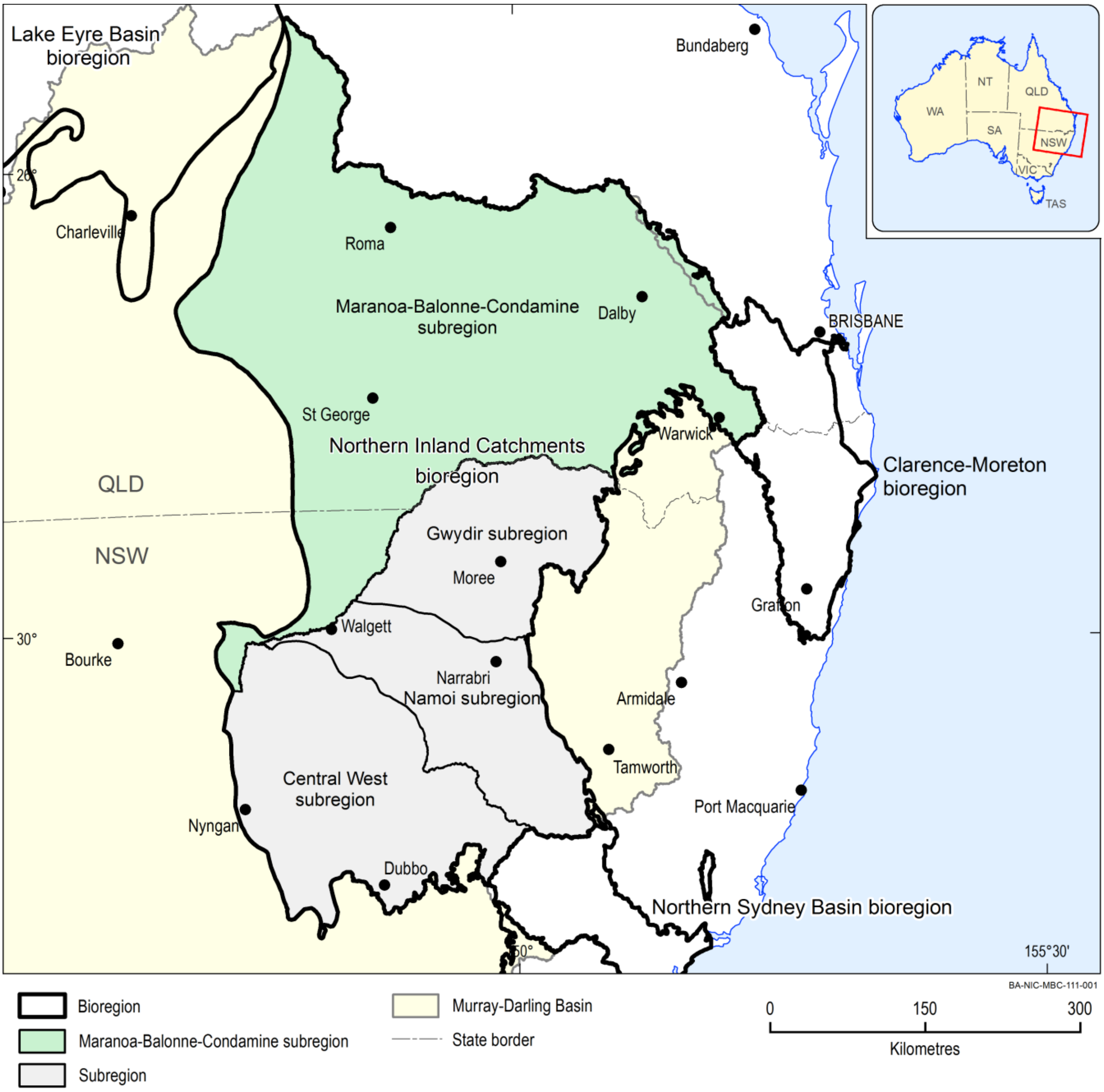

Figure 3 Northern Inland Catchments bioregion and subregions

1.1.2 Geography

Summary

The Maranoa-Balonne-Condamine subregion, in the Northern Inland Catchments bioregion, is located predominantly within the central and eastern part of the Queensland Murray–Darling Basin, with a small extension into NSW, west of the western margins of the three other Northern Inland Catchments subregions: Gwydir, Namoi and Central West (Figure 3). It spans an area of 144,890 km^2, extending from the headwaters of the Condamine River in the east and the Maranoa River in the north-west to floodplains of the Upper Darling Plains, where the river system fans out into a number of distributary channels, which discharge into the Barwon-Darling River system and the Narran Lakes system. Maximum and minimum elevations for the subregion itself are about 1350 mAHD in the Great Dividing Range and 100 mAHD west of Brewarrina in NSW, respectively.

The main rivers draining the subregion are the Condamine-Balonne, Maranoa, Moonie and Macintyre rivers, but these become or feed into other rivers, including the Narran, Culgoa and Bokhara rivers, and ultimately the Barwon-Darling River. The most significant water-dependent assets are the nationally significant Balonne River Floodplains, Gums Lagoon, Lake Broadwater, and Blackfellows Creek. The Culgoa River Floodplains (Queensland and NSW) and the Narran Lakes system (NSW) are downstream of the subregion. The northern part of the Narran Lakes system is an internationally significant wetland under the Ramsar Convention.

Soils vary considerably across the subregion, with extensive areas of Vertosols and Sodosols. The Vertosols are well structured and have a good mix of pores for both transmitting and storing water, so plant growth on these soils is typically very good relative to other soil types and they are productive or highly productive for agriculture. Kandosols are extensive in the west, particularly on the lower Balonne and lower Moonie floodplains. Overall, the land and soil resources of the subregion mean that the majority of the area is deemed ‘good quality agricultural land’ (QMDC, 2008). The most limiting land and soil hazards in the subregion are soil fertility decline, soil acidification and salinity. A number of legal and planning instruments have been introduced in Queensland to protect and conserve the land and soil resources.

The subregion has undergone significant modification of its land cover, with most areas having between 10 and 30% of their pre-clearing vegetation. Since the introduction of Queensland’s *Vegetation Management Act 1999*, land clearing rates have fallen dramatically. The historical loss of wetlands is up to 70% across the Queensland Murray–Darling Basin. There are six endangered ecological communities that are protected under the Commonwealth’s *Environment Protection and Biodiversity Conservation Act 1999*.

The subregion has an average annual rainfall of 585 mm (1900 to 2011). The climate varies from temperate conditions with no dry season and warm to hot summers in the upland areas to hot, persistently dry climate in the west.

The main population centres are Toowoomba, Warwick, Dalby, Chinchilla, Roma, St George and Goondiwindi. Agriculture is the mainstay of the economy, with the gross value of agricultural production in the Condamine and the Border Rivers Maranoa-Balonne natural resource management regions in 2010–11 estimated at $2.4 billion (ABS, 2012). Domestic tourism contributed $1.1 billion to the regional economy in 2011–12 (TQ, 2012).

1.1.2.1 Physical geography

The Maranoa-Balonne-Condamine subregion in the Northern Inland Catchments bioregion is located predominantly within the central and eastern part of the Queensland Murray–Darling Basin, with a small extension into NSW, west of the western margins of the three other subregions in the Northern Inland Catchments bioregion: Gwydir, Namoi and Central West (Figure 3). Its eastern boundary is defined by the Great Dividing Range, its northern boundary by the topographic divide with the Fitzroy river basin, and its south-eastern boundary by the Clarence-Moreton bioregion. The Dumaresq-Macintyre and Barwon rivers delineate the southern boundary, while the western boundary is defined by the western extent of the geological Surat Basin.

The subregion spans an area of 144,890 km^2, with elevations ranging from a maximum of 1350 mAHD in the Great Dividing Range (headwaters of the Condamine) to a minimum of about 100 mAHD near Brewarrina in NSW (Figure 4). The subregion extends north and westwards from the headwaters of the Condamine River near Warwick, taking in the prime cropping lands of the Darling Downs and mixed grazing and cropping lands further west. East of Surat, the Condamine River becomes the Balonne River (Figure 5). It flows westward through Surat and then southward to Beardmore Dam, where it is joined by the Maranoa River. Downstream of St George, the river spreads out onto the Upper Darling Plains, where it fans out into a number of distributary channels, including the Culgoa and Bokhara, which discharge into the Barwon-Darling River system, and the Narran River which terminates in the Narran Lakes system. The Macintyre, Moonie and Weir rivers are other significant rivers in the southern part of the subregion. The Moonie and Weir rivers join with the Macintyre north of Collarenebri in NSW. The southern portion of the Macintyre river basin, which is in NSW, is included within the Gwydir subregion. More detail on the surface water hydrology can be found in Section 1.1.5.

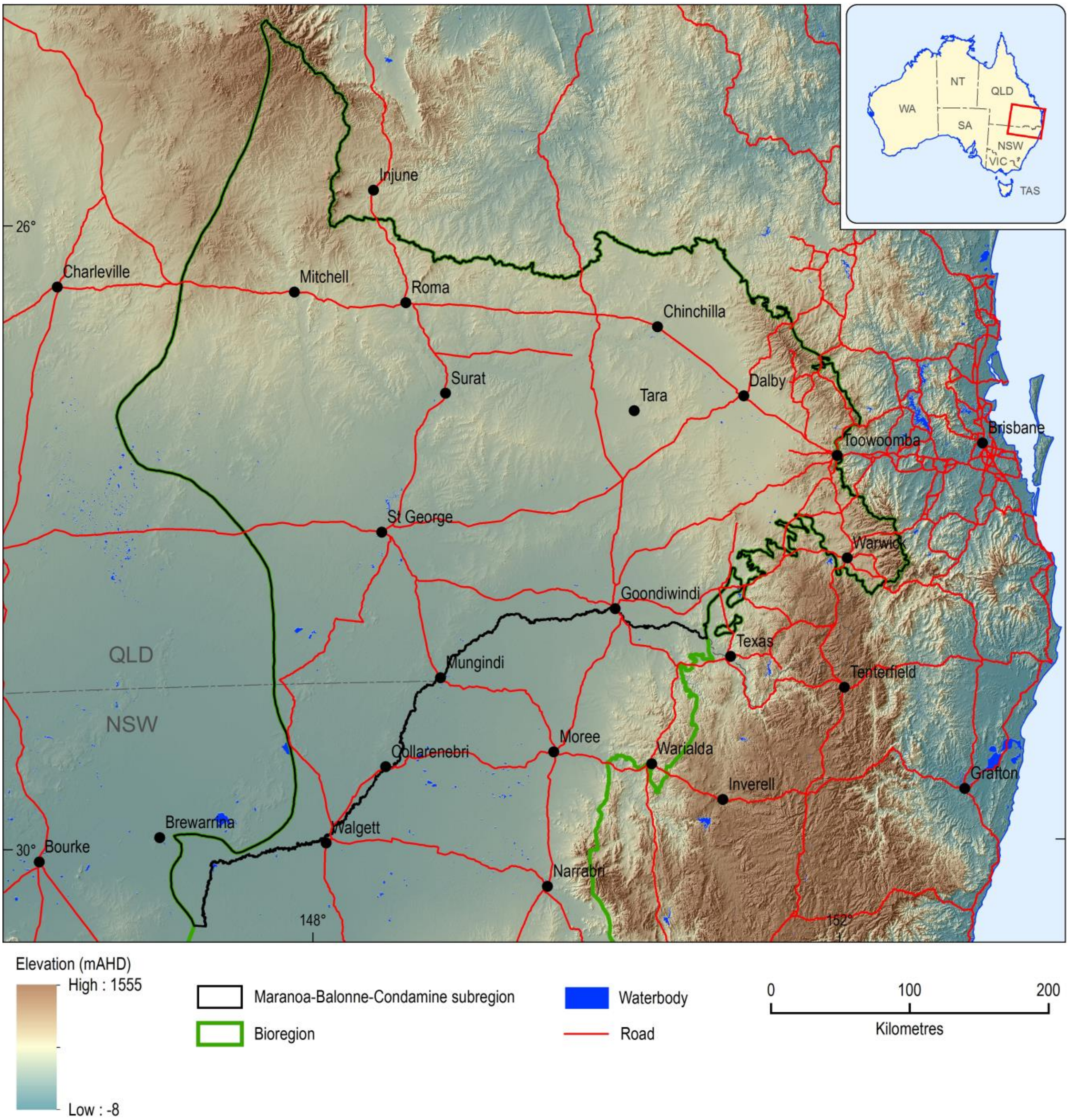

Figure 4 Topography of the Maranoa-Balonne-Condamine subregion, generated from the 3 second digital elevation model

Source data: 3 Second SRTM Derived Digital Elevation Model (DEM) version 1.0, GA (2011a)

1.1.2.1.1 Physiographic regions

Physiographic regions are defined by an internal coherence of their landform characteristics and underlying geology (Jennings and Mabbutt, 1986). By implication, they are considered to be areas of similar landform evolutionary history, which have given rise to similar groups of regolith materials. While the mapping criteria relate to landform attributes, the resultant mapped units can be described in terms of landform, underlying geology, regolith and soils (Pain et al., 2011).

The subregion spans a number of physiographic regions (Figure 5). The Toowoomba Plateau to the east of the Upper Condamine River is a basaltic plateau supporting highly weathered bedrock and soil on bedrock surfaces. Taroom Hills to the north is characterised by sandstone ridges with a saprolite drape and shale lowlands covered with alluvial sediments. Saprolite refers to in situ weathered rock, whereas alluvial sediments indicate depositional environments, where the regolith comprises transported material, rather than material that has weathered in place. In the northern Maranoa river basin, the Buckland Plateau is a dissected basaltic and sandstone landscape that adjoins the sandstone strike ridges and clay valleys of Nagoa Scarplands. The regolith of the valleys is alluvial sediments, with saprolite on the slopes. In the low-lying areas, the Condamine Lowlands region is undulating country of siltstone lowlands and sandstone hills with alluvial sediments on the floodplains of the Condamine River and highly weathered bedrock on the slopes. The sandplains of the St George Plain and the anastomosing river floodplains of the Upper Darling Plains are broken by a ridge of stony plains and minor silcrete-capped mesas of the Lightning Ridge Lowland. The Charleville Tableland in the centre and west is the largest physiographic region in the subregion, and is a low sandy tableland of weathered sandstone and shale.

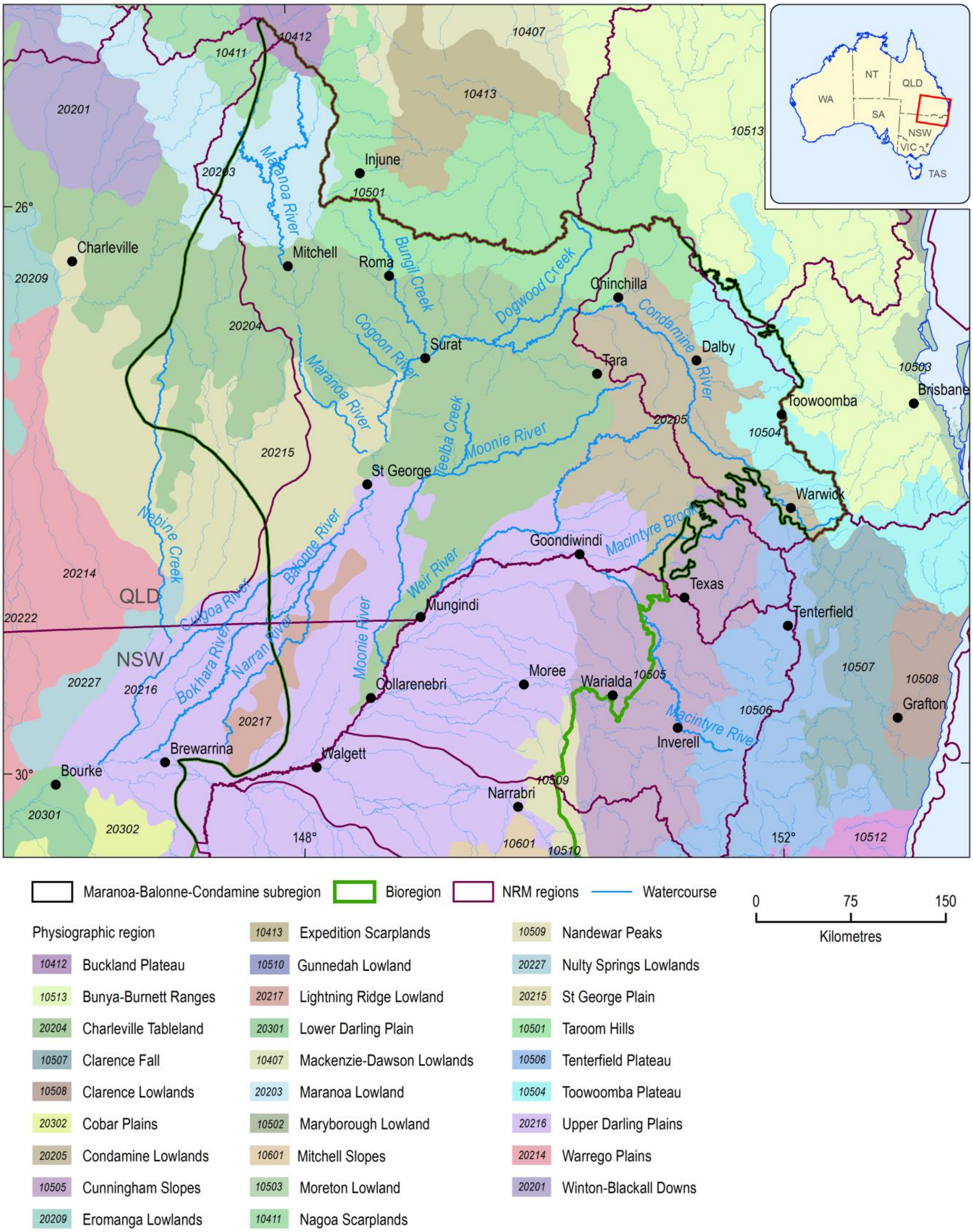

Figure 5 Physiographic regions

As defined in Pain et al. (2011)

1.1.2.1.2 Soils and land capability

Figure 6 shows the soils of the subregion based on the Australian Soil Classification (Isbell, 2002) and Table 2 summarises area (km^2) and extent (%) of coverage. The Upper Condamine valley and the floodplains of the St George Plain and Upper Darling Plains are dominated by Vertosols, clay soils with shrink-swell properties that exhibit strong cracking when dry. From an agricultural perspective, they are well structured and have a good mix of pores for both transmitting and storing water and high soil fertility, so plant growth on these soils is typically very good relative to other soil types. Because Vertosols can be worked under a very narrow range of moisture conditions, they are better suited to irrigated cropping rather than rain-fed cropping. Given their self-mulching properties, they can withstand comparatively frequent cultivation without changes to structure.

In addition to some areas of Vertosols, the western half of the Condamine Lowlands is dominated by Sodosols, which are soils with strong texture contrast between A horizons and sodic B horizons and disproportionately high levels of exchangeable sodium ions. This makes them quick to disperse in water and highly erodible and best suited to low intensity land uses, such as production forestry and grazing from relatively natural environments. Kandosols are extensive throughout the Charleville Tableland, the St George Plain and the Lightning Ridge Lowland. The Kandosols are red, yellow and grey massive earthy soils. They generally have a sandy to loamy surface soil, grading to porous sandy clay subsoils with low fertility and poor water-holding capacity. A wide range of crops can be grown on these soils where rainfall is higher or where irrigation is available. The Charleville Tableland, Maranoa Lowland and Taroom Hills have large areas dominated by Dermosols. These soils can be red, brown, yellow, grey or black and have loam to clay textures. The land tends to be used for livestock grazing from relatively natural environments. Tenosols dominate the Nagoa Scarplands, Buckland Plateau and Maranoa Lowland in the north-west. They tend to be low fertility, low water-holding capacity soils and are often shallow and stony. Production forestry and grazing from relatively natural environments occur in these areas (DNRM, 2010a). Overall, the land and soil resources of the subregion mean that the majority of the area is deemed ‘good quality agricultural land’ (QMDC, 2008).

Bell **et al.** (2010) investigated soil fertility in the major grain growing areas of Queensland in 2008 and found that soil fertility was declining at all studied sites. On average, cropped soils contained 60% less organic carbon, 48% less total organic nitrogen, 36% less particulate nitrogen, 68% less inorganic phosphorus and 55% less exchangeable potassium than uncropped reference sites (Bell et al., 2010).

Soil acidification is a problem across much of the cropping and grazing country, particularly on soils which have a naturally low pH or a low capacity to buffer against pH decreases and where past and/or current management practices are highly acidifying. In the subregion, 12% of lands (i.e. in western Condamine river basin and the lower Balonne) are estimated to be at high risk of soil acidification, while a further 31% (predominantly in the northern subregion) are at moderate risk (Barson, 2013).

Moderate to high salinity hazard areas include the Sodosols, Vertosols and Dermosols along the Upper Condamine, near Warwick, along the Moonie River, Macintyre River and lower Balonne floodplains and on the alluvial fan system downstream of St George, and these need to be managed to minimise hydrological changes which could mobilise stored salts. Small areas of irrigation salinity occur around St George, in the lower Border River alluvium and in the Granite Belt. Surface expressions of dryland salinity can be very climate dependent; saline sites occur around Roma and near Weengallon (between Goondiwindi and St George). These usually occur on footslopes at the contact with alluvium and do not appear to involve groundwater discharge (Biggs et al., 2010).

In recognition of the significance of agriculture for the Queensland and national economy and in response to widespread degradation of the land and soil resource due to erosion, declining soil fertility, salinity and deteriorating pasture condition, the Queensland Government enacted *State Planning Policy 1/92 – Development and Conservation of Agricultural Land* under the *Local Government (Planning and Environment) Act 1990* in 1992. This instrument provides guidance to local authorities on conserving good quality agricultural land in the public interest when carrying out their planning functions. The overarching principle of the instrument is that 'good quality agricultural land has a special importance and should not be built on unless there is an overriding need for development in terms of public benefit and no other site is suitable for the particular purpose' (Queensland Government, 1992).

Table 2 Soils, classified using Australian Soil Classification (Isbell, 2002)

ASC soil class	Area (km^2)	Percentage of total area of subregion (%)
Vertosols	44,916	32%
Kandosols	30,427	21%
Dermosols	27,529	19%
Sodosols	21,734	15%
Tenosols	10,142	7%
Chromosols	5,796	4%
Kurosols	1,449	1%
Rudosols	1,449	1%

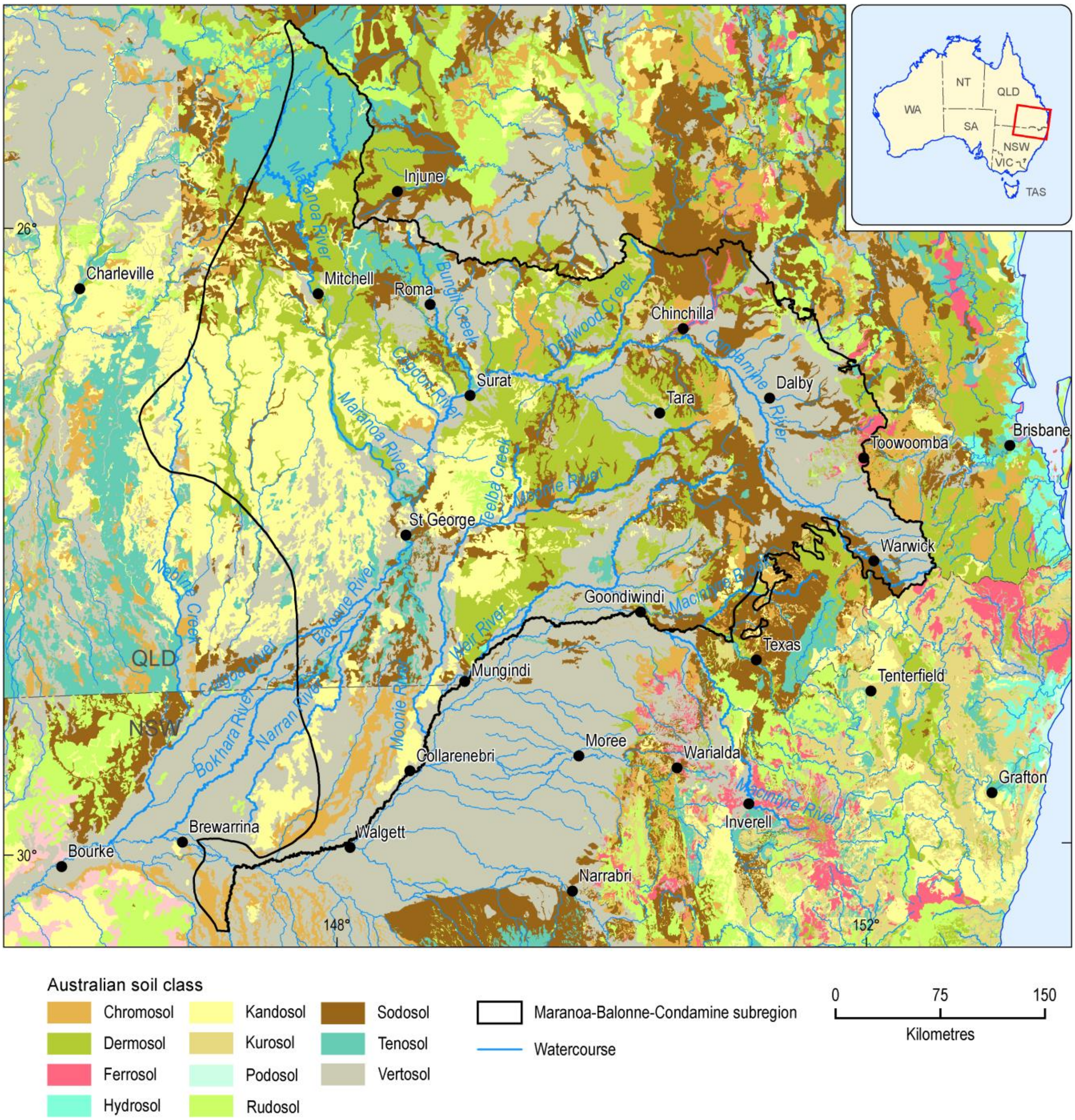

Figure 6 Soils classified using the Australian Soil Classification

Inconsistencies across the NSW-Queensland boundary are an artefact of the state-based mapping programs from which the national composite soils map was compiled.
Source data: National Soil Grids (ASRIS, 2011)

More recently, Queensland has committed to protecting its best cropping lands from developments that would have an adverse impact on the productive capacity of the land. Queensland's *Strategic Cropping Land Act 2011*, which commenced on 30 January 2012, has the objectives of protecting land that is highly suitable for cropping, managing the impacts of development on that land, and preserving the productive capacity of that land for future generations. Figure 7 shows the areas protected under this legislation. There is a very close correspondence with the areas of Vertosols across much of the subregion.

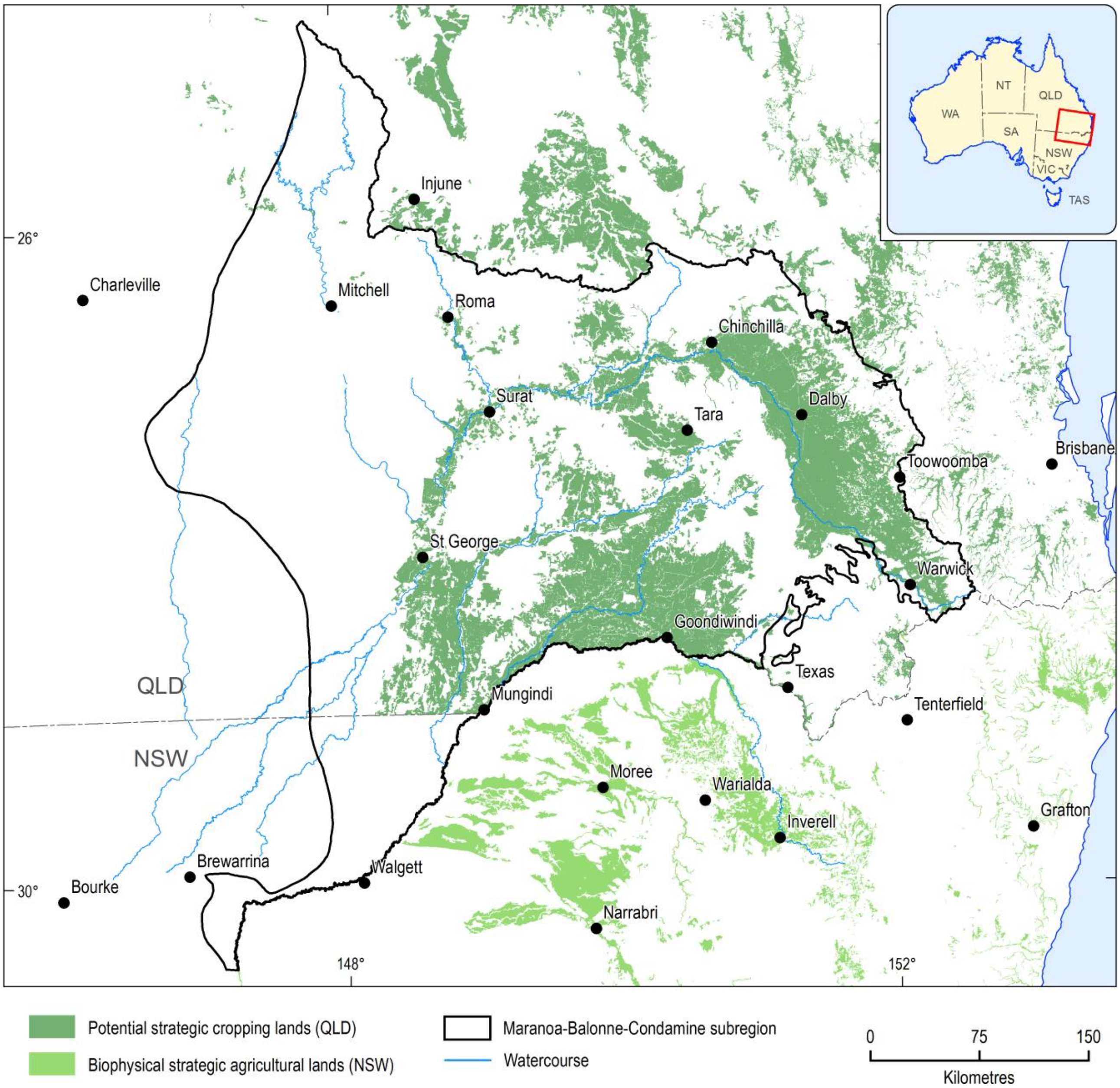

Figure 7 Strategic cropping lands

Source data: Trigger Map for Strategic Cropping Land in Queensland (DNRM, 2012) and Strategic Agricultural Lands (NSW Government, 2013)

Under Queensland's *Environmental Protection Act 1994* and *Land Act 1994*, all landholders have a duty of care to the land, which requires them to take all reasonable and practical steps to prevent harm to the environment, including land degradation.

In late 2012, the NSW government introduced its Strategic Regional Land Use Policy to protect valuable residential and agricultural land across the State from the impacts of mining and Coal Seam Gas (CSG) activity (NSW Government, 2014). Information was released in January 2014, identifying the areas of Biophysical Strategic Agricultural Land (BSAL) – land of high quality soil and water resources capable of supporting high levels of agricultural production – across NSW, which are deemed necessary to support the state's $12 billion per year agricultural industry (Figure 7).

1.1.2.1.3 Land cover

Figure 8 shows the land cover for the subregion in 2008, based on remotely sensed data that are post-processed to convert vegetation greenness to a land cover type (GA, 2011b). The Upper Condamine valley is notable for the predominance of cropping, with other significant areas of cropping on the Balonne, around Roma and in the Moonie and Macintyre river valleys. Crop and pasture account for almost 17% of the land cover in the subregion. There are small areas of open woodlands in higher parts of the river basin, but sparse to scattered woodlands cover most of the subregion (68%), with increasing areas of tussock and hummock grasses to the west (Table 3).

The subregion has undergone significant modification of its land cover, with most areas having between 10 and 30% of their pre-clearing vegetation, the exception being the western part of the Condamine Lowlands physiographic region with almost 60% of its original extent. Since the introduction of Queensland’s *Vegetation Management Act 1999*, land clearing rates have fallen dramatically. Between 1997 and 2005, annual rates of clearing in the west of the subregion were occurring at greater than 3.6% of starting vegetation in some areas, and between 0.6 to 3.6% elsewhere. In the east clearing rates have tended to be lower. Between 2005 and 2009, clearing in the east was at 0.05 to 0.1% per year of existing native cover and between 0.1 and 3.6% in more western areas (Accad et al., 2012). Most of the land cleared is for pasture, followed by infrastructure and forestry. Between 2004 and 2009, approximately 200,000 ha were cleared for pasture and 900 ha for mining (DNRM, 2010b; DNRM, 2010c) of which 55,000 ha were remnant vegetation. Woody vegetation (remnant and regrowth) covers 42% of the subregion.

Communities listed under the Commonwealth’s *Environment Protection and Biodiversity Conservation Act 1999* in the subregion are discussed in Section 1.1.7. Estimates of the extent of these communities pre-clearing was 25% (6.5 million ha) of the Queensland Murray–Darling Basin. Now the extent is 3.2% of the Queensland Murray–Darling Basin, or 13% (0.8 million ha) of its original extent. The slopes east of Warwick, the headwaters of the Maranoa River, the floodplains of the Maranoa and Balonne rivers and the alluvial outwash areas of the Balonne River downstream of St George are the main areas where these endangered ecological communities can still be found. The ecology of the subregion is covered in more detail in Section 1.1.7.

Some endangered ecological communities and species are protected in nature conservation areas: the Main Range National Park on the eastern divide of the subregion is part of the Gondwana Rainforest World Heritage area and contains the world's most extensive subtropical rainforest and nearly all of the world's Antarctic beech cool temperate rainforest. There are few places on Earth containing so many plants and animals that have remain relatively unchanged from their ancestors in the fossil record (Department of the Environment, 2013). Bunya Mountains National Park to the north-east of Dalby contains the largest stand of ancient bunya pines in the world (South Burnett Tourism, 2013). In the Southwood National Park, south-west of Dalby, Brigalow-belah forest remnants are conserved. Few intact examples of this vegetation type remain on the Darling Downs. Cypress pine, poplar box, wilga bush, false sandalwood, western teatree and other plant species common throughout the semi-arid lands also grow in the park (DNPRSR, 2013).

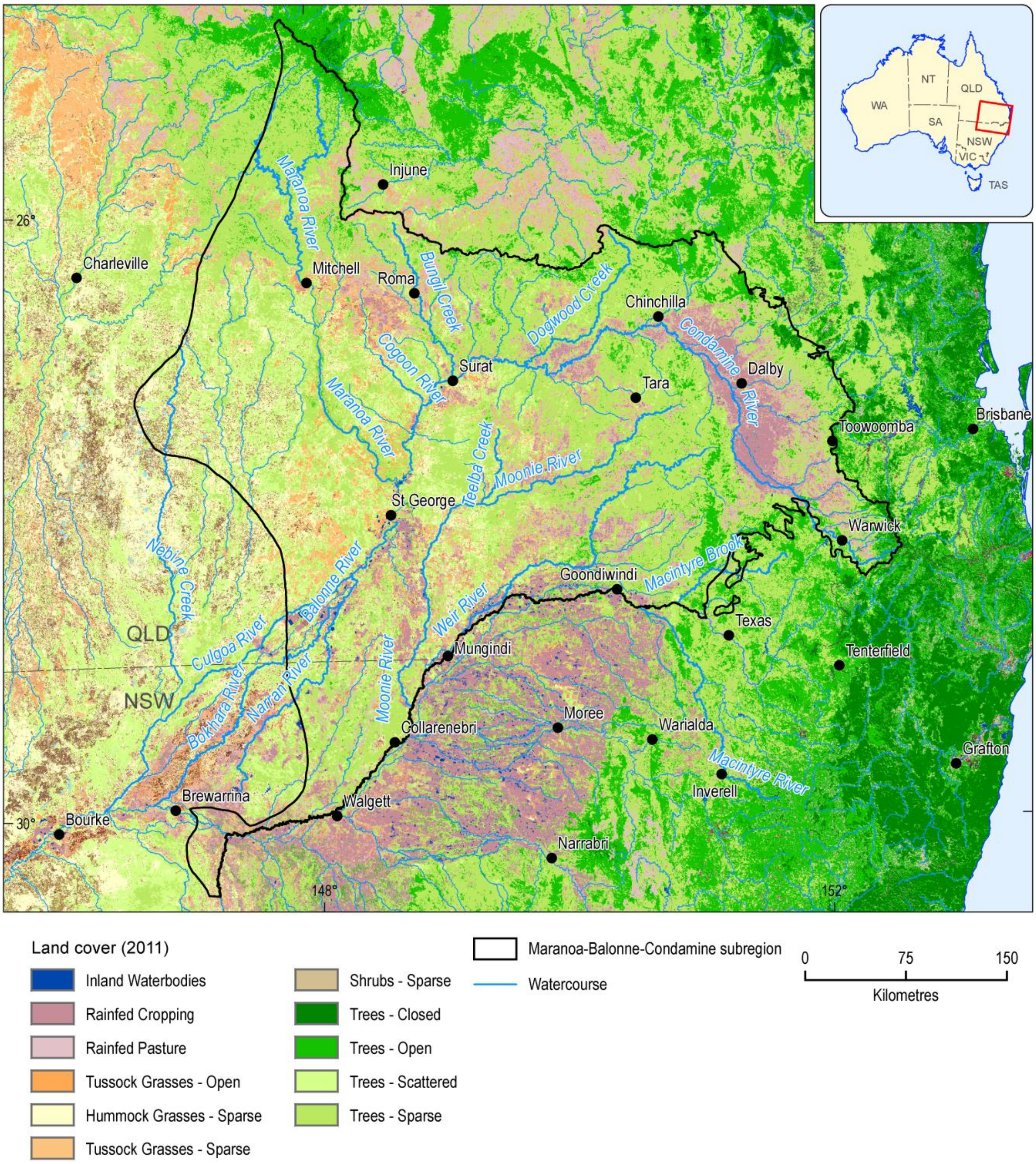

Figure 8 Land cover in the Maranoa-Balonne-Condamine subregion

Source data: The National Dynamic Land Cover Dataset, GA (2011b)
The methods used to produce the land cover map are not very sensitive to use of irrigation water and irrigated land covers are often mapped as rainfed covers. For irrigated land covers, the land use map (Figure 9) should be consulted.

Inland waterbodies and wetlands are mapped as covering 400 km^2 (0.3%) of the subregion. The Balonne River floodplain and Gums Lagoon are both listed as nationally important. The Balonne River floodplain is a small area of a couple of hundred hectares within the larger 24,000 ha floodplain area. It contains a significant aggregation of permanent and ephemeral freshwater billabongs and swamps on an inland floodplain. Despite major agricultural disturbance, the fringing and aquatic vegetation of the wetlands are reasonably intact, although there are ongoing pressures from the current land uses, which include high intensity irrigated agriculture, extensive grazing on native pasture, recreational fishing and water storage. The 343 ha Gums Lagoon (west of Dalby on the Surat road) supports a low open forest of river red gum over perennial tussock grasses. Ephemeral semi-aquatic plants occur during periods of inundation. It is significant because it is a relatively undisturbed wetland in a region of extensive habitat modification. Large numbers of waterbirds and fish are known to use the lagoon when it is full. The historical loss of wetlands is up to 70% across the Queensland Murray–Darling Basin. Ongoing loss over the 2001 to 2005 and 2005 to 2009 periods continues with the Maranoa losing wetlands at greater than 1% of 2001 extent (Queensland Government DEHP, 2012).

While the Ramsar-listed wetlands of the Narran Lakes system and the Culgoa River Floodplain are not in the subregion, the rivers draining this subregion supply water to these nationally important wetlands.

Table 3 Land cover

Land cover class	Area (km^2)	Percentage of total area of subregion (%)
Trees – Sparse	63,869	44.1%
Trees – Scattered	25,016	17.3%
Pasture and crops	23,987	16.6%
Tussock grasses	11,259	7.8%
Trees – Open	8,864	6.1%
Hummock grasses	7,527	5.2%
Shrubs	2,615	1.8%
Chenopods	809	0.6%
Trees – Closed	476	0.3%
Inland waterbodies and wetlands	402	0.3%
Grasslands	8	0.0%

1.1.2.2 Human geography

1.1.2.2.1 Population

The subregion contains significant parts of five Queensland local government areas (LGAs): Maranoa, Balonne, Goondiwindi, Western Downs and Toowoomba, with small encroachments into the Southern Downs, South Burnett and Murweh LGAs. The NSW part of the subregion is fully contained within the Walgett LGA. For Australian Bureau of Statistics reporting purposes, all of the Queensland LGAs, excluding the urban part of the Toowoomba LGA, are grouped together to form the Darling Downs-Maranoa Statistical Area Level 4 (SA4). Urban Toowoomba is a separate SA4. The full extent of the Darling Downs-Maranoa SA4 extends beyond the area covered by the subregion and some scaling back of the reported statistics is required. In 2011, the populations of Darling Downs-Maranoa SA4 and Toowoomba SA4 were about 125,000 and 144,000, respectively.

Both areas have seen population increases of 5.4 to 5.8% since 2007 (ABS, 2013). The Walgett LGA had a population of 6900 in 2011. About a quarter of this LGA is in the subregion.

Of the 125,000 people outside the Toowoomba SA4, 67,000 are in the Western and Southern Downs LGAs, of which 40,000 (based on fraction of LGAs within the subregion) are estimated to be in the subregion. Of the 32,000 people in the South Burnett LGA area, very few would be in the subregion, so a best estimate of the regional population is 65,000 to 70,000, or 210,000 to 215,000 when the Toowoomba population is included. Warwick (12,400), Dalby (12,300), Roma (6,900), Goondiwindi (6,400), Chinchilla (5,500) and St George (3,300) are significant population centres, their combined population making up 60% of the non-Toowoomba population. The largest population centre in the NSW part of the subregion is Collarenebri (770). Population density varies from around 64 persons/km^2 (Toowoomba SA4) to 0.2 persons/km^2 (Balonne, Maranoa and Walgett LGAs).

In the ABS (2011) census, 4.7% of the Darling Downs-Maranoa SA4 indicated they were Indigenous, with a slightly lower proportion (3.4%) in Toowoomba. In the Walgett LGA, 28.1% of respondents were Indigenous.

1.1.2.2.2 Economic activity

Approximately 120,000 people are employed in Darling Downs-Maranoa SA4, Toowoomba SA4 and Walgett LGA, or closer to 95,000 for the subregion, accounting for some of those workers being outside the subregion. Table 4 summarises the main sectors of employment for the Maranoa-Balonne-Condamine subregion (based on national regional profile data by SA4 and LGA (ABS, 2011)). Of the employed population, 12% works in agriculture, forestry and fishing, although if Toowoomba is excluded from the statistic, it is closer to 21% across the subregion. In Toowoomba, health care and social assistance, retail, education and training, and public administration and safety account for 42.5% of employment. These sectors account for 32% of employment in the wider area. Mining accounts for 3.2% of regional employment.

The gross value of agricultural production in the Condamine and the Border Rivers-Maranoa-Balonne natural resource management regions in 2010–11 was estimated at $2.4 billion, of which $1.5 billion was from crops. The highest value crops were $660 million (28%) from cotton, $580 million (24%) from cereal and legume crops and $216 million (9%) from fruit and vegetable horticulture (ABS, 2012). Livestock products generated $910 million (38%).

Domestic tourism contributed $1.1 billion to the regional economy (or $2.9 million/day) in the 2011–12 financial year for the Southern Queensland Country region, which covers the Maranoa-Balonne-Condamine subregion (TQ, 2012).

Table 4 Employment profile

Industry	Percentage of total for Darling Downs-Maranoa Statistical Area Level 4 (%)	Percentage of total for Toowoomba Statistical Area Level 4 (%)	Percentage of total for Walgett Statistical Area Level 4 (%)	Percentage of total for combined statistical areas (%)
Accommodation and food services	5.7%	6.1%	6.7%	6.1%
Administrative and support services	1.5%	2.4%	1.9%	2.0%
Agriculture, forestry and fishing	20.2%	3.8%	28.9%	12.0%
Arts and recreation services	0.6%	0.9%	1.6%	0.8%
Construction	7.8%	8.0%	3.8%	8.0%
Education and training	7.1%	10.4%	10.6%	9.1%
Electricity, gas, water and waste services	1.5%	1.1%	1.0%	1.3%
Financial and insurance services	1.3%	3.0%	0.8%	2.2%
Health care and social assistance	9.2%	13.9%	11.4%	12.0%
Information media and telecommunications	0.5%	1.0%	0.3%	0.8%
Manufacturing	7.6%	9.0%	2.4%	8.4%
Mining	3.2%	1.6%	2.2%	2.4%
Other services	3.4%	4.1%	2.7%	3.8%
Professional, scientific and technical services	3.0%	4.5%	2.0%	3.9%
Public administration and safety	5.3%	6.8%	8.1%	6.3%
Rental, hiring and real estate services	1.0%	1.4%	0.4%	1.2%
Retail trade	10.3%	11.4%	6.8%	11.1%
Transport, postal and warehousing	5.2%	4.7%	3.5%	5.0%
Wholesale trade	3.0%	3.9%	1.9%	3.5%

Source data: ABS (2011)

1.1.2.2.3 Land use

Land uses in the Maranoa-Balonne-Condamine subregion are shown in Figure 9. By far the most dominant land use is grazing on improved native pasture, which is undertaken over 75% (almost 110,000 km^2) of the subregion. In the east, the heart of the Condamine valley is dominated by cropping and more scattered areas of cropping occur to the west, but not extending much beyond the longitude of St George. Cropping, of predominantly cotton, cereals and legumes, is undertaken over 13.5% of the subregion and in 2010–11 contributed over 60% of gross agricultural production value. Production forestry (6.4%) is significant: most of Barakula State Forest, which is the largest state forest in the Southern Hemisphere and supplies much of Queensland's cypress pine timber resource, is situated to the north of Chinchilla; south-west of Dalby there are extensive areas of defined forest lands; another sizable area is between Chinchilla and Roma; and significant areas are in the Upper Maranoa river basin. Intensive animal production is significant to the north of

Toowoomba, with smaller areas to the west and south. Irrigated cropping is undertaken over a relatively small area (2%) of the subregion, but contributes significantly to the total value of agricultural commodities. A similar area of land is used for nature conservation and other minimal uses of natural land. Land use is summarised by area and percentage of subregion in Table 5.

The NSW Government has released coal seam gas exclusion zones based on current and future residential areas, with identified areas buffered by a 2 km exclusion zone (Figure 10).

Table 5 Land use

Land use	Area (km^2)	Percentage of total area of subregion (%)
Grazing natural vegetation	109,327.8	75.5%
Cropping	16,581.4	11.4%
Production forestry	9,278.5	6.4%
Conservation and natural environments	3,228.0	2.2%
Irrigated cropping	3,089.7	2.1%
Intensive production	970.9	0.7%
Water	911.2	0.6%
Residential, manufacturing, utilities, transport, services	829.1	0.6%
Grazing modified pastures	355.6	0.2%
Land in transition	129.0	0.1%
Plantation forestry	95.2	0.1%
Irrigated horticulture	45.1	0.0%
Mining	31.8	0.0%
Horticulture	16.1	0.0%
Grazing irrigated modified pastures	0.2	0.0%

Source data: ABARES (2012)

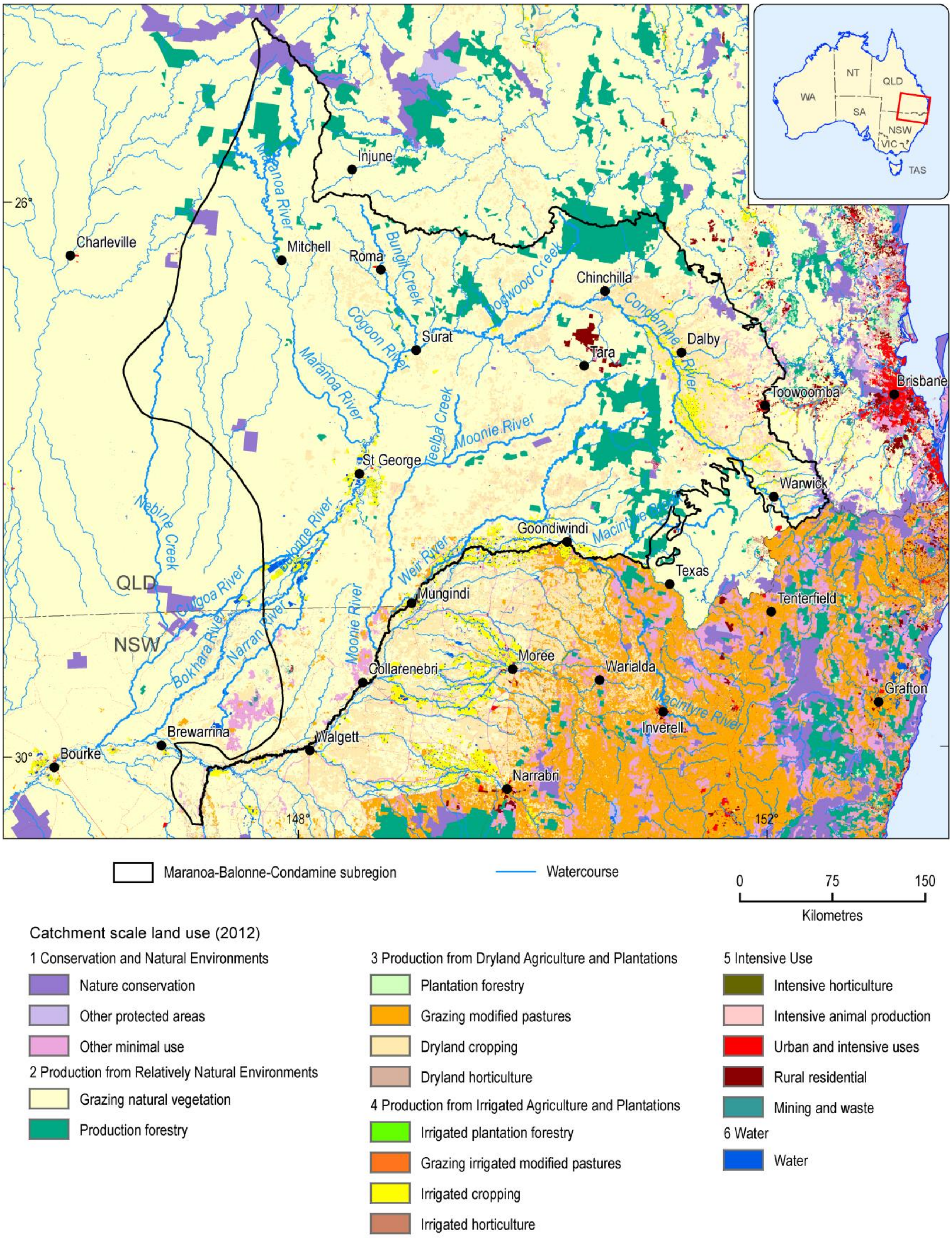

Figure 9 Land use

Source data: Catchment scale land use mapping for Australia update November 2012 (CLUM Update 11/12) dataset, ABARES (2012)

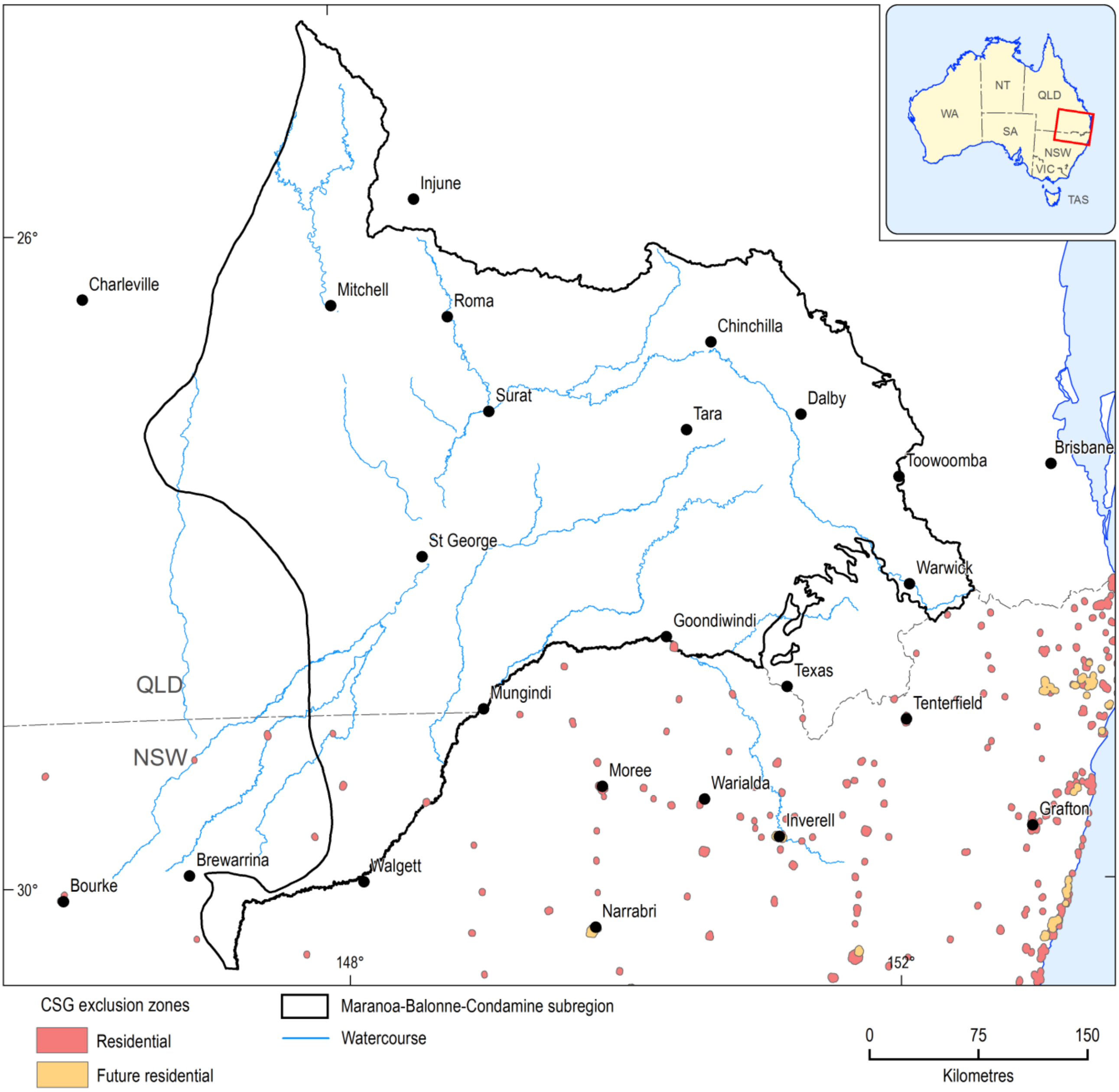

Figure 10 Coal seam gas exclusion zones

1.1.2.2.4 Indigenous heritage

The Indigenous languages map (Horton, 1994) of Australia shows that the Maranoa-Balonne-Condamine subregion was home to a large number of different Indigenous communities: the Barrungum people lived in the Upper Condamine area, the Mandandanji around the lower Condamine-Balonne-lower Maranoa area, the Bigambul people around the Moonie and Macintyre rivers, the Kooma people south and west of St George, the Murawari on the Culgoa floodplains, the Gomeroi around Lightning Ridge, and the Nguri in the Maranoa headwaters.

Queensland's *Aboriginal Cultural Heritage Act 2003* establishes a duty of care on those conducting activities in areas of significance to take all practical measures to avoid harming cultural heritage. Under the Act, a cultural heritage database and register have been established. Approximately 30,000 sites are listed on the register. Penalties of up to $1 million for a corporation and $100,000 for an individual can be imposed for breach of duty of care or damage to cultural heritage. The

NSW *National Parks and Wildlife Act 1974* requires that the potential impacts of development on an Aboriginal Place be assessed.

In NSW, Moordale Wells, to the north-east of Narran Lakes system, is a significant cultural site and on the NSW register. It lies just outside the subregion, but is within the downstream area of influence of the subregion. Similarly, the Brewarrina Ngemba Billabong, a 261 ha property which is home to four endangered species (the brolga, the blue-billed duck, the freckled duck and the red-tailed black cockatoo) and which was an important tribal meeting place for the Wailwan people, is just outside the subregion. This site was declared an Indigenous Protected Area (IPA) in 2010 under the Australian Government's IPA program. An IPA is an area of Indigenous-owned land or sea where Traditional Owners have entered into an agreement with the Australian Government to promote biodiversity and cultural resource conservation.

1.1.2.3 Climate

The climate varies from temperate conditions with no dry season and warm to hot summers in the east to a more subtropical climate through the centre with areas of no and/or moderately dry winters, to hot, persistently dry climates in the west. Between 1981 and 2012, maximum temperatures averaged 33 to 34 °C through the summer and 18 to 20 °C through the winter, while typical minimum temperatures in summer were 18 to 20 °C and 5 to 6 °C through winter (Figure 11).

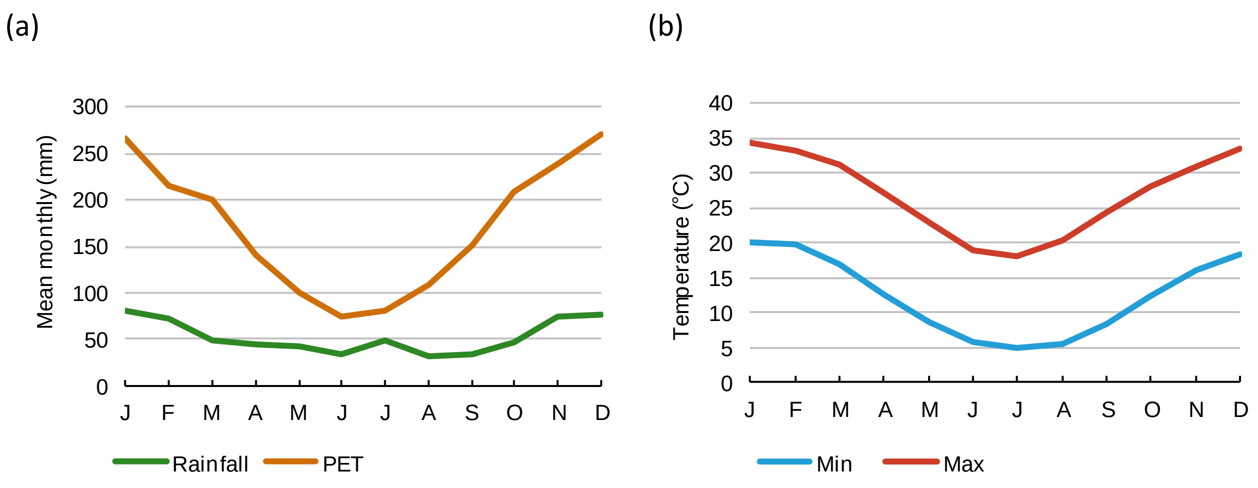

Figure 11 (a) Mean monthly rainfall and potential evapotranspiration and (b) mean monthly maximum and minimum temperatures over the subregion for the period 1981–2012

Source data: derived from (i) Mean monthly and mean annual rainfall data (Bureau of Meteorology, 2013a) and (ii) Mean monthly and mean annual maximum, minimum and mean temperature data (Bureau of Meteorology, 2013b)

In the subregion, average annual rainfall ranges from more than 800 mm around Toowoomba and Killarney on the Great Dividing Range to about 420 mm near Brewarrina (Figure 12). Figure 13 shows the annual time series of rainfall from 1900 to 2011 for the subregion. The mean annual rainfall for this period is 580 mm, but there is considerable variability with a low of 225 mm in 1902 and a maximum of 1060 mm in 1950. The orange line shows the low frequency trend for the record. The years between 1900 and 1946 were on average drier (530 mm/year) than the latter half of the 20th century (625 mm/year). The millennium drought is not particularly evident in the subregion with the rainfall average of 565 mm for 2002 to 2009 being only slightly lower than that for the full record. Rainfall is summer-dominant, varying from 230 mm (77 mm/month) for the December to February period to 115 mm (38 mm/month) between June and August (Figure 11).

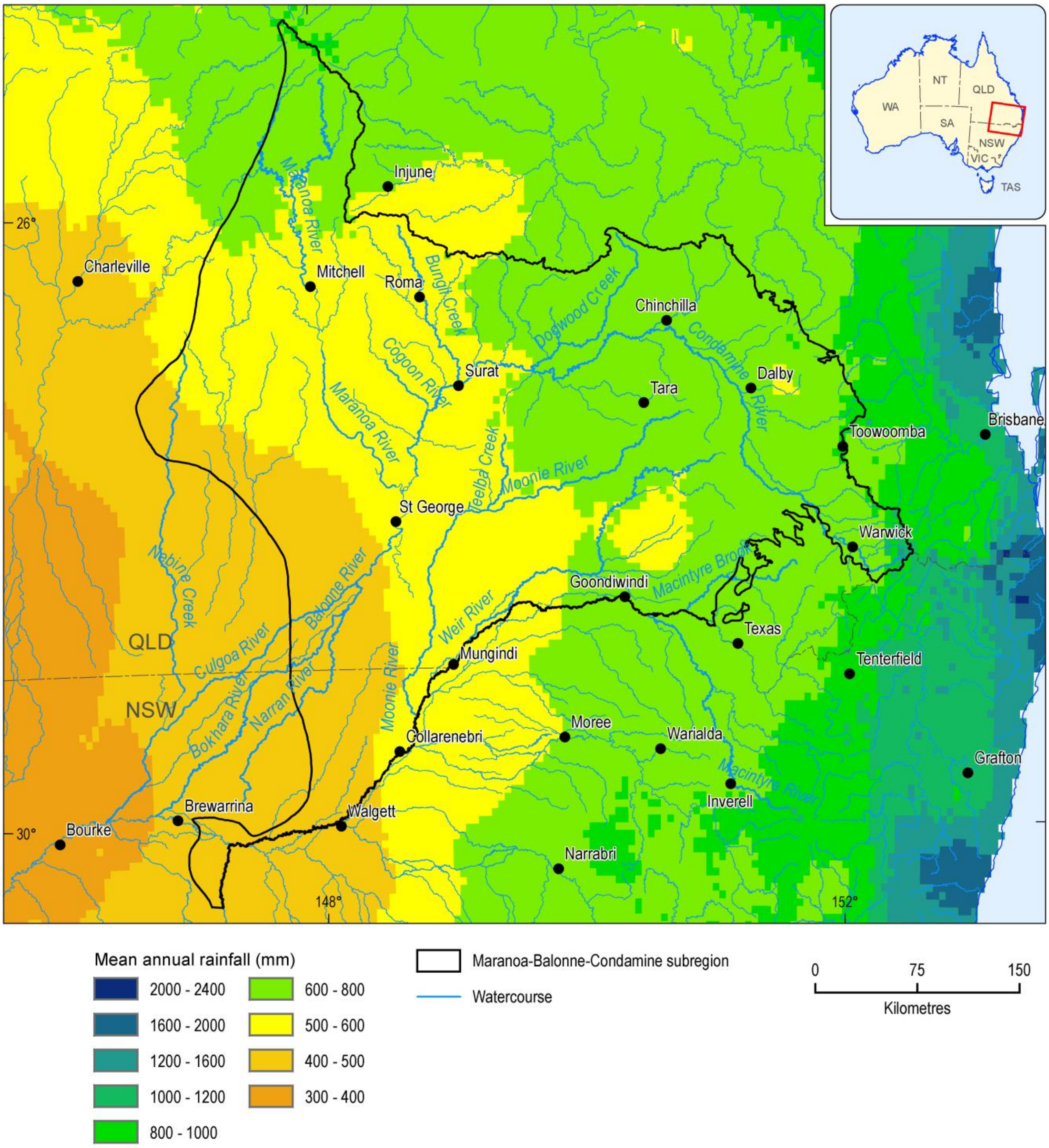

Figure 12 Mean annual rainfall distribution

Potential evapotranspiration (PET) was calculated on a daily time step using the Penman method with a wind spline for the period 1981 to 2012. The spatial pattern of mean annual PET for this period is shown in Figure 13 and varies across the subregion from 1500 mm in the ranges to the east of Warwick to 2370 mm at its most western point. The mean annual PET for the subregion is 2145 mm (1981 to 2012) and varies within the year between 75 mm/month in June to 270 mm/month in December and January, reflecting the annual temperature pattern. On average, evaporation is limited by water availability throughout the year (Figure 11) so actual evapotranspiration rates are not as high as the potential.

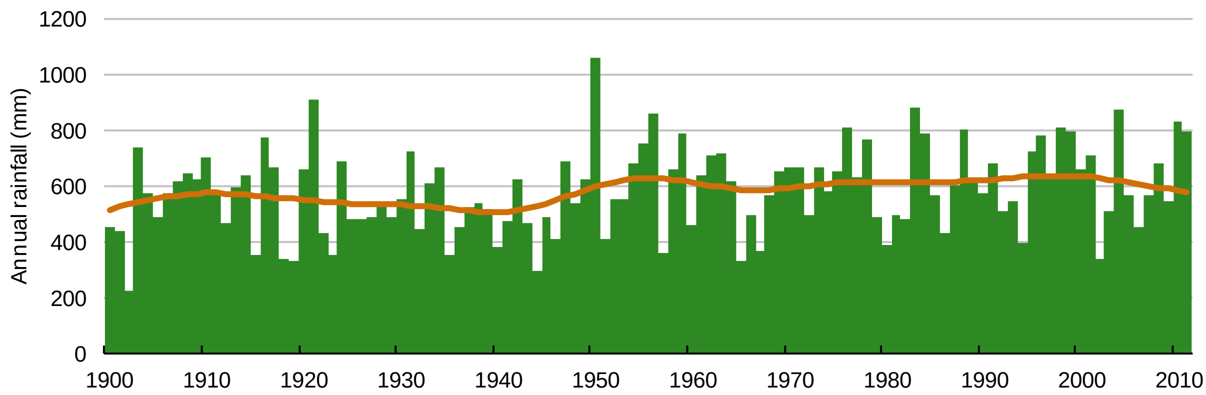

Figure 13 Annual rainfall with smoothed rolling average for the Maranoa-Balonne-Condamine subregion

Source data: Bureau of Meteorology (2012)

In a recent report by the South Eastern Australia Climate Initiative (SEACI) (CSIRO, 2010), the significance of the 1997 to 2009 drought was assessed relative to other recorded droughts since 1900 and as an indicator of what the future climate might look like. In the Condamine, rainfall was 5 to 20% less than the long-term average and around the Moonie and Macintyre rivers, rainfall was 5 to 10% above the average, but the rest of the subregion experienced about average rainfall. In terms of runoff, the Condamine-Balonne was up to 50% drier than average, while parts of the Moonie and Macintyre valleys were significantly wetter. In general, the impact upon streamflow of a small percentage change in rainfall is enhanced with a 5% reduction in average rainfall leading to a 10 to 15% reduction in streamflow and a 5% increase in rainfall leading to a 10 to 15% increase in streamflow in south-eastern Australia (Chiew, 2006). If the millennium drought is a sign of the future climate, then it would suggest that in the Maranoa-Balonne-Condamine subregion the Condamine and Balonne river basins could experience less water availability on average, but the Moonie and Macintyre valleys could experience more water availability.

However, the most recent analysis of likely future climate for the region suggests that the probability of runoff reductions is greater than 50%. Post et al. (2012) modelled future runoff at a 5 km grid resolution for south-eastern Australia. The climate series was informed by simulations from 15 global climate models used in the Intergovernmental Panel on Climate Change Fourth Assessment Report, taking into account changes in daily rainfall distributions and seasonal rainfall (and potential evapotranspiration) amounts, for an increase in global average surface air temperature of 1.0 °C (2030 relative to 1990), and 2.0 °C (2070 relative to 1990). In the northern Murray–Darling Basin, there is significant variation between models: changes in average rainfall range from 4 to –11% (median of –3%), which correspond to a change in runoff of between 12 and –29% (median of –10%). In the Condamine-Balonne river basin, the median projection under 1.0 °C of warming was for a 4% reduction in rainfall (Table 6) and 13% reduction in runoff (Table 7). In the Moonie river basin, the median projection under 1.0 °C of warming was a 5% reduction in rainfall (Table 6) with a 12% reduction in runoff (Table 7). Across all models, the potential evaporation was projected to increase by 3 to 4% (44 to 70 mm). In summary, increasing temperatures and evaporation and more prolonged drought, combined with periodic extreme flow events, are projected to be the main climate change impacts affecting the Maranoa-Balonne-Condamine subregion (EPH, 2009).

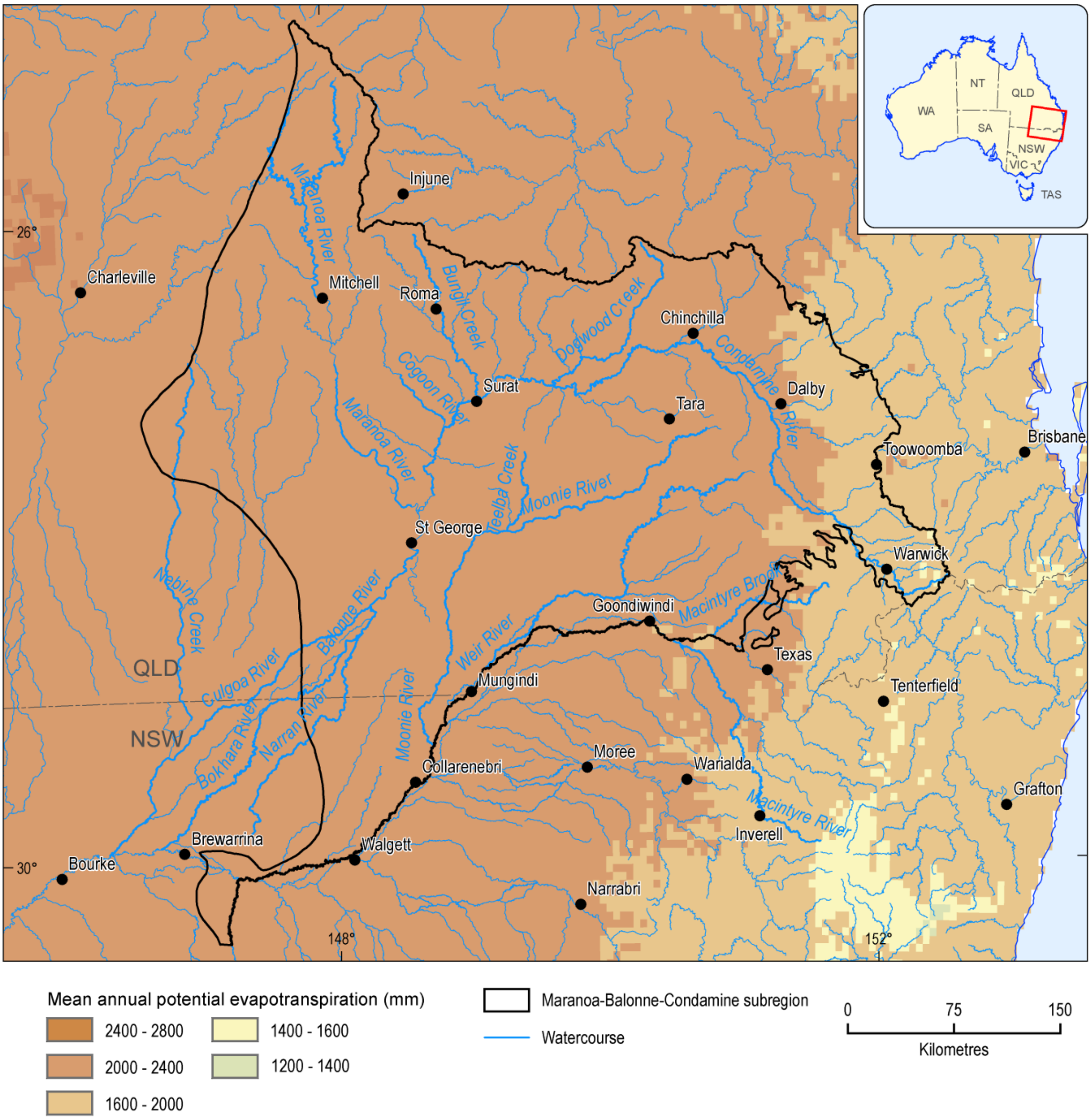

Figure 14 Mean annual potential evapotranspiration distribution

Source data: Bureau of Meteorology (2014)

Figure 15 shows the distribution of rainfall and runoff changes across the year for the historical record and projected changes at Toowoomba, in the higher rainfall part of the subregion. Decreases in autumn rains will likely result in reduced runoff, although small decreases in spring runoff do not appear to impact spring runoff. The wider range of projections between January and July for runoff indicate greater uncertainty in runoff projections relative to the rainfall projections.

There is far greater consistency between model predictions of late winter to spring runoff predictions, which suggest little change from historical trends during these months.

Table 6 Summary of projected impacts of climate change on rainfall for the broad vicinity of the Maranoa-Balonne-Condamine subregion

			1 °C of global warming			2 °C of global warming		
River basin	Historical rainfall (mm/year)	Number of GCMs[a] (out of 15) projecting a decrease in future rainfall	Dry extreme	Median	Wet extreme	Dry extreme	Median	Wet extreme
Condamine-Balonne	519	11	−12%	−4%	4%	−23%	−8%	7%
Moonie	528	11	−11%	−5%	3%	−22%	−10%	6%
Border Rivers	641	10	−11%	−5%	3%	−21%	−10%	6%
Barwon-Darling	328	10	−11%	−4%	4%	−23%	−7%	8%

Source: Table 2 in Post et al. (2012)
[a]Global Climate Model

Table 7 Summary of projected impacts of climate change on runoff for the broad vicinity of the Maranoa-Balonne-Condamine subregion

			1 °C of global warming			2 °C of global warming		
River basin	Historical runoff (mm/year)	Number of GCMs[a] (out of 15) projecting a decrease in future runoff	Dry extreme	Median	Wet extreme	Dry extreme	Median	Wet extreme
Condamine-Balonne	16	11	−33%	−13%	14%	−54%	−21%	31%
Moonie	16	11	−32%	−12%	9%	−53%	−20%	24%
Border Rivers	32	11	−30%	−14%	7%	−52%	−25%	22%
Barwon-Darling	9	10	−25%	−8%	13%	−38%	−12%	30%

Source: Post et al. (2012); their Table 3
[a]Global Climate Model

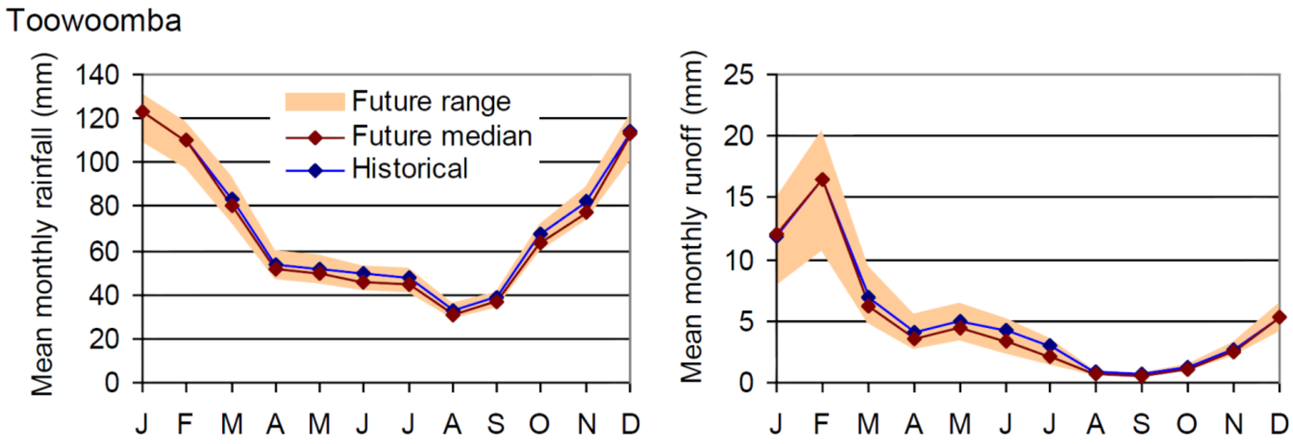

Figure 15 Mean monthly rainfall and runoff for Toowoomba based on historical data (blue line), median climate projections in 2030 (red line) and future range based on the model ensemble (beige shading)

Source: Figure 18 in Post et al. (2010)

The impacts of climate change in the Maranoa-Balonne-Condamine subregion are projected to be increased pressure on water supplies; reduction in grain quality due to increased temperature, evaporation and decreased rainfall; and increased risk and intensity of bushfires (DERM, 2010). In the DERM (2010) report, which assesses likely climate change impacts in Queensland, it is noted that the impacts of declining rainfall and runoff into streams are already being felt by primary producers and that the effects of temperature changes are likely to be felt within the next decade. Cobon et al. (2009) use a climate change risk management matrix for the Queensland grazing industry, from which they conclude that the combined effect of hotter, drier conditions, changed seasonality of rainfall and more bushfires will likely be a reduction in pasture growth, decreased ground cover, decreased plant available water, more wind erosion and generally long-term negative impacts on ecosystem function. These same negative impacts will be felt by the cropping sector. The assessment of climate change impacts on biodiversity is similarly grim, with projections for declining biodiversity, increasing weeds and pests, landscape-level tree mortality due to water stress and reduced extent and diversity of ecosystems.

The CSIRO attempted to quantify the impacts of a changing climate on the water resources of the Condamine-Balonne (including Maranoa) (CSIRO, 2008a) and Moonie river (CSIRO, 2008b) basins in 2030 based on Intergovernmental Panel on Climate Change Fourth Assessment climate change projections and assuming current levels of development. While the mean runoff reduction forecasts for these basins were 9% and 10%, respectively (relative to the historical average (1895– 2006)), slightly less than the 12% reduction projected in the more recent SEACI report, the assessment of impacts remains relevant. Table 8 summarises impacts on the water resource and wetland inundation events under the best (median) and dry and wet forecast scenarios. For a 9 to 10% reduction in runoff and assuming no new development in the basins (e.g. construction of no new water storages or significant land cover change), the CSIRO estimated 8% and 12% reductions in water availability in Condamine-Balonne and Moonie, 12% and 13% reductions in end-of-system flows and 5% and 6% reductions in diversions in the Condamine-Balonne and Moonie river basins, respectively.

In terms of impacts on wetlands, the CSIRO (2008a) study found that using the median estimate for 2030, the average period between flood events to nationally important wetlands on the lower

Balonne River floodplain would increase slightly (9%). Both average flood size and annual flood volume would likely reduce leading to adverse effects on the floodplain vegetation and an 11% reduction in the frequency of years with optimal flows for waterbird breeding habitat. Under the driest scenario modelled, the average period between floods on the lower Balonne River floodplain would increase by nearly two years, the average annual flood volume would be more than halved and there would be a 35% reduction in the number of years with optimal breeding and feeding habitat in the Narran Lakes system. Conversely under the wet extreme, the flood frequency and magnitude would increase somewhat leading to improved conditions on the lower Balonne River floodplain and in the Narran Lakes system.

Depending on the climate change projection, rainfall recharge to groundwater could either increase or decrease; however, the change would not exceed 10%, which is a relatively minor impact on groundwater resources in comparison to groundwater extraction.

There are considerable uncertainties in the climate change projections which make definitive conclusions about the direction and magnitude of changes on water resources difficult to make. However, the SEACI modelling suggests even drier 'best' estimates than the earlier studies, so the weight of evidence is for a shift to drier conditions.

Table 8 Projected impacts of climate change on water resources and wetland inundation in 2030 relative to the historical average (1895–2006)

	Condamine-Balonne			Moonie		
	Dry	Median	Wet	Dry	Median	Wet
Water availability (%)	–27%	–8%	+17%	–29%	–12%	+24%
End-of-system flows (%)	–35%	–12%	+21%	–31%	–13%	+27%
Diversions (%)	–17%	–5%	+7%	–16%	–6%	+10%
Average period between important wetland inundation events (%)	+94%	+9%	–25%	+58%	+24%	–34%
Average flooding volume per year (%)	–57%	–20%	+51%	–56%	–28%	+59%

Source data: tables 4-6, 4-7 and 7-2 in CSIRO (2008a); tables 4-4, 4-5, 4-6 and 7-2 in CSIRO (2008b)

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1.1.3 Geology

Summary

This section summarises the geological context of the three coal-bearing sedimentary basins of the Maranoa-Balonne-Condamine subregion, the northern-most subregion of the Northern Inland Catchments bioregion (Figure 16). The underlying basement rocks and overlying alluvial and volcanic sequences are not discussed here. The largest basin (by area) in the Maranoa-Balonne-Condamine subregion is the Surat Basin, although the area is also underlain by the southern Bowen Basin, and the north-western section of the Clarence-Moreton Basin. The Surat Basin and the north-western part of the Clarence-Moreton Basin are part of the Great Artesian Basin (GAB).

The basins range in age from Late Carboniferous to Early Cretaceous and all contain compositionally similar sedimentary rocks that formed in depositional environments spanning shallow marine to fluvial settings. The most common rock types are sandstone, siltstone, mudstone, shale, coal, and conglomerate. All of the basins also contain volcanic rocks such as tuff, rhyolite and andesite.

The oldest coal basin in the Maranoa-Balonne-Condamine subregion is the Bowen Basin. It started to form during the Late Carboniferous to Early Permian, mainly due to tectonic extension and subsidence. Subsequent volcanic activity helped to bind the basin before deposition ceased in the Late Triassic. After a time of non-deposition (approximately 30 million years) the Surat Basin formed above the Bowen Basin during a period of steady subsidence. A compressional system caused fault reactivation and volcanic activity within the basin to occur before uplift in the Middle Cretaceous halted the formation of the Surat Basin. The Clarence-Moreton Basin is a wedge-shaped segment of sedimentary rocks derived from a nearby subduction zone. The basin formed during the Late Triassic to Early Cretaceous with Late Cretaceous strike-slip faulting controlling deformation of the basin. Volcanic activity also binds this basin, with reverse faulting and uplift marking an end to deposition.

Black coal is mined extensively from the Bowen Basin's main coal reserves in the Blackwater Group and Bandanna Formation. The Walloon Coal Measures occur in both the Surat and Clarence-Moreton basins and are the main coal seams developed for coal and coal seam gas in these basins.

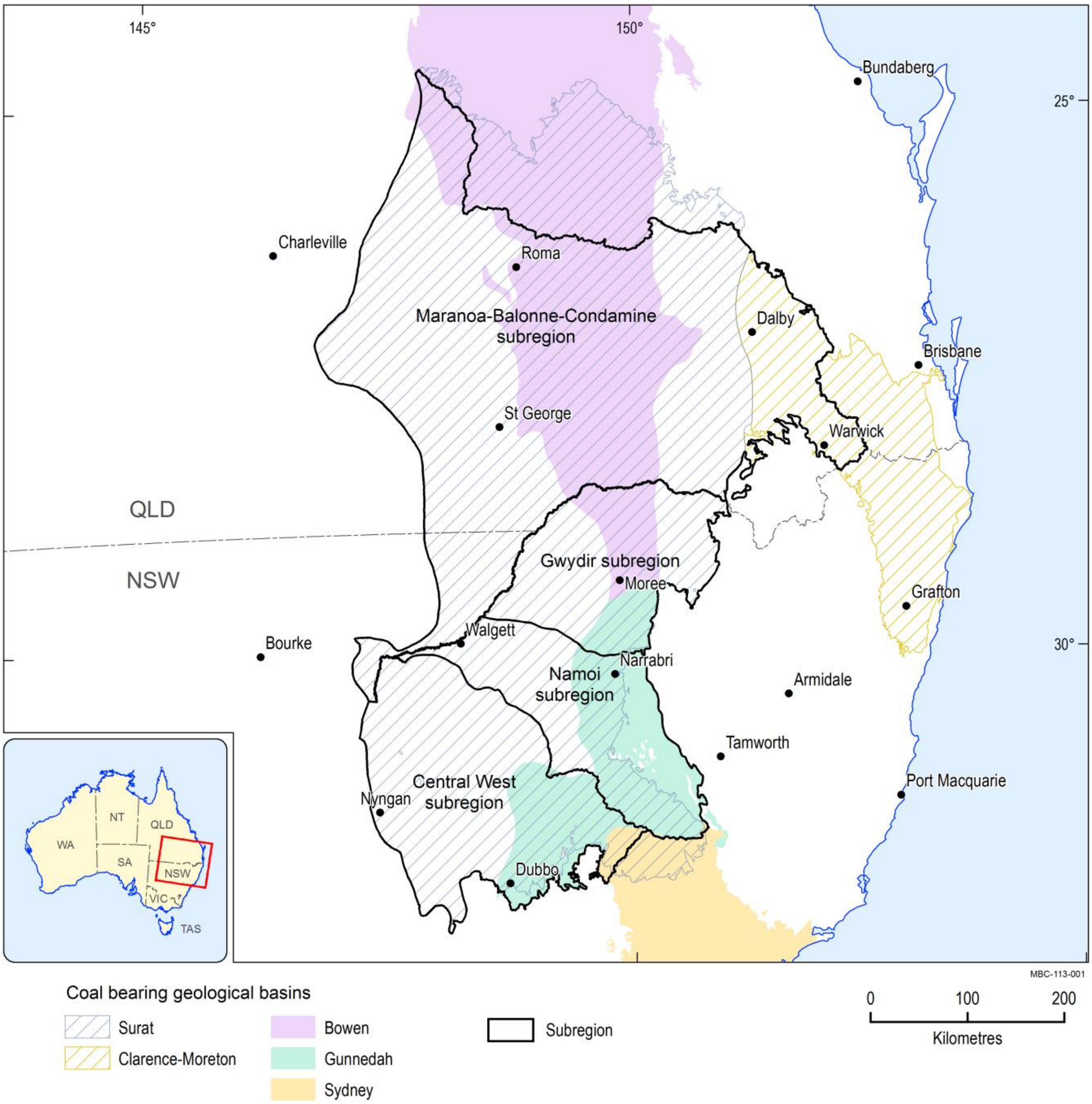

Figure 16 Location of the Maranoa-Balonne-Condamine subregion within the Northern Inland Catchment bioregion and its relation to the geological Surat, Bowen and Clarence-Moreton basins

1.1.3.1 Geological structural framework

1.1.3.1.1 Basin extents and regional geological context

The Bowen Basin spans roughly 200,000 km^2 of eastern Australia, covering a large area of eastern Queensland and part of northern NSW (Cadman et al., 1998). In the Maranoa-Balonne-Condamine subregion, the Surat Basin, which is part of the GAB, overlies the southern Bowen Basin, and also extends beyond the margins of these older stratigraphic sequences (Figure 17). However, the main depositional centres of both the Bowen and Surat basins are co-located (the Taroom Trough and Mimosa Syncline, respectively), meaning that the thickest stratigraphic sequences in both basins occur in roughly similar locations.

The Surat Basin covers approximately 300,000 km^2, and like the Bowen Basin occurs in Queensland and NSW (Exon, 1976). The Clarence-Moreton Basin, the north-western part of which is part of the GAB, is small in comparison, about 38,000 km^2 and is adjacent to the Surat Basin (note that the size of the Clarence-Moreton Basin is inaccurate in some older publications). It also occurs in southern Queensland and northern NSW.

The Bowen, Surat and Clarence-Moreton basins are intracratonic sedimentary basins that have been variably affected by tectonic deformation. These processes have widely caused faulting, folding, volcanic activity and subsidence throughout the basins (Cadman et al., 1998).

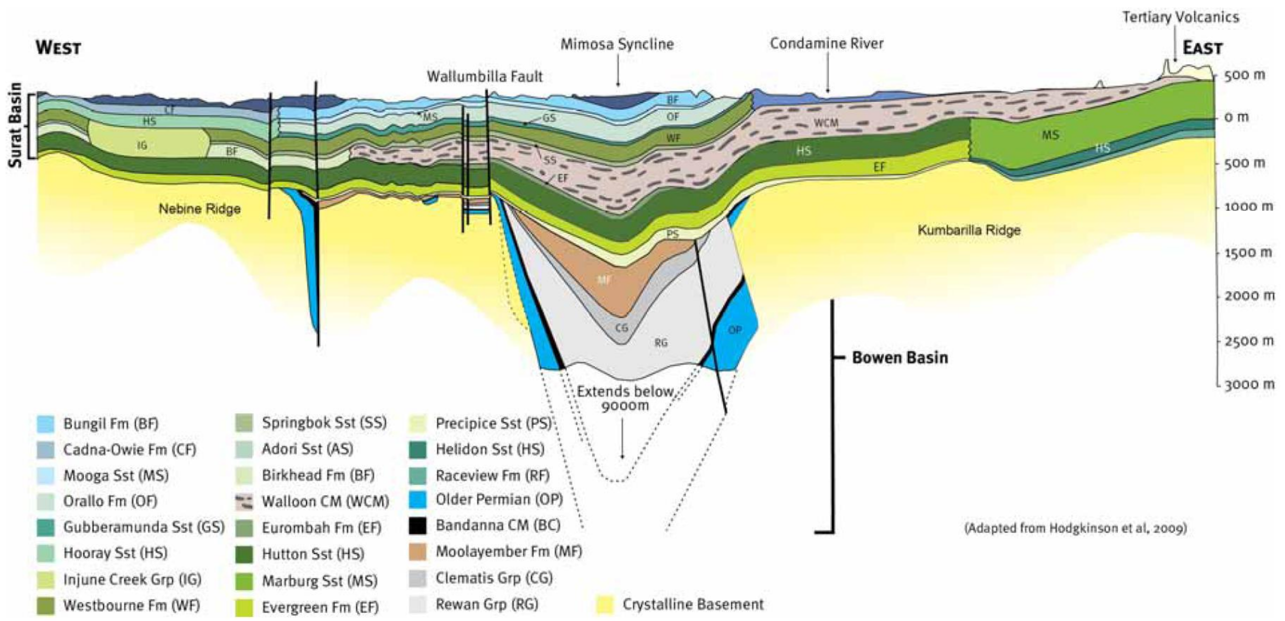

Figure 17 Cross-section of the Surat and Bowen basins

Source: Esterle et al. (2013) as modified from Hodgkinson et al. (2009) and QWC (2012)
Note: The Helidon Sandstone is a superseded stratigraphic name. It has been replaced by the Woogaroo Subgroup.

1.1.3.1.2 Sub-basins

There are currently no formally recognised sub-basins for either the Bowen or Surat basins. However, the Bowen and Surat basins are divided into distinct regions based on the structural features that control both the location and thickness of the sedimentary sequences. The main structural features of the Maranoa-Balonne-Condamine subregion are displayed in Figure 18.

The Clarence-Moreton Basin is composed of three sub-basins: the Cecil Plains Sub-basin, the Laidley Sub-basin and the Logan Sub-basin (Martin and Saxby, 1982). The latter two are outside the Maranoa-Balonne-Condamine subregion and only a portion of the Cecil Plains Sub-basin falls within the subregion. Some authors suggest that due to the continuation of sedimentation and other geological similarities between the Surat Basin and the Cecil Plains Sub-basin, the Cecil Plains Sub-basin should form part of the Surat Basin and not the Clarence-Moreton Basin (Jell et al., 2013).

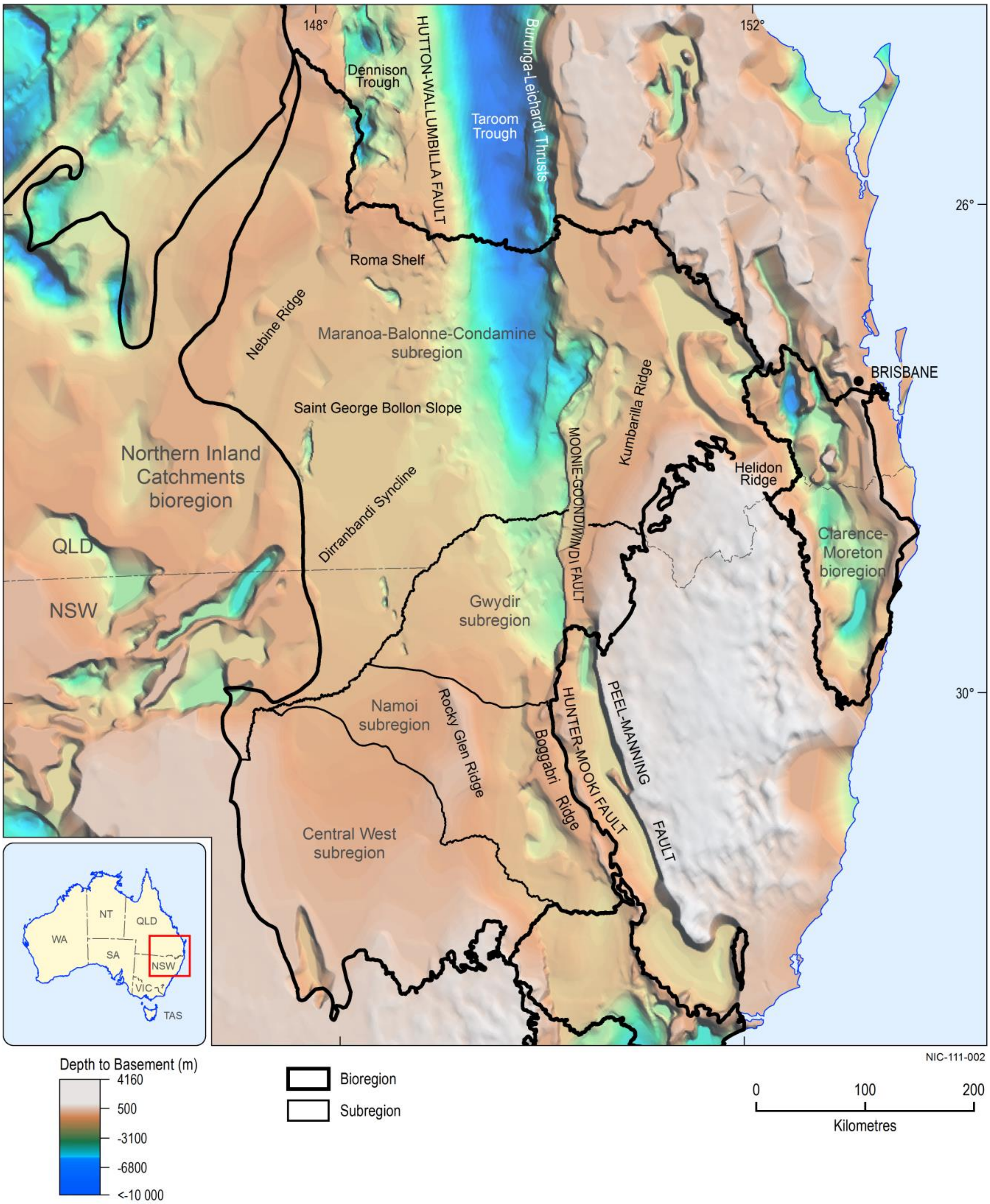

Figure 18 OZ SEEBASE™ map of the depth to basement in the Northern Inland Catchments bioregion with major structural elements

1.1.3.1.3 Basin thickness

The spatial distribution and thickness of the sedimentary rocks of the three coal basins in the Maranoa-Balonne-Condamine subregion is varied (Figure 18) (Exon, 1976; Cadman et al., 1998). The thickest and most complete (continuous) stratigraphic sections occur within the deeper portions of each basin, at the main depositional centres (Exon, 1976; Cadman et al., 1998). The maximum stratigraphic thickness in the Bowen Basin is in the Taroom Trough (Figure 18), which contains a 9 km thick sedimentary succession (Cadman et al., 1998). The infill sequences of the Surat and Clarence-Moreton basins are much thinner in comparison, with total sedimentary thicknesses of 2.5 km and 3 km, respectively (McElroy, 1969; Exon, 1976; Johnstone et al., 1985).

1.1.3.1.4 Structure

The Bowen Basin is bounded to the east by north-striking faults, including a Triassic thrust system that extends south of the Auburn Arch (Cadman et al., 1998). The Taroom Trough is the major sediment depositional centre in the basin and extends throughout the Maranoa-Balonne-Condamine subregion (Cadman et al., 1998; Draper, 2013). It formed during crustal extension in the Late Carboniferous to Early Permian (McKellar, 1998; Fielding et al., 1993). In the south-west of the Bowen Basin, sedimentary sequences pinch-out and thin over the Nebine Ridge and Saint George-Bollon Slope (Figure 18) (Cadman et al., 1998; Draper, 2013). Half-grabens in the Denison and Taroom troughs are evidence of Late Carboniferous and Early Permian tectonic extension (Cadman et al., 1998; Elliott, 1989). To the west, in the central Bowen Basin, the Springsure Shelf is a half-graben that marks the western boundary of the basin (Draper, 2013). Faulting in the southern Bowen Basin is dominantly north-south oriented. Most faults have normal displacement, although many recent faults are reverse faults (Draper, 2013).

The Moonie-Goondiwindi Thrust and the Burunga-Leichhardt Thrust (Figure 18) are major thrust faults that extend through the strata of the Surat Basin from the underlying Bowen Basin, forming the eastern margin of the Taroom Trough (Exon, 1976; Rohead-O'Brien, 2011; Cook and Draper, 2013). The Hutton-Wallumbilla Fault (Figure 18) is also a major lower basement structure, but is not as strongly developed in the Surat Basin as the previously mentioned faults (Rohead-O'Brien, 2011; Cook and Draper, 2013). These thrust fault systems have formed anticlines and synclines along the outer margins of the subregion (Surat Basin) (Rohead-O'Brien, 2011). The most prominent of these features is the Mimosa Syncline, a reflection of the Taroom Trough in the underlying Bowen Basin (Fielding et al., 1993; McKellar, 1998). The Mimosa Syncline is the main depositional centre of the Surat Basin (Fielding et al., 1993; Yago, 1996; McKellar, 1998). As the subsidence rate slowed during the Middle Jurassic, deposition centred on the Dirranbandi Syncline (Figure 18), once thought to be part of the Mimosa Syncline (Exon, 1976).

The Nebine Ridge is an Early Paleozoic structure, part of the south-eastern Thomson Fold Belt. It is a north-north-east trending basement high, separating the Surat and Eromanga basins (Finlayson et al., 1990; Cook and Draper, 2013). The Nebine Ridge is a fragment of Precambrian cratonic crust that has been altered significantly by tectonism (plutonic and compressional events) in the Carboniferous, and by later uplift in the Middle Jurassic (Exon, 1976). The Roma Shelf (Figure 18) is a structural high, bounded by the Hutton-Wallumbilla (Figure 18) and the Arbroath and Merivale faults (Exon, 1976; Cook and Draper, 2013). Other faults and half-grabens occur west of the Arbroath and Merivale faults (both later reactivated as thrusts), with maximum fault displacements less than 100 m (Exon, 1976; Cadman et al., 1998). The Auburn Arch and the Yarrol Orogen (northern extent of the New England Fold Belt) are structural basement highs that separate the sedimentary rocks of the Surat and Clarence-Moreton basins (Exon, 1976; Finlayson et al., 1990; Cook and Draper, 2013). The separation zone is a Jurassic uplift structure known as the Kumbarilla Ridge (Figure 18) (Exon, 1976; Cook and Draper, 2013).

The Clarence-Moreton Basin is bounded by older granitic and metamorphic basement blocks. Major post-Triassic uplift created the synclinal depression of the Cecil Plains, forming the Cecil Plains Sub-basin, one of the main structural features in the north-western Clarence-Moreton Basin (Jell et al., 2013). The Cecil Plains Sub-basin sits on top of the Horrane Trough, a half-graben feature thought to have formed during strike-slip faulting (Jell et al., 2013). Other significant structural features within the basin are the Helidon Ridge, Gatton Arch, and a small portion of the Richmond Horst is in the subregion (Cadman et al., 1998; Johnstone et al., 1985). The Gatton Arch is outside of the Maranoa-Balonne-Condamine subregion, but forms the main separation zone of the two northern sub-basins.

1.1.3.2 Stratigraphy and rock type

1.1.3.2.1 Bowen Basin

There are almost 50 stratigraphic units recognised in the Bowen Basin (Australian Stratigraphic Units Database, 2013). The spatial distribution and stratigraphic relationships of these rock units vary within the basin, particularly between the main depositional centres such as the Taroom and Denison troughs. The most important coal-bearing stratigraphic units in the Bowen Basin that occur in the Maranoa-Balonne-Condamine subregion are summarised in this section, and are visually represented in Figure 19.

Arbroath beds

Early Permian deposition within a half-graben structure formed this unit, which consists of shale and siltstone with some sandstone, conglomerate and coal (Green et al., 1997). A correlative of the more widely distributed Reids Dome beds, this unit is known only from the Roma Shelf region.

Muggleton Formation

The Muggleton Formation occurs in the Roma region and is considered the lowermost formation of Permian age in the vicinity (Green et al., 1997). It is a shale, siltstone and sandstone unit with minor coal and tuff layers (Green et al., 1997). The Lorelle Sandstone Member, a sub-unit of the Muggleton Formation, is composed largely of sandstone with minor shale, siltstone, coal and tuff (Green et al., 1997).

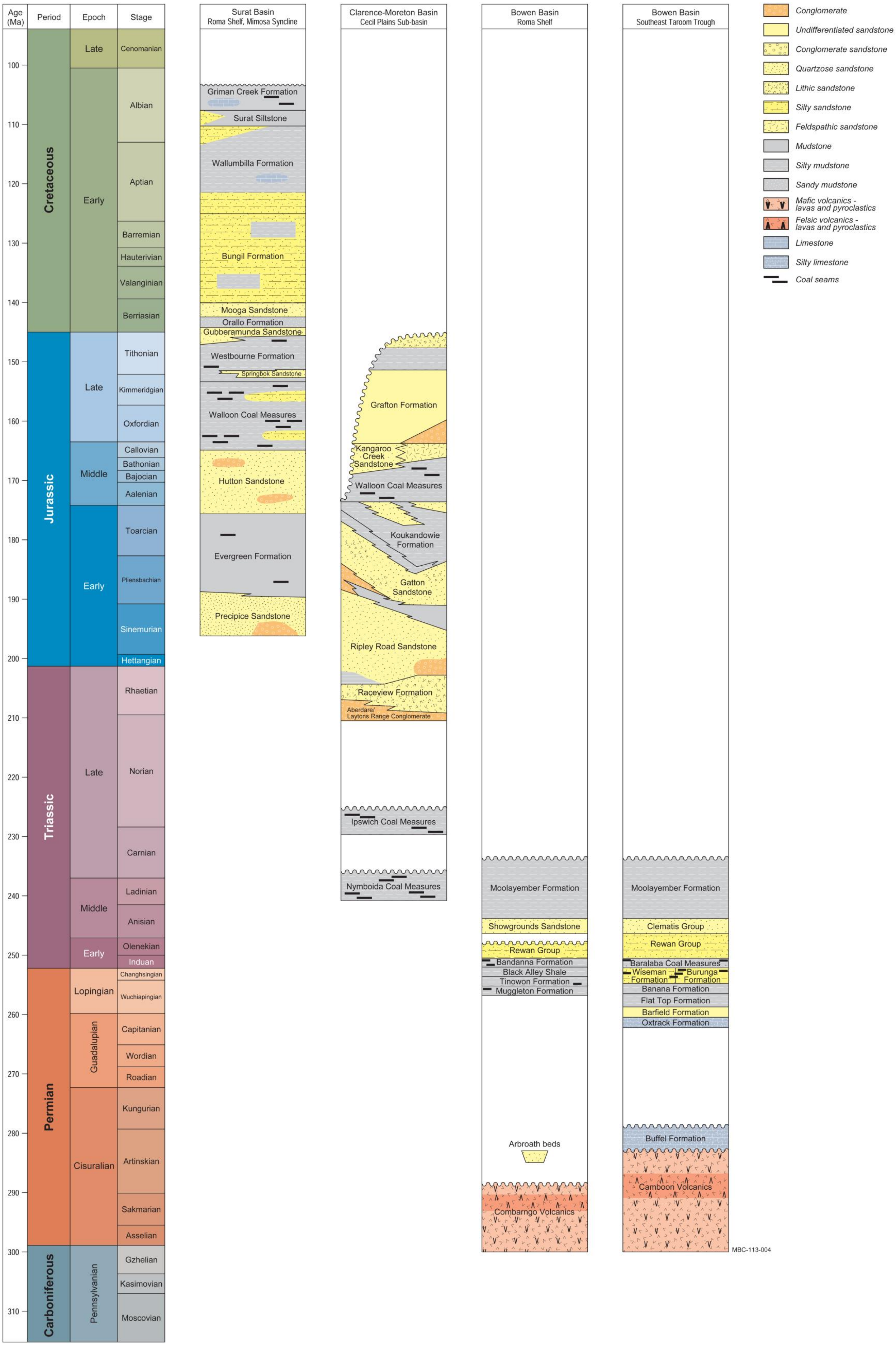

Figure 19 Stratigraphic column of the Maranoa-Balonne-Condamine subregion

The stratigraphic units listed here are those that could not be definitively excluded from the subregion based on the current literature.
Source data: derived from data presented in McKellar (1998), Wells and O'Brien (1994), Totterdell et al. (2009), Doig and Stanmore (2012) and Cook and Draper (2013)
This figure has been optimised for printing on A3 paper (297 mm x 420 mm)

Tinowon Formation

An Early Permian fluvio-deltaic and brackish marine unit consisting of shale, siltstone, sandstone and coal (Green et al., 1997). Significant amounts of coal from the Tinowon Formation occur on the Roma Shelf (Green et al., 1997). The Wallabella Coal Measures, part of the Tinowon Formation, is a swamp coal deposit that occurs in relatively thick and continuous sections (Green et al., 1997), and is interbedded with shale, siltstone, tuff and minor sandstone (Green et al., 1997).

Flat Top Formation

The Flat Top Formation formed in a delta fan to shallow marine setting and is composed of siltstone, sandstone, mudstone, conglomerate, coal and tuff (Draper, 2013).

Banana Formation

The Banana Formation is an assemblage of mudstone, shale, siltstone and sandstone with minor coal formed during the Late Permian in brackish to marine settings (Green et al., 1997).

Burunga Formation

The Burunga Formation is a Late Permian sandstone, shale, siltstone, tuff and clay unit with significant lithological variations from region to region (Green et al., 1997). In the central and southern Bowen Basin this unit appears in three distinct layers, with the upper and lower layers being coal measures and the middle layer a marine mudstone (Green et al., 1997). A sub-unit within the Burunga Formation is the Scotia Coal Member, which contains sandstone, shale, siltstone, coal and tuff (Green et al., 1997).

Black Alley Shale

A shale-rich unit with beds of tuff, coal and sandstone formed in brackish marine conditions during a Late Permian transgression, followed by a change to freshwater lake sedimentation (Mollan et al., 1969; Green et al., 1997; Hoffmann et al., 1997). This unit also contains the Winnathoola Coal Measures, a thin bed of coal and sandstone formed in a deltaic setting along the Roma Shelf (Green et al., 1997).

Bandanna Formation

Formed as infill sediments within a large lake or inland sea by deltaic input, the Bandanna Formation is composed of sandstone, mudstone, siltstone and rare coal (Green et al., 1997; Draper, 2013). It is part of the Blackwater Group and is one of the main geological units mined for coal in the Bowen Basin.

Baralaba Coal Measures

A marine and fluvial unit deposited during the Permian containing sandstone, siltstone, mudstone, coal and tuff (Green et al., 1997). The basal sub-unit of the Baralaba Coal Measures, the Kaloola Member, consists of siltstone, sandstone, tuff and conglomerate (Green et al., 1997).

1.1.3.2.2 Surat Basin

There are close to 70 stratigraphic units recognised across the entire Surat Basin, most of which belong to one of five main stratigraphic groups (Australian Stratigraphic Units Database, 2013). The spatial distribution and stratigraphic relationships of these units vary within the basin, particularly between the main depositional centre and the other structural elements of the basin. Summaries of the most important coal-bearing stratigraphic units in the Maranoa-Balonne-Condamine subregion (Figure 19) of the Surat Basin are given in this section. The major aquifers are discussed in Section 1.1.4.

Evergreen Formation

The Evergreen Formation consists of siltstone, shale, sandstone and coal that formed in a fluvial depositional setting on a coastal plain, with possible deltaic influence (Exon, 1976; Cook and Draper, 2013). The formation contains two sub-units, the Boxvale Sandstone Member and the Westgrove Ironstone Member (Exon, 1976; Cook and Draper, 2013). The Boxvale Sandstone Member, consisting of sandstone, siltstone and coal, was deposited during a brief marine transgression (Exon, 1976).

Walloon Coal Measures

The Walloon Coal Measures are the most significant coal resource in the Surat Basin, and the only unit mined for coal in the basin. A compositionally varied formation that consists of thinly bedded claystone, shale, siltstone, sandstone (lithic and sublithic to feldspathic arenite), coal seams and minor limestone (Exon, 1976). A muddy pebble conglomerate also occurs in several locations (Exon, 1976). The depositional environment is interpreted as fluvial and swampy plains (Exon, 1976). The Walloon Coal Measures can be subdivided into four sub-units: the Durabilla Formation, Taroom Coal Measures, Tangalooma Sandstone and the Juandah Coal Measures (Exon, 1976; Swarbrick, 1973). The Taroom Coal Measures are a mixed sequence of sandstone, siltstone and mudstone, with abundant coal and carbonaceous mudstone interbeds (Scott et al., 2004). A mixed assemblage of sandstone, siltstone, mudstone, claystone, tuff and thin coal to carbonaceous mud seams form the Tangalooma Sandstone (Rohead-O'Brien, 2011). The sandstone is commonly heavily cemented or in-filled with clay (Rohead-O'Brien, 2011). The Juandah Coal Measures are similar in composition and coal volume to the Taroom Coal Measures (Scott et al., 2004).

Westbourne Formation

A Late Jurassic formation of interbedded mudstone, siltstone, sandstone and some coal (Exon, 1976).

Orallo Formation

The Orallo Formation is composed of thin beds of siltstone and mudstone with some sandstone and minor conglomerate and coal deposited by fluvial channels in the Early Cretaceous to Late Jurassic (Exon, 1976).

Griman Creek Formation

A sandstone-dominated unit grading in places to siltstone and mudstone. Minor conglomerate and coal bands occur throughout and are more common in the upper section (Exon, 1976). The lower part of the Griman Creek Formation (Wallangulla Sandstone Member) is interpreted to have formed in a marine environment whereas the upper section (Coocoran Claystone Member) is interpreted as non-marine (Exon, 1976).

1.1.3.2.3 Clarence-Moreton Basin

There are close to 40 stratigraphic units in the Clarence-Moreton Basin, most of which belong to one of two main sub-groups (Australian Stratigraphic Units Database, 2013). The spatial distribution and stratigraphic relationships of these units vary across the basin. There are several different interpretations for the base of the Clarence-Moreton Basin, the two most common being the base of the Woogaroo Subgroup (the Aberdare Conglomerate) or the base of the Nymboida Coal Measures (Wells and O'Brien, 1994; Doig and Stanmore, 2012). For this product, the base of the Nymboida Coal Measures will be considered to be the base of the Clarence-Moreton Basin. Summaries of the most important coal-bearing units (Figure 19) in the Clarence-Moreton Basin are given in this section.

Nymboida Coal Measures

The Nymboida Coal Measures formed during the Middle Triassic in lake and marsh depositional environments (Stewart and Adler, 1995; Cadman et al., 1998). This unit is composed of interbedded sandstone, shale, siltstone, claystone, conglomerate, felsic tuff, basalt and coal, forming a unit up to 1000 metres in thickness to the east, thinning to the west (Stewart and Adler, 1995; Cadman et al., 1998). There are also some rhyolitic tuff deposits (Packham and Day, 2008). The Cloughers Creek Formation and Basin Creek Formation are the coal-bearing sub-units of the Nymboida Coal Measures. The Cloughers Creek Formation is a shale-rich formation, carbonaceous in places, that outcrops as lenses in creek beds sporadically throughout the basin (McElroy, 2008). In some places this unit may also contain conglomerate, breccia, siltstone, sandstone and coal (McElroy, 2008). The Basin Creek Formation is a thick unit of sandstone, shale, conglomerate and some coal (McElroy, 2008). The rocks are generally finely laminated, forming a unit up to 1000 metres in thickness (Stewart and Adler, 1995; McElroy, 2008).

Ipswich Coal Measures

During the Late Triassic the Ipswich Coal Measures of Queensland were deposited across the basin after a period of uplift and erosion, but are not located to the west of the West Ipswich Fault (Korsch et al., 1989; Cadman et al., 1998; Chern, 2004). Composition is a varying mix of interbedded sandstone, siltstone, claystone, conglomerate and coal, as well as some volcanic rocks (Stewart and Adler, 1995; Cadman et al., 1998). In Queensland the Ipswich Coal Measures can reach a thickness of one kilometre (Stewart and Adler, 1995) The Ipswich Coal Measures have two equivalent units in the Maranoa-Balonne-Condamine subregion in NSW: the Red Cliff Coal Measures and the Evans Head Coal Measures (Stewart and Adler, 1995). The Red Cliff Coal Measures are a conglomerate, sandstone, shale, breccia, siltstone, mudstone and coal unit deposited during the Triassic, reaching up to 600 m in thickness (McElroy, 2008; Doig and

Stanmore, 2012). The Red Cliff Coal Measures correlate with the Ipswich and Evans Head Coal Measures (Doig and Stanmore, 2012). The group, up to 300 m thick, is composed of sandstone, shale, conglomerate and mudstone with minor coal forming parting of very fine bands make up the Evans Head Coal Measures (McElroy, 2008; Doig and Stanmore, 2012). This sequence correlates to the Ipswich and Red Cliff Coal Measures (Stewart and Adler, 1995; McElroy, 2008).

Woogaroo Subgroup

The Woogaroo Subgroup formed during the Late Triassic and is divided into four separate units, which combine for a maximum thickness of 1200 m: the Aberdare Conglomerate, Laytons Range Conglomerate, Raceview Formation and Ripley Road Sandstone (Wells and O'Brien, 1994; Australian Stratigraphic Units Database, 2013). Both the Raceview Formation and the Ripley Road Sandstone contain coal and fall within the Maranoa-Balonne-Condamine subregion. The Raceview Formation is composed of sandstone, siltstone and shale, with some limited coal deposited in a fluvial, lacustrine and swamp environment (Wells and O'Brien, 1994). In the Maranoa-Balonne-Condamine subregion the Raceview Formation is located in the deeper depositional sites (Wells and O'Brien, 1994). The Ripley Road Sandstone is a sandstone-rich unit with conglomerate, minor mudstone and coal, deposited as channel fill and point bar deposits (Wells and O'Brien, 1994; Ingram and Robinson, 1996). It has a maximum thickness of 150 m (Wells and O'Brien, 1994; Ingram and Robinson, 1996).

Gatton Sandstone

The Gatton Sandstone is a stacked channel sand unit from the Early Jurassic composed of thick beds of sandstone, with carbonate material and clay; some pebble beds are also noted (Wells and O'Brien, 1994; Ingram and Robinson, 1996; Cadman et al., 1998). It stands alone as a formation of the Marburg Subgroup, but is also composed of two sub-units that are found in the lower sections of the Gatton Sandstone, which contain no coal seams: the Koreelah Conglomerate Member, a conglomerate and sandstone unit, and the Calamia Member of thin mudstones and siltstones (Wells and O'Brien, 1994; Ingram and Robinson, 1996; Cadman et al., 1998).

Koukandowie Formation

An Early Jurassic Marburg Subgroup formation consisting of interbedded sandstones, siltstone, claystone and minor coal (Willis, 1994). Reaching a maximum thickness of 500 m, the Koukandowie Formation can be further divided into three sub-units: the Heifer Creek Sandstone, the Ma Ma Creek Member and the Towallum Basalt (Wells and O'Brien, 1994). The Ma Ma Creek Member is dominantly shale with siltstone interbedding and some sandstone deposited during a lacustrine incursion over a fluvial system; some minor fossilised wood and conglomerate bands have also been observed (Wells and O'Brien, 1994). The Hiefer Creek Sandstone Member is asandstone to conglomeritic sandstone deposited as fluvial bedload and point bar facies (Powell et al., 1993; Ingram and Robinson, 1996).

Walloon Coal Measures

Middle Jurassic lakes and rivers deposited the Walloon Coal Measures in the Clarence-Moreton Basin, which is slightly different from the fluvial and swampy plains depositional environment of the Surat Basin Walloon Coal Measures in Section 1.1.3.2.2 (Cadman et al., 1998; McElroy, 2008).

The unit is compositionally similar to strata in the Surat Basin, containing calcareous sandstone, siltstone, mudstone, claystone and discontinuous coal; volcanic ash falls are also common (Cadman et al., 1998; McElroy, 2008). Also similar to the Surat Basin sequence, it is divided into several distinct sub-units (Wells and O'Brien, 1994). The Taroom Coal Measures are a compositionally mixed sequence of sandstone, siltstone and mudstone, with abundant coal and carbonaceous mudstone beds (Scott et al., 2004). The Tangalooma Sandstone is an interbedded mix of sandstone, siltstone, mudstone, claystone, tuff and thin coal to carbonaceous mud seams (Rohead-O'Brien, 2011). The Juandah Coal Measures are unit similar in composition and coal volume to the Taroom Coal Measures of the same subgroup (Scott et al., 2004).

Kangaroo Creek Sandstone

A massive sandstone member with layers of siltstone and carbonaceous mudstone, it formed in fluvial channel environments (Doig and Stanmore, 2012). It is observed as a coarse to very coarse grained, highly friable sandstone (P Baker (Department of the Environment), 2014, pers. comm.). Currently the Kangaroo Sandstone Member stands as a separate unit above the Walloon Coal Measures, although there is a current review of the stratigraphic nomenclature and this unit may soon form part of a newly proposed unit, the Orara Formation (Wells and O'Brien, 1994; Doig and Stanmore, 2012; Australian Stratigraphic Unit Database, 2013).

Grafton Formation

A Late Jurassic to Early Cretaceous unit composed of sandstone, siltstone, mudstone and minor coal from a dominantly fluvial environment (Wells and O'Brien, 1994).

1.1.3.3 Basin history

1.1.3.3.1 Tectonic evolution

The formation of the Bowen Basin began in the Late Carboniferous and Early Permian with tectonic extension (Cadman et al., 1998; Elliott, 1989; Draper, 2013). Extensional subsidence during the Early Permian led to the deposition of the earliest known sedimentary rocks in the basin (Cadman et al., 1998). During this time, volcanic deposits formed east of the Roma Shelf, and andesitic rocks were extruded near the Auburn Arch (Cadman et al., 1998). Subsidence continued steadily into the Early Triassic, driving continued deposition (Draper, 2013). During the Late Triassic, deposition ceased, with an approximately 30 million year period of erosion marking the divide between the Permian-Triassic Bowen Basin and the Jurassic-Cretaceous Surat Basin (Cadman et al., 1998). The Surat Basin began forming due to thermal subsidence following the Hunter-Bowen Orogeny, after deposition of the sedimentary rocks of the Bowen Basin (McKellar, 1998; Fielding et al., 1993). Deposition of most sedimentary sequences is attributed to large inland fluvial systems across an alluvial plain, interspersed with swamps, lakes and deltas (Exon, 1976; Rohead-O'Brien, 2011). Sediment input was largely controlled by the steady rate of subsidence (Fielding et al., 1993). Early sedimentation patterns provide evidence for periods of erosion and tectonic reactivation from underlying faults in the Bowen Basin (McKellar, 1998; Fielding et al., 1993). Basin formation ceased once uplift began during the Middle Cretaceous (Yago, 1996). Subsequently, volcanic activity during the Cenozoic resulted in localised compression and some folding (Yago, 1996; Fielding et al., 1993; Finlayson et al., 1988; Brown et al., 1983).

The basement rocks of the Clarence-Moreton Basin are remnants of an accretionary wedge of pre-Permian crust that formed from westerly dipping subduction at a nearby plate boundary (Cadman et al., 1998). Volcanic activity is evident in the rock record through the Late Triassic, as well as uplift and erosion (Cadman et al., 1998). Compressive tectonic activity resulted in reverse faulting, four way dip closures on faults and the formation of intrusive and extrusive igneous rocks throughout the Late Oligocene and Early Miocene (Cadman et al., 1998).

1.1.3.3.2 Volcanism and intrusives

Volcanic activity occurred during the Early Permian in the Bowen Basin. This led to the formation of the Combarngo Volcanics to the east of the Roma Shelf, as well as andesitic extrusives (Camboon Volcanics) near the Auburn Arch (Cadman et al., 1998).

In the Surat Basin, Jurassic volcanism in the east contributed significant amounts of lithic detritus that were subsequently incorporated in the sedimentary record of the basin (Exon, 1976). Andesitic volcanism during the Middle and Late Jurassic also contributed material to the Springbok Sandstone, Orallo Formation and Westbourne Formation in the north of the basin (Exon, 1976).

Through the Middle and Late Triassic volcanic activity in the Clarence-Moreton Basin formed the Copes Creek Tuff and the Chillingham Volcanics (Cadman et al., 1998). During the Late Oligocene to Early Miocene tectonic activity formed numerous igneous rock bodies (intrusive and extrusive) throughout the basin (Cadman et al., 1998). The Mount Warning volcanic complex and the Main Range and Lamington volcanic flows, as well as various sills, were also formed during this time (Cadman et al., 1998).

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1.1.4 Hydrogeology and groundwater quality

Summary

This summarises the groundwater around and above the coal-bearing formations in the Maranoa-Balonne-Condamine subregion. The Maranoa-Balonne-Condamine subregion includes groundwater systems in alluvial aquifers associated with major rivers (and antecedent systems), basalt aquifers associated with the Main Range Volcanics Formation and aquifers of the Surat Basin within the Great Artesian Basin (GAB). The Maranoa-Balonne-Condamine subregion lies within the Murray–Darling Basin and the above-mentioned groundwater systems are included in the Commonwealth's *Basin Plan 2012*, with the exception of the GAB formations in the northern part of the Maranoa-Balonne-Condamine subregion.

Throughout the subregion, groundwater is widely extracted for stock and domestic purposes, and – to a lesser extent – for town water supply and intensive agriculture. Groundwater extraction for irrigation is concentrated within alluvial aquifers flanking the upper reaches of the Condamine River, sections of the Macintyre and Dumaresq rivers, Macintyre Brook and an area north-west of St George. Across the entire subregion, aquifers of the GAB are a major water source for stock and domestic and town water supply purposes. In addition, a significant amount of groundwater is extracted from the Walloon Coal Measures of the GAB sequence, as a by-product of coal seam gas production.

Within the Maranoa-Balonne-Condamine subregion, groundwater monitoring has historically been undertaken by state water agencies for a variety of purposes including water level, water quality and salinity monitoring. Monitoring is focused on priority groundwater areas including the GAB, Condamine Alluvium, Border Rivers Alluvium and the St George Alluvium and basalts of the Main Range Volcanics Formation. More recently, an increasing amount of groundwater monitoring is undertaken by coal seam gas and mining companies, as is required under the current Queensland regulatory framework and Australian Government approval conditions.

Groundwater flows in the alluvial groundwater systems, with the exception of the Condamine Alluvium, are generally topographically driven with lateral flow directions similar to that of major drainage. Areas of potential inter-formational flow from alluvial aquifers into GAB formations exist across parts of the subregion, where water levels in the alluvium are higher than in the GAB formations.

Groundwater flow in intake beds and in the uppermost formations of the GAB is to the south and south-west.

The NSW Government undertakes groundwater planning and management via water sharing plans. Water sharing plans allow for management of individual groundwater systems and are effective for ten years from their date of commencement. Groundwater planning and management is undertaken by the Queensland Government via water resource plans. Water resource plans are subordinate legislation under the Commonwealth's *Water Act 2007*, prepared at a river basin scale, and they specify the outcomes and strategies that will be used

for each plan area. They expire after ten years unless they have been formally extended. Groundwater is not managed in every water resource plan. Sustainable yield (considering an integrated surface water – groundwater assessment) was not available for the three water resource plans in the Maranoa-Balonne-Condamine subregion. Resource operation plans implement the outcomes and strategies specified in the water resource plans.

In response to coal seam gas development in the Queensland portion of the Surat and southern Bowen basins, the Queensland Government has established a cumulative management area to enable monitoring and assessment of the cumulative impacts of coal seam gas activities upon groundwater resources. Within the Surat Cumulative Management Area, the Queensland Office of Groundwater Impact Assessment is responsible for assessing impacts and establishing integrated management arrangements in the Underground Water Impact Report for the Surat Cumulative Management Area (QWC, 2012). The Underground Water Impact Report obliges coal seam gas companies to undertake monitoring and in some cases construct new monitoring points.

1.1.4.1 Groundwater systems

1.1.4.1.1 System boundaries and hydrostratigraphic units

The Maranoa-Balonne-Condamine subregion includes the following geological environments (from youngest to oldest) that contain individual groundwater systems:

- alluvial aquifers associated with major rivers (i.e. the Condamine, Balonne, Dumaresq and Macintyre rivers) and antecedent systems that form paleochannel infill and a broad alluvial cover over much of the subregion
- fractured rock aquifers within the Main Range Volcanics Formation
- sedimentary rocks of the geological Surat Basin that comprise aquifers of the Great Artesian Basin (GAB).

Most of the Maranoa-Balonne-Condamine subregion lies within the Murray–Darling Basin and the above-mentioned groundwater systems are included in the Commonwealth's *Basin Plan 2012* (developed under the Commonwealth's *Water Act 2007*), with the exception of the GAB formations in the northern part of the Maranoa-Balonne-Condamine subregion. Under the Basin Plan, the Maranoa-Balonne-Condamine subregion includes ten groundwater sustainable diversion limit resource units that lie entirely within the subregion (Figure 20).

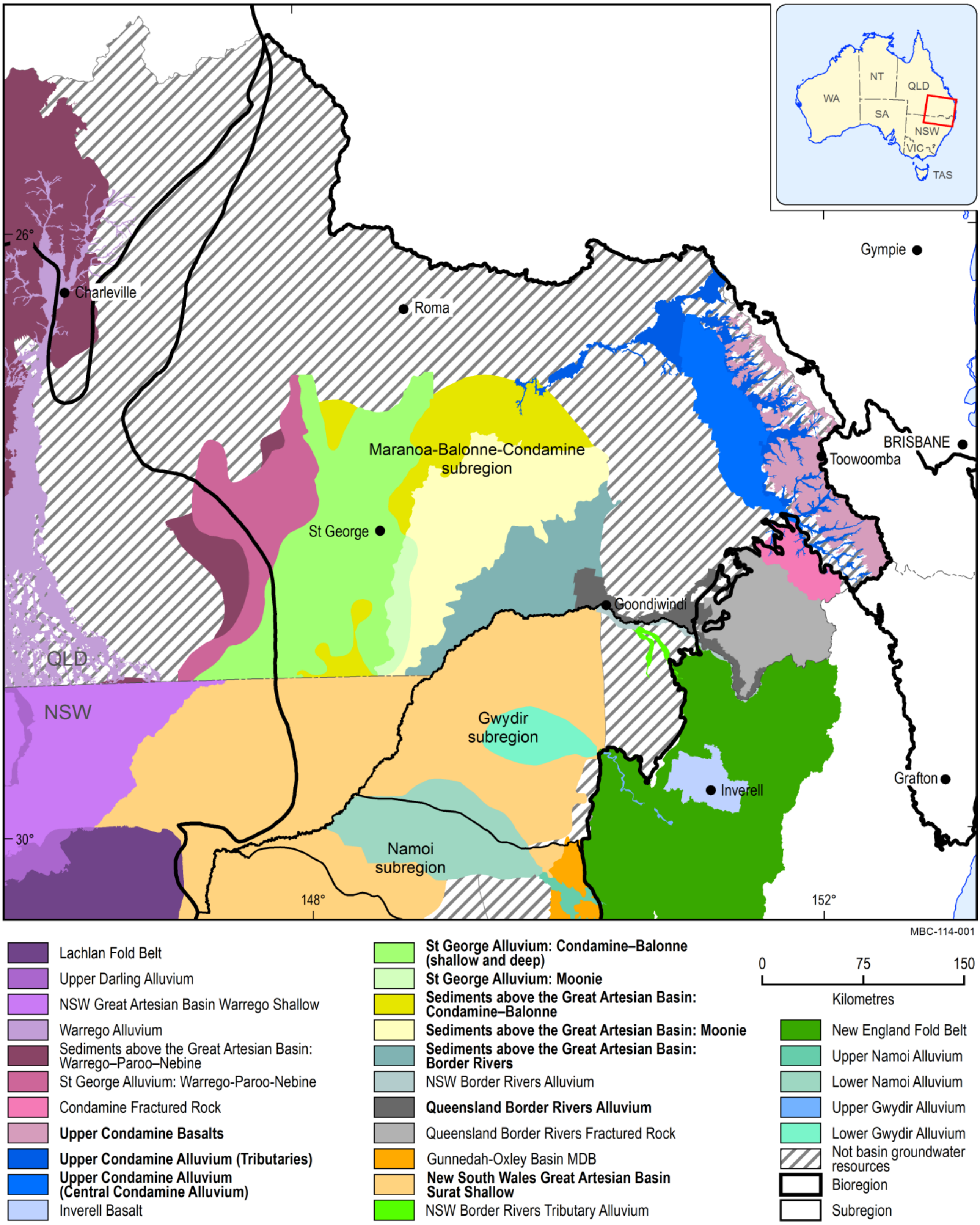

Figure 20 Groundwater sustainable diversion limit resource units for the Commonwealth's *Basin Plan 2012*, developed under the Commonwealth's *Water Act 2007*

Resource units that lie entirely within the subregion are in bold within the legend.

Throughout the subregion, groundwater is widely extracted for stock and domestic purposes, and to a lesser extent town water supply and intensive agriculture (e.g. feedlots). Groundwater extraction for irrigation is concentrated within alluvial aquifers flanking the upper reaches of the

Condamine River, sections of the Macintyre and Dumaresq rivers, Macintyre Brook and north-west of St George. Aquifers of the GAB are a major water source for stock and domestic and town water supply purposes across the entire subregion. In addition, a significant amount of groundwater is extracted from the Walloon Coal Measures, within the GAB sequence, as a by-product of coal seam gas production.

1.1.4.1.2 Alluvial aquifer systems

Much of the subregion is covered, to varying extents, by an upper and lower alluvial system containing groundwater. The deeper system was previously referred to by the Murray-Darling Basin Commission as the Gunnedah Subsystem (in NSW, this includes the Gunnedah Formation and underlying Cubbaroo Formation, although these are not widely recognised in Queensland). The deeper system is overlain by the more extensive Narrabri Subsystem (in NSW consisting of the Narrabri Formation, which again is not widely recognised in Queensland) (Barnett et al., 2004).

The extent of the Gunnedah Subsystem is poorly defined as a result of being obscured by the overlying Narrabri Subsystem (Skelt et al., 2004b). Within the Maranoa-Balonne-Condamine subregion much of the Gunnedah Subsystem is restricted to the southern part of the Border Rivers river basin, extending south into NSW between Mungindi and the south-eastern boundary of the subregion (to the west of Texas).

Kellett et al. (2006) reported a lower alluvial aquifer confined to a north-east to south-west buried paleochannel (the Dirranbandi paleochannel), roughly paralleling the Culgoa-Balonne rivers from north of St George to the NSW border.

The most productive alluvial groundwater systems in order of usage are located within the Condamine (Upper Condamine Alluvium), Maranoa-Balonne and Border Rivers river basins.

Condamine river basin

The Condamine Alluvium lies within a broad alluvial plain flanking the upper reaches of the Condamine River to the south-east of Chinchilla (Figure 24). The alluvium is on average between 20 and 30 m thick but thickens to 150 m south of Dalby (Hillier, 2010). The most productive groundwater area occurs in sand and gravel aquifers located in the central part of the area of mapped alluvium. No large groundwater reserves occur in the western area of mapped alluvium (Hillier, 2010). Skelt et al. (2004a) recognise alluvial aquifers within the area as part of the extensive Narrabri Subsystem that covers much of the subregion and extends into NSW. However, this designation is not universally accepted, and it has been suggested that the deeper alluvial aquifers may be equivalent to the Gunnedah Formation (which is included in the Gunnedah Subsystem by Skelt et al., 2004a).

Groundwater in the area has been used extensively for irrigation, industrial and stock and domestic purposes, with large-scale expansion first occurring in the 1960s. By 1970 it was recognised that the groundwater system was being over-exploited and an embargo on the issue of further groundwater extraction licences was introduced in the same year (Skelt et al., 2004a). Further, the Basin Plan has recognised this overuse and has set the sustainable diversion limit (SDL) less than the current use (baseline diversion limit (BDL)) (Table 9 and Table 10). Huxley (1982) reported that the aquifers of the Condamine Alluvium range from unconfined to semi-confined conditions and divided the alluvial sediments in to two groups based on depositional environment and hydraulic behaviour. The first group comprised sheetwash alluvium from adjacent weathered hard rock areas, consisting of predominantly clayey sediments, flanking the valley margins; the second group comprised sandier floodplain alluvium within the Condamine River Valley and tributary valleys deposited by the Condamine River and its antecedents. The two groups of alluvium are likely to intertongue, but the actual relationship is unknown (Huxley, 1982).

Border Rivers river basin

Within the Border Rivers river basin, groundwater exists within alluvial sediments associated with the Dumaresq and Macintyre rivers and Macintyre Brook. East of the confluence of the Macintyre Brook and the Dumaresq River, alluvial sediments are increasingly confined to narrow valleys. This contrasts with alluvial sediments to the west of the Dumaresq and Macintyre confluence, which are more extensive and are characteristic of an alluvial plain. Most water bores are located upstream of the Dumaresq and Macintyre confluence where fresh supplies are found, and these are dominantly used to irrigate lucerne and other fodder crops (Baskaran et al., 2009).

Both the Narrabri and Gunnedah formations are recognised within the area. The Gunnedah Formation is a fining upward sequence comprised of sands, gravels and clays up to 70 m thick (CSIRO, 2007). The Gunnedah Formation is overlain by the Narrabri Formation, which comprises sands, gravels and silts 10 to 30 m thick that form an unconfined aquifer (CSIRO, 2007). The topmost parts of the Gunnedah Formation consist of a 2 to 15 m thick semi-permeable clay sequence that separates the Narrabri Formation from underlying high permeability units.

Maranoa-Balonne river basin

Within the Maranoa-Balonne river basin, alluvial sediments associated with the Maranoa and Balonne rivers systems are widespread across much of the southern portion, reaching thicknesses of greater than 180 m (Exon, 1976). Both upper and lower alluvial aquifers are present, the latter only occurring in a small band in the south of the river basin. Most of the groundwater is saline; however, good quality water occurs in the vicinity of St George. The upper, coarse-grained, unconfined to semi-confined, alluvial aquifer system occurs extensively across much of the area. Aquifer thicknesses range from 20 m in the south-east adjacent to the Moonie River, to 60 m in the west (Kellett et al., 2006). The variable distribution of clay and sand within the upper alluvial aquifer is considered to result in a reduced vertical and horizontal hydraulic connection between sand beds when compared to the lower alluvial aquifer. The upper alluvial aquifer system has previously been referred to as the Narrabri Subsystem (Skelt et al., 2004b) and currently (for most of its extent) as the 'St George Alluvium shallow' groundwater sustainable diversion limit resource, under the Basin Plan. However, portions of the alluvial system in the north-east and north and south are within the 'Sediments above the GAB: Condamine-Balonne' groundwater sustainable diversion limit resource unit.

Underlying the upper alluvial system in the south of the river basin is a less extensive confining bed and lower alluvial aquifer system (referred to as the 'St George Alluvium deep' under the Basin Plan), which are restricted in distribution to the Dirranbandi paleochannel (Figure 23) (Kellett et al., 2006). Large thicknesses of Cenozoic alluvium in the Maranoa-Balonne river basin have only been encountered in this paleochannel.

The confining bed is considered to be leaky, consisting of 20 to 60 m of sediment dominated by clay and silt with minor sand beds in the lower part of the sequence.

The lower confined alluvial aquifer is higher yielding than the shallow alluvial aquifer and consists of a basal sequence of clay, silt and fine sand overlain by up to 20 m of coarse sand and gravel (Kellett et al., 2006). The aquifer thickness typically ranges between 20 and 40 m over much of its extent, increasing to 100 m at the depocentre of the Dirranbandi paleochannel (about 50 km south-west of St George).

Groundwater is extracted from the lower alluvial aquifer for irrigation and is concentrated in an area about 30 km north-west of St George. The distribution of bores within the upper alluvial aquifer is more widespread, and extracted groundwater is used mainly for stock and domestic purposes.

Moonie river basin

Little information is available regarding the shallow alluvial system (Narrabri Subsystem (MDBC, 2000)) within the Moonie river basin. Alluvial sediments are possibly up to 100 m thick with groundwater drawn from depths of between 10 and 35 m for stock and domestic use (CSIRO, 2008). A small portion of the St George Alluvium Shallow extends into the river basin.

Groundwater development in the Moonie river basin is low and widely distributed, and the surface – groundwater connectivity in the region is largely unknown (CSIRO, 2008).

1.1.4.1.3 Fractured rock aquifer systems

Condamine river basin

Within the Condamine river basin, significant but variable amounts of groundwater occur with the basalts of the Main Range Volcanics Formation (previously referred to as the Queensland Basalts (Barnett et al., 2004) and as the Upper Condamine Basalts in the Basin Plan). Located along the eastern margin of the Condamine river basin at depths of between 11 and 41 m, the aquifers generally consist of an upper unconfined weathered and fractured zone with a lower, more limited in extent, semi-confined fractured zone. Average aquifer thicknesses are in the order of 28 m (Skelt et al., 2004a). The basalts of the Main Range Volcanics Formation are covered in part with alluvium, including the Condamine Alluvium (QWC, 2012).

Groundwater is of excellent quality and is extracted for irrigation, stock and domestic use and town water supplies.

1.1.4.1.4 The Great Artesian Basin

The GAB is a variably confined groundwater basin comprising a multi-layered complex of sandstone aquifers (Figure 21). These aquifers are separated and confined by fine-grained mudstone and siltstone aquitards (Smerdon and Ransley, 2012).

The entire Maranoa-Balonne-Condamine subregion falls within the boundary of the geological Surat Basin which forms part of the wider GAB. To varying extents, the intake beds for the GAB outcrop over much the northern and eastern areas of the subregion – where alluvial cover is absent. In the northernmost extension of the region (north of Mitchell) the entire Mesozoic sequence of the GAB outcrops.

Groundwater bores intersecting the GAB are widespread within the subregion. Bores tapping the deeper aquifers of the GAB (i.e. Hutton and Precipice sandstones) tend to be located toward the shallower parts of the GAB, i.e. the north-western and eastern margins of the subregion. In contrast, bores tapping the shallower Cadna-owie – Hooray and equivalents aquifer are widely distributed across the entire subregion. Groundwater extraction is primarily for stock and domestic purposes, and town water supply.

Extraction of groundwater from the GAB aquifers has occurred since the late 1800s and has been historically elevated due to uncontrolled flow from artesian bores. Extraction has resulted in groundwater declines by up to tens of metres in some areas (Habermehl, 2002). The St George – Cunnamulla area has experienced the greatest decline in artesian pressure of anywhere in the GAB: over 100 m since development (Habermehl and Lau, 1997). This large drop in pressure has reversed vertical hydraulic gradients to the extent that in the St George area the hydraulic head in the Gubberamunda Sandstone is now 25 m lower than the head in the Mooga Sandstone.

The pressure decline in the St George area has been arrested since the Great Artesian Basin Sustainability Initiative was introduced in 1999. Under this initiative and earlier programs, 1287 bores had been controlled and 22,412, km of bore drains had been removed and replaced with 38,877 km of piped systems throughout the GAB at July 2013 (Great Artesian Basin Coordinating Committee, 2014). This reportedly resulted in an estimated water saving of 326,999 ML/year. The Queensland Department of Natural Resources and Mines (2005) reported in 2005 that water pressures had increased, resulting in an increase in hydraulic head of over 8 m in some bores in the St George – Cunnamulla area. However, it is noted that some areas have shown continued decline where hydraulic heads have not yet responded to reduced extraction (Macaulay et al., 2009).

The recent expansion of coal seam gas extraction from the Surat Basin in the east of the subregion has given rise to increasing volumes of co-produced groundwater extraction from the Walloon Coal Measures. The Walloon Coal Measures are considered an aquitard at a regional scale; however, more locally, some portions of the sequence act as an aquifer (QWC, 2012; Habermehl, 1980). The Walloon Coal Measures are laterally continuous with the Birkhead Formation of the Eromanga Basin, which occurs toward the western boundary of the subregion.

1.1.4.1.5 Hydrostratigraphic relationships

As of June 2012, an estimated 1400 coal seam gas wells (including wells that had produced water during the test phase) were reported as extracting water from the Walloon Coal Measures (QWC, 2012). Concerns surround the possible impact that large-scale extraction of groundwater from the Walloon Coal Measures may have on aquifers such as the Hutton, Springbok and Gubberamunda sandstones, as well as the Condamine Alluvium where it is in direct contact with the Walloon Coal Measures. Current management arrangements and future assessments of coal seam gas impacts in the Surat Basin are detailed in the Underground Water Impact Report for the Surat Cumulative Management Area (QWC, 2012).

Hydrostratigraphic relationships in the Maranoa-Balonne-Condamine subregion are presented in Figure 21, which indicates the temporal sequence of geological unit development and relative groundwater flow potential. The ‘Cenozoic aquifers and aquitards’ shown in Figure 21 represent the alluvial aquifers in the Maranoa-Balonne-Condamine subregion.

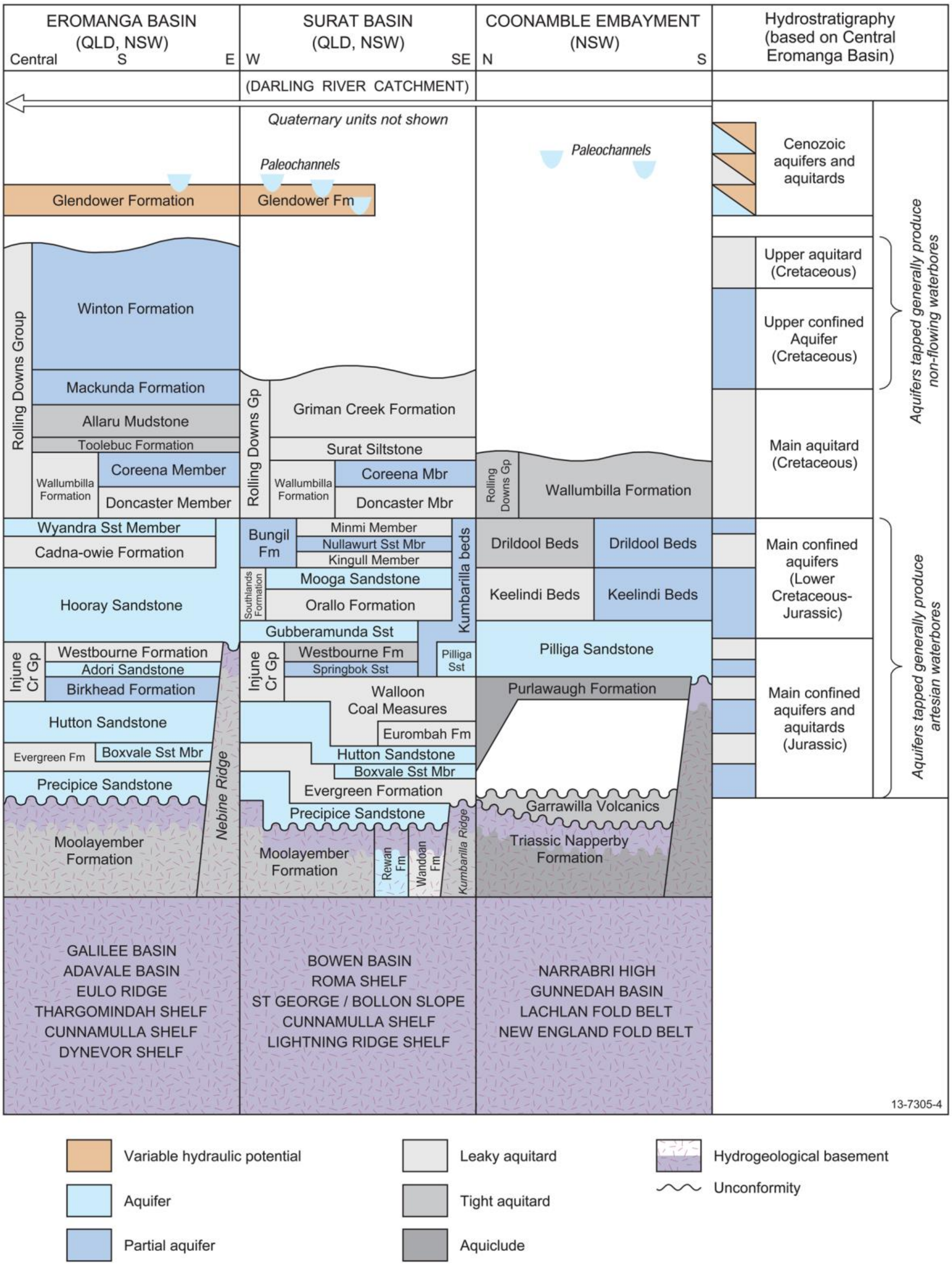

Figure 21 Hydrostratigraphic relationships in the Surat Basin, Coonamble Embayment and adjoining Eromanga Basin of the Great Artesian Basin

Source data: derived from data presented in Figure 4.4 in Ransley and Smerdon (2012)
Recent geological mapping by the NSW Government has resulted in some changes to the stratigraphy in the Coonamble Embayment where the Griman Creek Formation has now been recognised as the topmost GAB formation.

1.1.4.1.6 Groundwater monitoring and assessment

Queensland

Within the Maranoa-Balonne-Condamine subregion groundwater monitoring is undertaken by state water agencies for a variety of purposes including water level, water quality and salinity monitoring. Monitoring is focused on priority groundwater areas including the GAB, Condamine Alluvium, Border Rivers Alluvium, the St George Alluvium, and basalts of the Main Range Volcanics Formation. Within Queensland, water quality and water level data are collected by the Department of Natural Resources and Mines as part of the state's Groundwater Ambient Water Quality Network and Groundwater Level Network to assist planning and management of groundwater resources. Water quality sampling frequency varies from one to three years and water level measurement frequency varies between two and four years depending on location (Department of Natural Resources & Mines, 2013a, b).

In addition, the Department of Natural Resources and Mines operates separate network monitoring water levels within the GAB in order to assess impacts of development and to gauge the effectiveness of management strategies such as the Great Artesian Basin Sustainability Initiative bore rehabilitation program.

Additional monitoring is undertaken by coal seam gas companies in parts of the Surat Basin. A cumulative management area has been established within the Surat Basin under the current Queensland regulatory framework, where monitoring aims to assess the cumulative impacts of coal seam gas activities on groundwater resources. Within the Surat Cumulative Management Area the Queensland Office of Groundwater Impact Assessment is responsible for assessing impacts and establishing integrated management arrangements in the Underground Water Impact Report for the Surat Cumulative Management Area (QWC, 2012). The Underground Water Impact Report obliges coal seam gas companies to undertake monitoring and in some cases construct new monitoring points, which contribute to:

- a regional monitoring network
- reporting of water pressure and quality
- reporting of water production data
- reporting of water quality and bottom hole pressures in selected coal seam gas wells (QWC, 2012).

In some cases coal seam gas companies may be required to undertake monitoring activities on lands other than those over which they hold tenure (QWC, 2012).

Increasingly, there is a requirement for mining companies, as part of mine approval conditions, to undertake local-scale monitoring and report unexpected groundwater level changes to the Department of Natural Resources and Mines.

New South Wales

The NSW Office of Water (2009) states that over 500 artesian bores in the NSW portion of the GAB Groundwater Source have been monitored for pressure, flow, temperature and groundwater quality. However, monitoring has been discontinued in many bores as they were decommissioned, became sub-artesian or were assessed as unsuitable for monitoring due to the condition of the borehead. The NSW Office of Water (2009) indicated that 60 of these GAB bores were being monitored at least once every two years.

No non-GAB bores are monitored within the NSW portion of the Maranoa-Balonne-Condamine subregion.

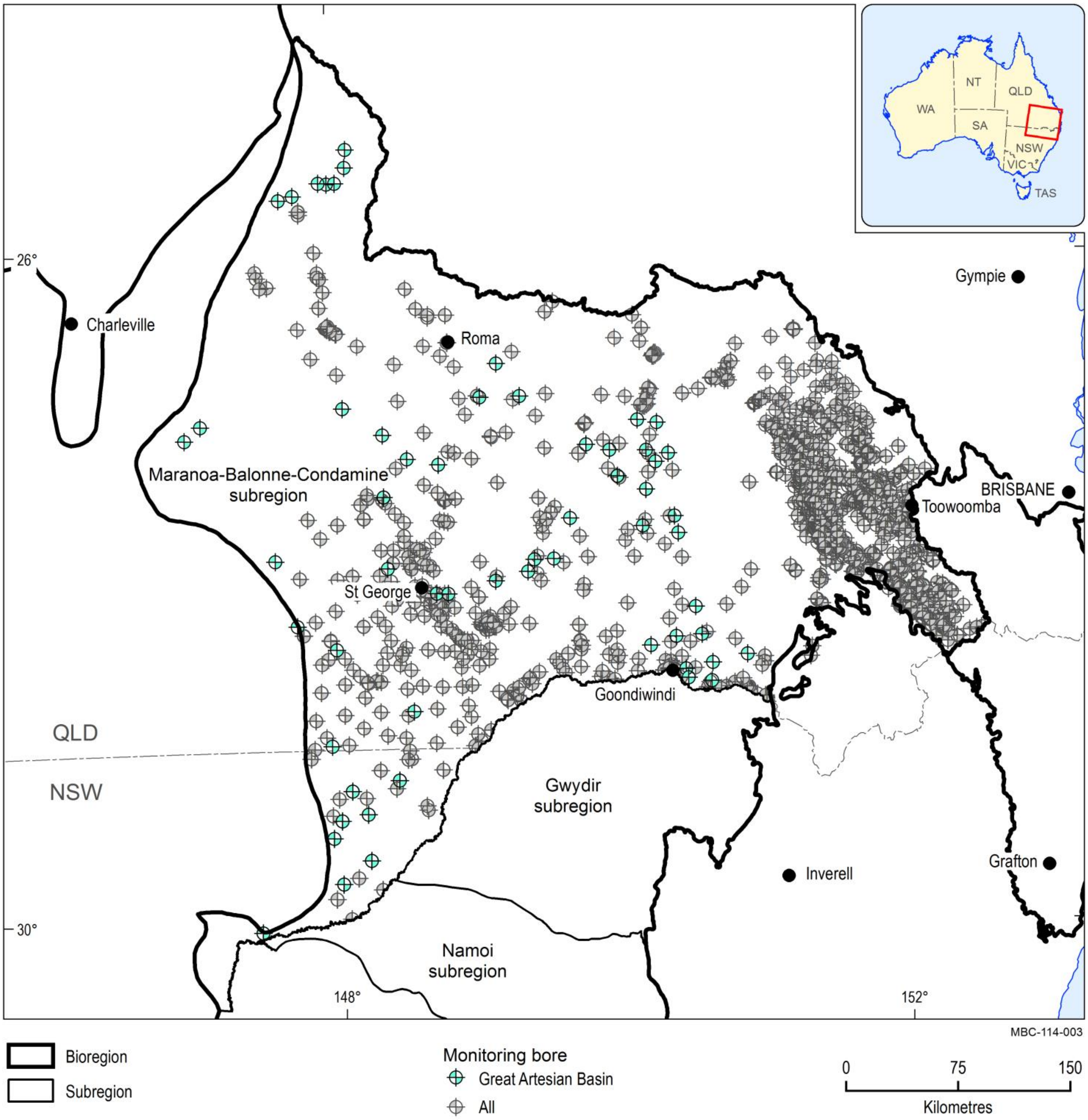

Figure 22 Distribution of Queensland and NSW groundwater monitoring bores in the National Groundwater Information System database

Source data: Bureau of Meteorology (2013)
'Great Artesian Basin' monitoring bores are those locations where groundwater is actively monitored in the GAB; the remaining groundwater wells may be installed in any of a number of groundwater systems (including the GAB).

1.1.4.2 Groundwater levels and flow

1.1.4.2.1 Alluvial aquifers

Shallow groundwater levels are shown on Figure 23 for the shallow alluvium in the subregion and surrounds. Shallow groundwater flows, with the exception of the Condamine Alluvium, are generally topographically driven with lateral flow directions similar to that of major drainage. In addition, Figure 23 identifies areas of potential inter-formational flow from alluvial aquifers into the GAB formation, where water levels in the alluvium are higher than in the uppermost GAB formations. Conversely, where heads in the uppermost GAB aquifer are higher than the alluvium, there is potential for upward flow, provided the saprolite aquitard on top of the GAB sediments is breached or absent. Based on current knowledge, this condition is only satisfied in the Dirranbandi paleochannel, the Namoi paleochannel and possibly in the deepest (eastern) section of the Condamine River Valley.

Condamine Alluvium

High levels of groundwater development and extraction within the Condamine Alluvium and tributaries have resulted in a significant decline in groundwater levels over most of the area (Figure 24), with local pockets of groundwater level rise in the north and central east of the Condamine river basin (Kelly and Merrick, 2007). Hillier (2010) reported groundwater levels recorded in selected bores between the mid 1960s and the early 2000s, all of which show an overall decline. The decline in groundwater levels has resulted in large groundwater depressions, one about 20 km to the east of Cecil Plains and another centred around Macalister, that have significantly altered pre-development flow directions. CSIRO (2008) indicate that recharge to the Condamine Alluvium is via rainfall infiltration throughout the Condamine river basin, flood recharge in the lower areas, lateral flow from adjacent upstream aquifers and upward leakage from the basalts of the Main Range Volcanics Formation. Non-flood streambed leakage from the Condamine River is considered to be the largest source of recharge to the alluvium (Huxley, 1982), with additional contributions from irrigation water via deep drainage.

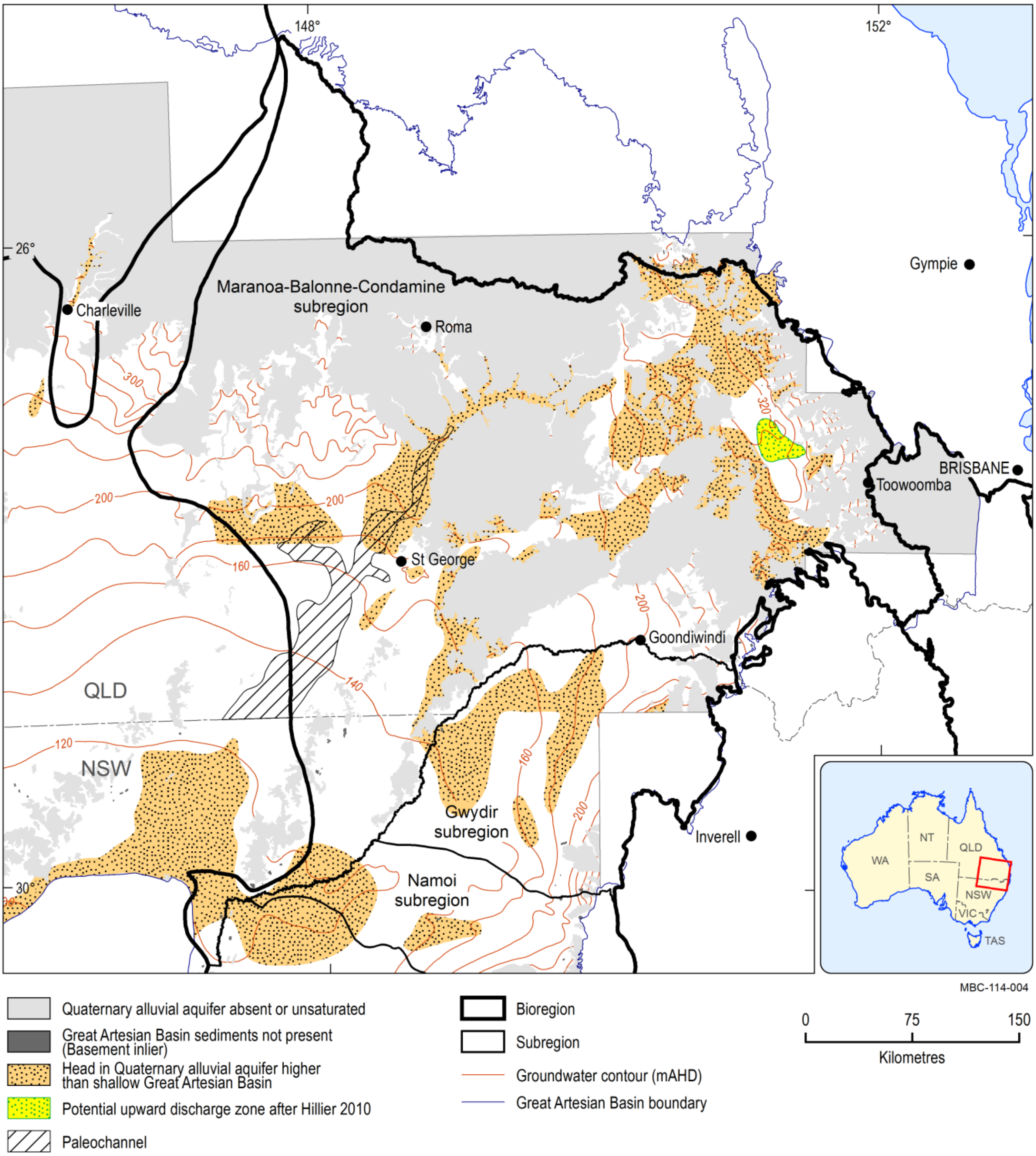

Figure 23 Groundwater levels in the shallow alluvial system (Narrabri Formation) showing areas where groundwater heads are higher than in the upper parts of the Great Artesian Basin

Source data: modified from Kellett and Stewart (2013) with paleochannel outline from Kellett et al. (2006) and potential upward discharge zone from Hillier (2010)

Hatched area represents the location of the deep alluvial aquifer within the Dirranbandi paleochannel in Queensland. Potential upward discharge zone is from the Walloon Coal Measures to the Condamine Alluvium.

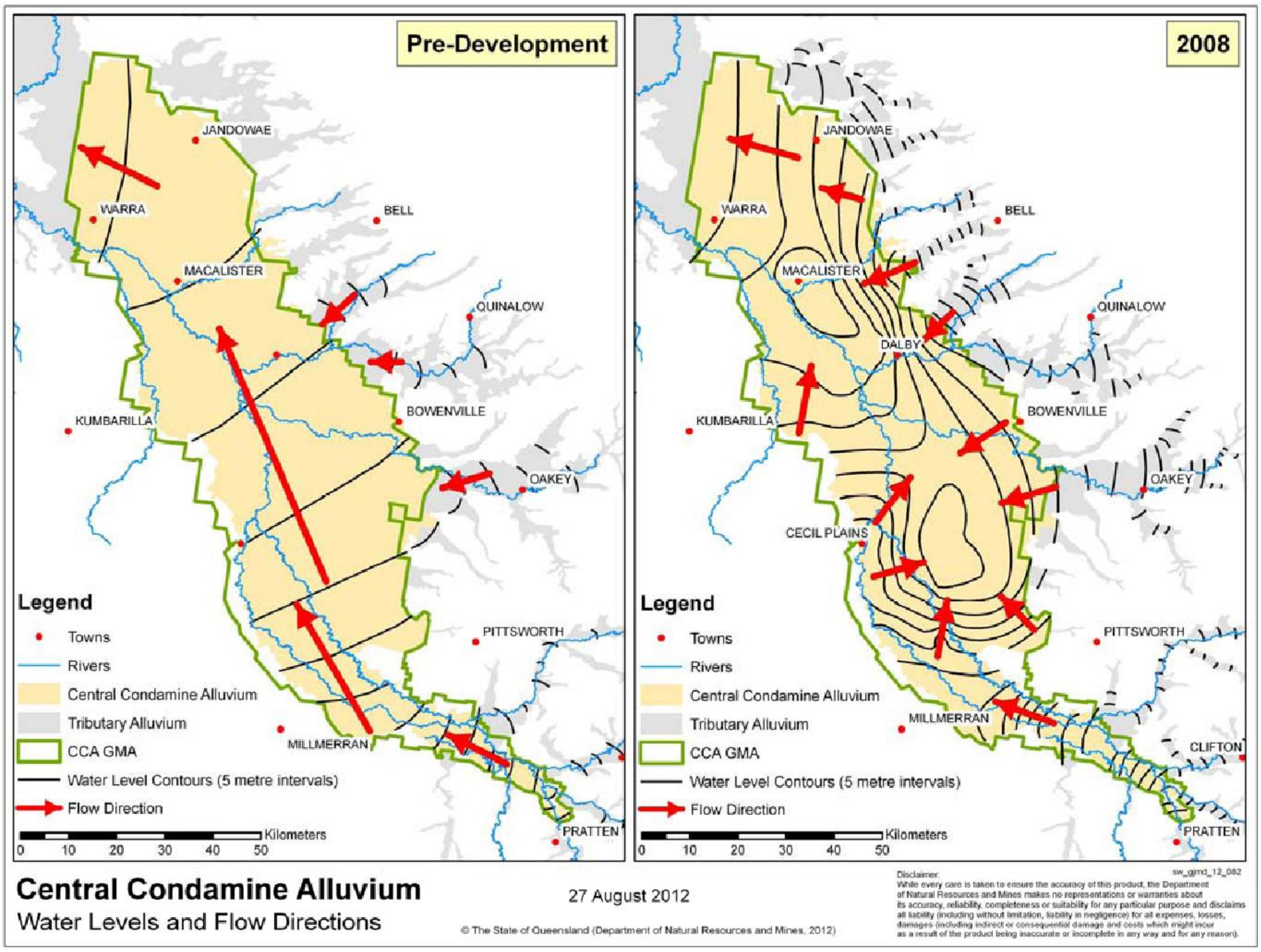

Figure 24 Effect of groundwater developments on groundwater levels and flow directions

Source: Figure 2 in Department of Natural Resources and Mines (2012)

Border Rivers Alluvium

Useable groundwater is restricted to sediments deposited in a narrow valleys associated with the Dumaresq and Macintyre rivers and the Macintyre Brook. The valley broadens downstream of Keetah Bridge where groundwater generally becomes too saline for use.

An unconfined Narrabri Formation aquifer (10 to 30 m thick) and deeper, confined Gunnedah Formation aquifer (up to 70 m thick) are identified in this area. The coarser sediments of the Gunnedah Formation form a paleochannel that meanders through the valley fill (CSIRO, 2007).

The Gunnedah Formation aquifers fine upward into Gunnedah Formation clays of variable permeability that are between 2 and 15 m thick and separate the aquifers from those of the Narrabri Formation (CSIRO, 2007).

CSIRO (2007) indicate that recharge to the Narrabri Formation is mostly from stream losses, with minor contributions from rainfall and excess irrigation, with recharge to the deeper Gunnedah Formation being mostly via cross-formational flow and upward leakage from underlying GAB aquifers. However recharge from the Dumaresq River and Macintyre Brook are not strongly manifested in the groundwater surface (see Figure 23) which generally suggests either no interaction with streams or discharge to them in many areas (although the area near Goondiwindi is an exception where mounding is evident in the groundwater surface which has been attributed to local hydraulic loading by the town weir). There is evidence for some upward leakage from the underlying Surat Basin in this area as outlined in the section on groundwater quality in Section 1.1.4.3.

Milne-Home et al. (2007), showed that although average water levels in the Border River Alluvium fell by about 2.5 m in the east near Yelarbon from 1990 to 2005, they increased in the west by about 2.5 m south of Goondiwindi, suggesting that the water resource is not highly stressed

St George Alluvium

Kellett et al. (2006) provide a detailed description of the St George Alluvium including water level and flow direction maps for both the shallow and deep alluvial aquifers between about 75 km north of St George to the Queensland – NSW border. They report that groundwater flow directions in the shallow alluvial aquifer are mainly north to the south-west, and radially outward along the axis of the Balonne River north of Whyenbah. Further, groundwater flow in the deeper alluvial aquifer is from north-east to south-west, parallel to the axis of the Dirranbandi paleochannel. Water levels in the deeper aquifer are lower than in the shallow aquifer.

Water levels in the upper alluvial aquifer, during the period 1998 to 2004, remained stationary over most of the subregion with the exception of irrigation areas in the vicinity of St George where: groundwater mounding occurred in the shallow alluvial aquifer within the St George Irrigation Area, about 20 km south-east of St George, due to infiltration of excess irrigation water; an overall decline in groundwater levels in the deeper alluvial aquifer occurred, within the groundwater irrigation area, about 30 km north-west of St George (Kellett et al., 2006).

Groundwater recharge to the shallow alluvium occurs via multiple mechanisms, namely river flooding recharging sandy floodplain sediments, natural river bed leakage from the Maranoa and Balonne rivers upstream of St George, the Balonne River north of Whyenbah and local recharge via the Narran and Culgoa rivers, and artificial recharge via infiltration of excess irrigation water in the St George Irrigation Area and groundwater irrigation area (Kellett et al., 2006).

Groundwater recharge to deep alluvial aquifers is via bed underflow from the Balonne River upstream of Beardmore Dam where the aquifer is unconfined, and leakage from the shallow alluvial aquifer in the groundwater irrigation area (Kellett et al., 2006).

1.1.4.2.2 Fractured rock aquifers

Main Range Volcanics Formation

Basalt aquifers of the Main Range Volcanics Formation generally exhibit relatively dynamic and rapid water level variations in response to rainfall recharge and pumping events, and natural depletion. Recharge is via direct rainfall infiltration and river leakage.

Barnett et al. (2004) assessed water level changes for the period 1990 to 2000 as well as seasonal variations, concluding that the trend of water levels in the Main Range Volcanics Formation has close correlation with rainfall and in general does not indicate either a rising or falling trend. The dynamic nature of the groundwater system is evident in bores with seasonal water level variations of 1 to greater than 3 m and (in some cases) water level variations in the order of 11 m between periods of high rainfall and drought.

1.1.4.2.3 Surat Basin

Groundwater level contours for water in the uppermost units of the Surat Basin, presented by Kellett et al. in Smerdon and Ransley (2012), are shown in Figure 25. The water levels mostly represent water in the areas of outcrop of all the GAB aquifers (intake beds) and aquitards along the western slopes of the Great Dividing Range. Water then passes into the Rolling Downs Group (Figure 21) which abuts the intake beds and dips gently basinward to the south-west. The groundwater surface tends to be topographically controlled.

Groundwater recharge mostly occurs along the southern and eastern edge of the GAB via rainfall and streamflow, in an area known as the ‘intake beds’. The intake beds outcrop in the east and north of the Maranoa-Balonne-Condamine subregion.

From the intake beds, groundwater levels are commensurate with general flow to the south and south-west.

The groundwater gradients between the Surat Basin and overlying alluvium indicate potential for upward leakage to the alluvial deposits in parts of the subregion, except for the locations shown on Figure 25 where the groundwater level in the alluvium is higher.

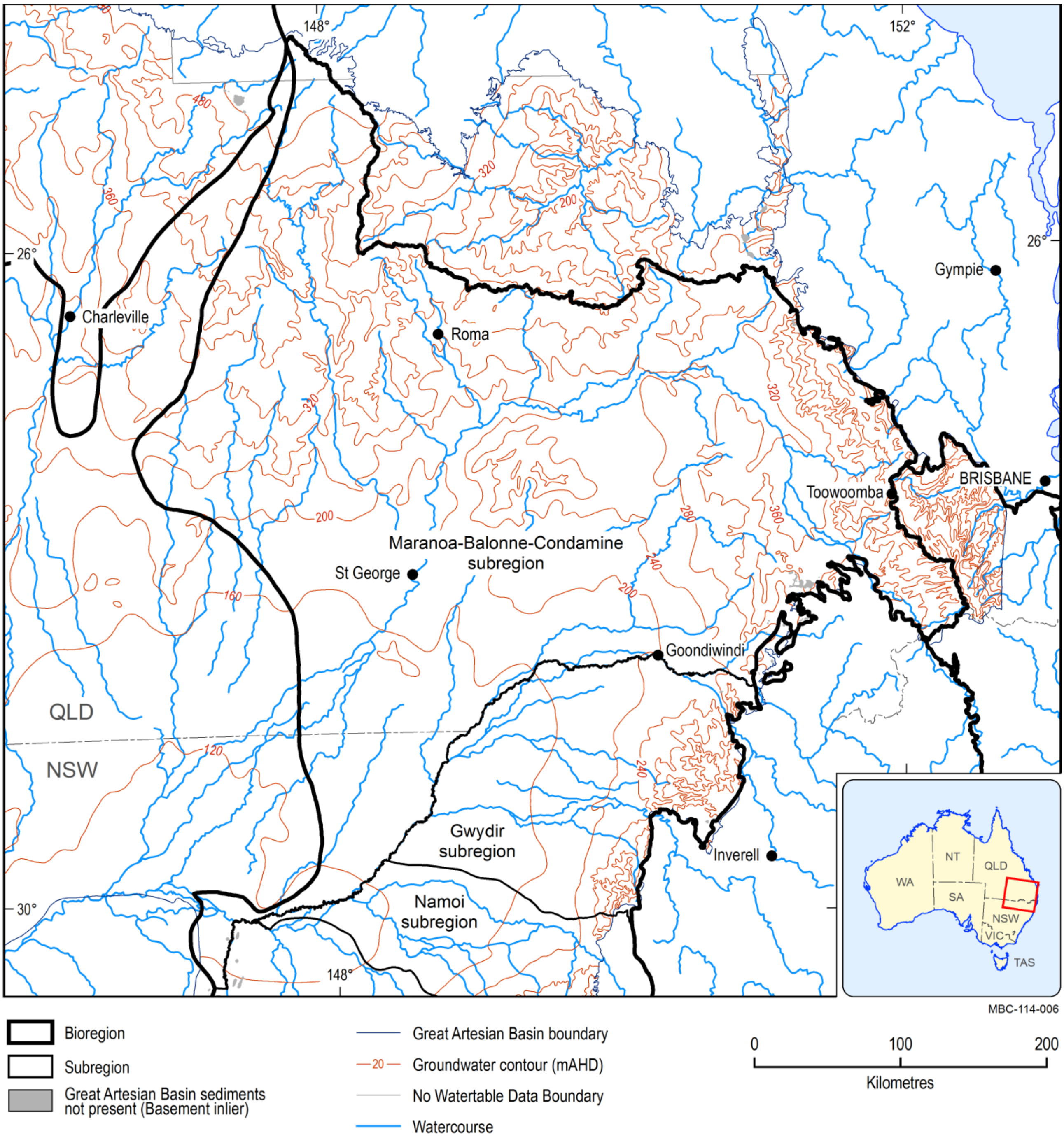

Figure 25 Groundwater level contours for the upper units of the Surat Basin

Source data: derived from data presented in Figure 5.19 in Ransley and Smerdon (2012)

1.1.4.2.4 Inter-aquifer connectivity

As outlined in preceding sections, while the alluvium in the south of the subregion near the Border Rivers is typically separated, in the literature, into the overlying Narrabri Formation and underlying Gunnedah Formation, the contact between them is difficult to determine lithologically in places and some authors question the validity of this separation. Some degree of hydraulic connectivity is often reported between the aquifers of both formations (e.g. Carr and Kelly, 2010), with leakage from the Narrabri Formation commonly cited as a source of recharge to the Gunnedah Formation aquifers.

Kellett and Stewart (2013) indicate that intense weathering of exposed GAB rocks prior to deposition of overlying alluvium resulted in development of a basin-wide saprolite layer. This layer has a low permeability basal portion that is considered to reduce connectivity with overlying systems. Kellett and Stewart (2013) state that in some places the saprolite has been removed by erosion making hydraulic connection possible. Such areas occur beneath paleochannels of which there are reportedly many in the Surat Basin, commonly occurring beneath or next to modern stream channels. Depending on the relative groundwater levels between the alluvium and GAB, there may be upward or downward flow of water in these areas (see Figure 23).

In the Maranoa-Balonne-Condamine subregion, Kellett and Stewart (2013) indicate that areas where downward flow of water from the alluvium to the underlying GAB is highly likely include:

- the Condamine-Balonne River from Macalister to Beardmore Dam
- the Condamine River (South Branch) from Millmerran to Cecil Plains
- the Balonne River from Blue Lagoon to Whyenbah.

Areas where Kellett and Stewart (2013) indicate that groundwater flow from the GAB to the overlying alluvium in is highly likely in the subregion include:

- the Border Rivers (Macintyre and Dumaresq rivers and Macintyre Brook) upstream of Goondiwindi (there is evidence of upward recharge in groundwater chemical data near the Peel Fault zone in this area, as outlined in Section 1.1.4.3)
- the Dirranbandi Paleovalley from St George to Hebel
- the Condamine River (North Branch)/Oakey Creek from Brookstead to Macalister.

Two recent studies have focused on the question of groundwater flow between the Walloon Coal Measures and the Condamine Alluvium. The first, by Hillier (2010), was limited in scope to the Dalby-Millmerran-Oakey region and found that water levels in the alluvium, in the western Oakey Creek Valley (south of Dalby) and in the Condamine River Valley, are lower than those in the underlying Walloon Coal Measures of the GAB. Hillier (2010) concluded that while there was therefore potential for flow from the Walloon Coal Measures to the alluvium, if pressures in the Walloon Coal Measures were reduced due to coal seam gas extraction, potential flow directions could be reversed, inducing flow away from the alluvium (Figure 23). The second, more extensive, study by the Office of Groundwater Impact Assessment (2013) analysed the hydrogeochemistry of aquifers in the Condamine Alluvium footprint. It found no evidence of connection between the Walloon Coal Measures and Condamine Alluvium. The study concluded that based on the available data, the hydraulic connectivity between the Condamine Alluvium and Walloon Coal Measures is likely to be low. The GAB aquifers adjacent to the Walloon Coal Measures comprise the Springbok Sandstone above, and the Hutton and Marburg sandstones below.

Across most of the subregion, the Walloon Coal Measures appear (for the most part) to be hydraulically isolated above and below by low permeability aquitard layers. The area of the Condamine Alluvium, where the Walloon Coal Measures sub-crop, is an exception. The aquitard layer above the productive coal seams of the Walloon Coal Measures is typically 15 m thick. However, in parts of the north-eastern Surat Basin, this aquitard is absent and a higher degree of interconnectivity is expected (QWC, 2012). The aquitard beneath the Walloon Coal Measures is about 45 m thick (QWC, 2012). QWC (2012) report that while there are historically little water level monitoring data for the Walloon Coal Measures and surrounding aquifers at some locations, a difference in water levels, prior to coal seam gas development, existed between the Walloon Coal Measures and adjacent aquifers, which suggests limited interconnectivity.

Within the Surat Basin, little is understood about the extent and influence of geological structures such as faults and fractures and the role they may play as conduits for interconnectivity between formations. The Queensland Office of Groundwater Impact Assessment has identified research into the interconnectivity between the Walloon Coal Measures and adjacent aquifers in the Surat Basin as a priority (QWC, 2012).

A methodology to assess the risks to groundwater associated with coal seam gas development in the Surat Basin and southern Bowen Basin has been developed for the Queensland Department of Natural Resources and Mines (Worley Parsons, 2013). The study considered the risk to aquifer storage in aquifers above and below the Walloon Coal Measures and concluded that there is a relatively high risk for the Lower and Upper Springbok Sandstone, Hutton Sandstone and Gubberamunda Sandstone in locations to the east of Roma, west and southwest of Chinchilla and west of Dalby, within the Surat Basin (Worley Parsons, 2013).

A preliminary desktop assessment of the potential for hydraulic connectivity between the GAB and underlying basins was undertaken as part of the Great Artesian Basin Water Resource Assessment (CSIRO, 2012). Connectivity can occur where aquifers, partial aquifers and leaky aquitards are juxtaposed below and above the base of the GAB (noting that faults may also act as conduits in places through otherwise low permeability formations). Figure 26 shows that hydraulic connectivity between the GAB and underlying formations is likely to be relatively poor across much of the subregion. Local exceptions include the area west of St George; several areas east, north and west of Roma; and a narrow band stretching northward from the area north-west of Moonie. In these locations, the Surat Basin has a heightened potential connectivity with the underlying Bowen Basin strata.

It is emphasised that relative hydraulic heads and thus potential flow directions are not fixed and might change over time in response to stresses such as groundwater extraction (e.g. for irrigation or coal seam gas development).

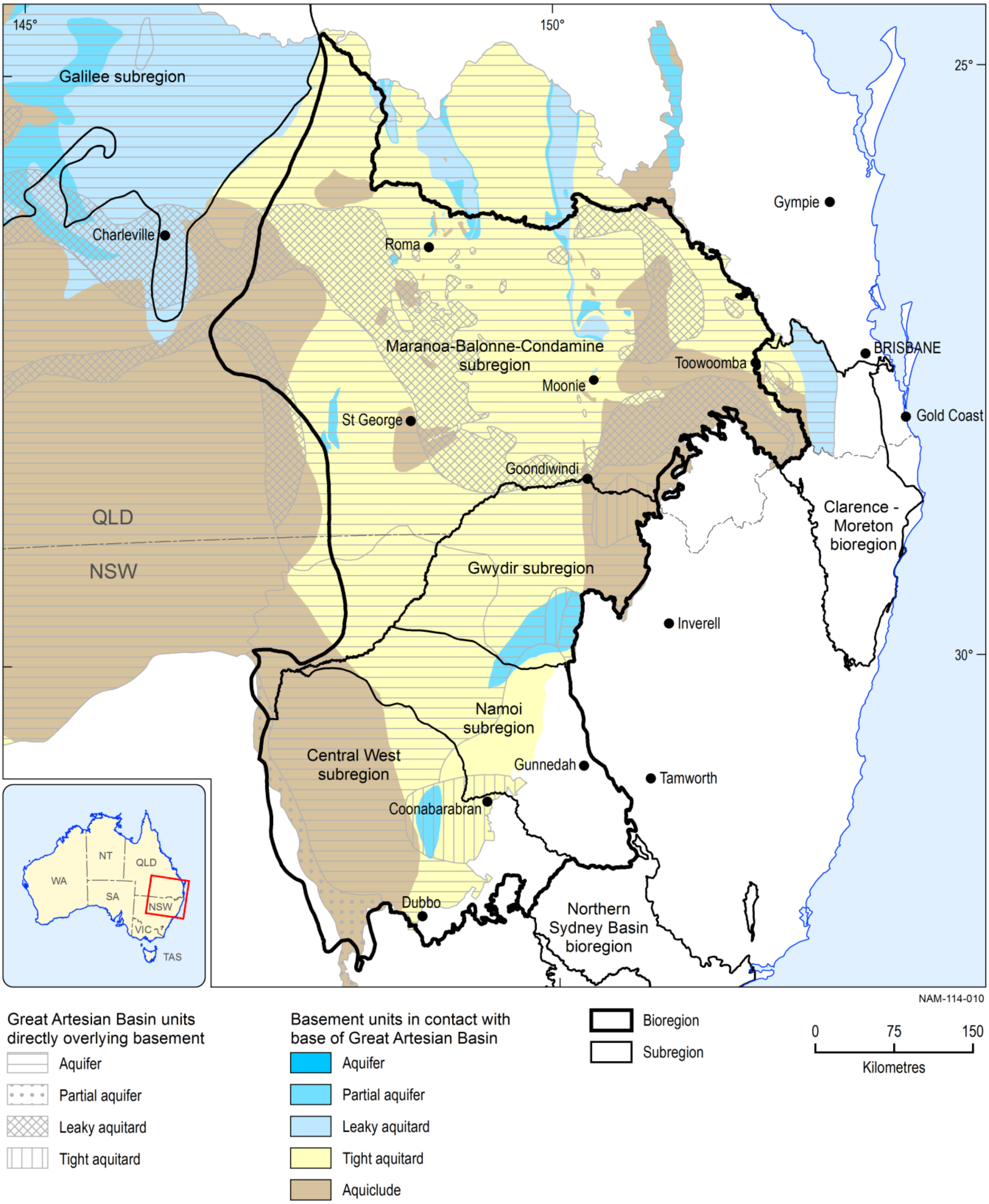

Figure 26 Potential hydraulic interconnection between the Great Artesian Basin and basement units in the Northern Inland Catchments bioregion

Source data: derived from data presented in Figure 5.7 in CSIRO (2012)

1.1.4.3 Groundwater quality

1.1.4.3.1 Alluvial aquifers

The main alluvial aquifers of the subregion are those associated with the Condamine, Maranoa-Balonne and Border Rivers (Macintyre Brook, and Dumaresq and Macintyre rivers) river systems. Other alluvial systems in the subregion are also identified in literature, but these are less developed.

Upper Condamine Alluvium

Groundwater from the Upper Condamine Alluvium is of relatively good quality, being used intensively for irrigation, industrial and stock and domestic purposes. CSIRO (2008) states that the water is suitable for most purposes and that salinity ranges from 900 to 2100 mg/L total dissolved solids (TDS). MDBA (2012) includes a map based on MDBC (2000) data that shows that groundwater salinity in the Upper Condamine Alluvium (see Figure 20) is variable. Along the eastern margin and flanking the main river course, low total TDS concentrations are recorded in the range from zero to 1500 mg/L. Higher TDS concentrations are recorded away from these areas, mostly in the range from 1500 to 3000 mg/L, but in places concentrations in the range from 3000 to 14,000 mg/L are shown.

Kelly and Merrick (2007) highlight that saline water is present adjacent to and overlying the freshwater intervals extracted for irrigation. Some of this water has salinity levels that would affect crop yields and there is concern that heavy extraction might result in salinisation of freshwater sources. Kelly and Merrick (2007) report that Huxley (1982) showed that groundwater evolves along flow paths from low salinity, magnesium bicarbonate – dominated water in the upstream areas associated with Main Range Volcanics Formation to relatively higher salinity, sodium chloride – type water downstream. A similar trend was noted in recent work by the Queensland Office of Groundwater Impact Assessment (2013) that incorporated more recent data. Kelly and Merrick (2007) highlight that a previous study by McNeil and Horn (1997) showed that groundwater salinity may be rising in the area between Dalby and the convergence of the North Branch with the main channel of the Condamine River.

The sodium adsorption ratio of groundwater is generally low, indicating that it is suitable for irrigation. However, Kelly and Merrick (2007) record that Islam (2006) did identify some areas around Dalby and Chinchilla where the sodium adsorption ratio was somewhat elevated.

Kelly and Merrick (2007) raise the issue that since pesticides have at times been detected in the Condamine River, it is likely that some level of pesticide contamination is present in the shallow aquifers in losing stream reaches.

The Office of Groundwater Impact Assessment (2013) analysed water chemistry data of aquifers within the footprint of the Condamine Alluvium using multivariate statistical techniques to identify differences in groundwater chemistry between aquifers, groundwater chemistry evolution within aquifers, and the potential for inter-aquifer connectivity between the Condamine Alluvium and Walloon Coal Measures. Data from 1980 to 2011 were used in the analysis. They concluded that on the basis of hydrogeochemistry, large-scale mixing and flow of water from the Walloon Coal

Measures to the Condamine Alluvium is unlikely, although some local-scale mixing could not be ruled out.

Border Rivers Alluvium

Groundwater in the Queensland Border Rivers Alluvium (Figure 20) is shown in MDBA (2012) to be relatively fresh, with TDS concentrations mostly in the range from zero to 1500 mg/L. This generally matches work presented by Please et al. (2000) who identified TDS concentrations in this area of less than 1000 mg/L. Please et al. (2000) indicated that salinity increases significantly downstream, west of these areas. In the east, groundwater had mixed cationic composition (sodium dominant), and whereas shallow groundwater was dominated by chloride anions, deeper groundwater was dominated by bicarbonate. Further west, water was generally sodium- and bicarbonate-dominated, while high salinity areas in the far west had sodium chloride – type waters. Similar findings were reported from a more recent study by Baskaran et al. (2009).

The fact that these groundwater sources support irrigation, stock and domestic use confirms they are of relatively good quality. However, Please et al. (2000) indicate that groundwater does have a high sodium hazard rating in some places, particularly close to the Peel Fault zone (about 45 km east of Goondiwindi) where sodium concentrations are elevated in the alluvial system. This might be due to upward leakage of groundwater from the GAB, which is known to have elevated sodium concentrations.

St George Alluvium

Salinity levels for the deep aquifer in this area generally range from 1800 to 13,300 mg/L TDS (CSIRO, 2008). Although the higher salinity groundwater is unsuitable for stock or irrigation purposes, lower salinity groundwater is present west of Beardmore Dam (Lake Kajarabie) around the lower reaches of the Maranoa River and the upper reaches of the Balonne River. In this area, MDBA (2012) record TDS concentrations in the range from zero to 1500 mg/L based on MDBC (2000) data.

Kellett et al. (2006) show that in the shallow aquifer, electrical conductivity (EC – another measure of salinity), is lowest close to the major rivers, where values below 600 µS/cm were recorded in places. Away from the major rivers, salinity reportedly increases towards the south, with values in excess of 50,000 µS/cm recorded in places. In the lower aquifer in the main paleochannel, the range in salinity is considerably less, increasing from about 3000 to 5000 µS/cm in the north to greater than 10,000 µS/cm in the south.

Kellett et al. (2006) include data showing that where measured, water in the shallow aquifer is predominantly of sodium-bicarbonate-chloride type with a significant portion being of sodium chloride type. In contrast, groundwater from the deeper aquifer is sodium chloride – dominated. The sodium chloride – type waters are typically associated with higher salinity.

1.1.4.3.2 Fractured rock aquifers

Main Range Volcanics Formation

The main groundwater source in the Main Range Volcanics Formation included in the Basin Plan is the Upper Condamine Basalts sustainable diversion limit unit. MDBA (2012) present MDBC (2000) data showing that groundwater is of low salinity, having TDS concentrations mostly in the range zero to 1500 mg/L, increasing slightly in the north to 1500 to 3000 mg/L. Water quality is generally suitable for all purposes, with salinity in the range from 500 to 1500 mg/L (CSIRO, 2008).

1.1.4.3.3 Surat Basin

Habermehl (2002) states that groundwater quality of the GAB is variable but salinity is generally in the range from 500 to 1500 mg/L in the Lower Cretaceous-Jurassic aquifers. Groundwater salinity reportedly increases away from the recharge areas in the east and north (<250 mg/L TDS in places) along groundwater flow paths to the south and west to over 2000 mg/L in places (Radke et al., 2000).

Groundwater in the Lower Cretaceous-Jurassic aquifers is typically of sodium-bicarbonate-chloride type (chloride becoming more dominant away from the intake beds), and generally suitable for domestic, town supply and stock use (although elevated fluoride concentrations in places – mostly Queensland – may cause issues for stock watering). However, it is unsuitable for irrigation in most areas due to its high sodium adsorption ratio (Smerdon and Ransley, 2012).

In NSW, the upper confining units of the Surat Basin (managed under the NSW GAB Shallow Groundwater Source Water Sharing Plan to a depth of 60 m) generally consist of low permeability claystone, mudstone, calcrete and shale with minor conglomerate and sandstone (Green et al., 2012). The aquifers they contain are described as sporadic and often low yielding, producing brackish to saline water of limited use. Burton (2011) recognised the uppermost GAB unit as the Griman Creek Formation in northern NSW, noting that underlying units also outcrop in the east and west. At the scale of the Surat Basin, the Griman Creek Formation is described as a partial aquifer by Kellett et al. (2012).

The Walloon Coal Measures (the main lithological unit in the Surat Basin prospective for coal seam gas) contain groundwater of comparatively high salinity, ranging from 950 to greater than 12,000 mg/L TDS and averaging around 4,500 mg/L (Moran and Vink, 2012). The quality of co-produced water necessitates treatment prior to beneficial use. This process results in saline brines and salt requiring management.

1.1.4.4 Groundwater management and use

Groundwater planning and management is undertaken by the Queensland Government via water resource plans. The Queensland water resource plans are subordinate legislation under the Water Act 2000 (Queensland), prepared at a river basin scale, and they specify the outcomes and strategies that will be used for each plan area. They expire after ten years unless they have been formally extended. Groundwater is currently not managed under the three Queensland water resource plans in the bioregion, it is in the main, managed under state regulations. Groundwater resources of the GAB in Queensland are managed through the Great Artesian Basin water resource plan. The Queensland Government manages non-GAB groundwater extraction limits by limiting the volume of entitlement that is made available in a plan area (plan limit). In areas where overuse is an issue (e.g. Upper Condamine Alluvium), an announced entitlement process is used to manage overuse and other impacts. Water resource plans lead to the development of resource operation plans, which implement the outcomes and strategies specified in the water resource plan.

The groundwater systems within the bioregion (excluding those of the GAB) are also represented in the Basin Plan for the Murray–Darling Basin as sustainable diversion limit (SDL) resource units. Relevant NSW and Queensland water sharing plans within the Maranoa-Balonne-Condamine subregion are listed in Table 9, and aligned with corresponding SDL resource units of the Basin Plan. The Queensland water resource plans of interest are the Border Rivers, Condamine and Balonne, and Moonie River plans. These currently do not include the management of the groundwater resources. Current limits under existing planning regimes and future extraction limits for these groundwater systems are prescribed within the Basin Plan as baseline diversion limits (BDLs) and SDLs (Basin Plan 2012).

Groundwater extraction and use varies significantly between the groundwater systems in terms of volumes extracted, extraction as a proportion of estimated limits, and actual water use. Current entitlement levels, entitlement limits and recent annual extraction estimates are provided for each groundwater system in Table 10. It should be noted that a number of sustainable diversion limit resource units extend beyond the boundary of the subregion. In such cases the baseline diversion limit and sustainable diversion limits values are representative of an area greater than that which falls within the subregion.

The Sediments above the Great Artesian Basin: Warrego-Paroo-Nebine and the Upper Condamine Basalt aquifers have the greatest sustainable diversion limits for the area (99.2 and 79.0 GL/year respectively). These, however, only comprise a small portion of the subregion. The NSW Government (2010) indicates that there is consultation between NSW and Queensland on the management of the Border Rivers Alluvium.

Groundwater extraction from the GAB is largely for stock and domestic use, and has been historically elevated by uncontrolled flow from artesian bores. This issue has been progressively addressed by programs such as the Great Artesian Basin Sustainability Initiative, which commenced in 1999. As of July 2012, 256 bores in the NSW Surat Basin had been controlled under the Great Artesian Basin Sustainability Initiative and previous programs, with estimated water savings of 50,037 ML/year (Great Artesian Basin Coordinating Committee, 2011). Within the Queensland Surat management zone 44 out of 54 uncontrolled bores have been rehabilitated and over 5000km of bore drains have been replaced by pipes and troughs, under the Great Artesian Basin Sustainability Initiative and its predecessors. Estimated water savings are in the order of 24,500 ML, which equates to over 90% of the potential losses prior to implementation of the rehabilitation schemes (C Walton (DNRM), 2014, pers. comm.)

Table 9 Comparison of groundwater extraction limits in water resource plans, water sharing plans and the Commonwealth's *Basin Plan 2012*

Groundwater system	Water resource plan	Date commenced	Sub-component of water sharing plan (and long-term average annual extraction limit)	Basin Plan sustainable diversion limit resource unit (and sustainable diversion limit)[c]
Alluvial aquifers	Water Sharing Plan for the NSW Great Artesian Basin Shallow Groundwater Sources 2011	14 November 2011	GAB Surat Shallow Groundwater Source 143,335 ML/y	NSW GAB Surat Shallow BDL: 6.57 GL/y SDL: 15.5 GL/y
Alluvial aquifers	Condamine-Balonne Water Resource Plan	1 February 2005	The plan does not currently manage groundwater	St George Alluvium: Condamine-Balonne Shallow BDL: 0.77 GL/y Shallow SDL: 27.7 GL/y Deep BDL: 12.6 GL/y Deep SDL: 12.6 GL/y
Alluvial aquifers	Condamine-Balonne Water Resource Plan	1 February 2005	The plan does not currently manage groundwater	St George Alluvium: Warrego-Paroo-Nebine[d] BDL: 0.21 GL/y SDL: 24.6 GL/y
Alluvial aquifers	Condamine-Balonne Water Resource Plan	1 February 2005	The plan does not currently manage groundwater	Sediments above the GAB: Warrego-Paroo-Nebine[d] BDL: 1.21 GL/y SDL: 99.2 GL/y
Alluvial aquifers	Condamine-Balonne Water Resource Plan	1 February 2005	The plan does not currently manage groundwater	Sediments above the GAB: Condamine-Balonne BDL: 0.66 GL/y SDL: 18.1 GL/y[b]
Alluvial aquifers	Condamine-Balonne Water Resource Plan	1 February 2005	The plan does not currently manage groundwater	Upper Condamine Alluvium (Central Condamine Alluvium) BDL: 81.4 GL/y SDL: 46.0 GL/y
Alluvial aquifers	Condamine-Balonne Water Resource Plan	1 February 2005	The plan does not currently manage groundwater	Upper Condamine Alluvium (Tributaries) BDL: 45.5 GL/y SDL: 40.5 GL/y
Alluvial aquifers	Moonie River Water Resource Plan	1 July 2004	The plan does not currently manage groundwater	St George Alluvium: Moonie BDL: 0.01 GL/y SDL: 0.69 GL/y
Alluvial aquifers	Moonie River Water Resource Plan	1 July 2004	The plan does not currently manage groundwater	Sediments above the GAB: Moonie BDL: 0.10 GL/y SDL: 32.5 GL/y
Alluvial aquifers	Border Rivers Water Resource Plan	1 July 2004	The plan does not currently manage groundwater	Sediments above the GAB: Border Rivers BDL: 0.04 GL/y SDL: 14.4 GL/y

Groundwater system	Water resource plan	Date commenced	Sub-component of water sharing plan (and long-term average annual extraction limit)	Basin Plan sustainable diversion limit resource unit (and sustainable diversion limit)[c]
Alluvial aquifers	Border Rivers Water Resource Plan	1 July 2004	The plan does not currently manage groundwater	Queensland Border Rivers Alluvium BDL:14.0 GL/y SDL: 14.0 GL/y
Great Artesian Basin	Great Artesian Basin Water Resource Plan	1 March 2006		
Great Artesian Basin	Water Sharing Plan for the NSW Great Artesian Basin Groundwater Sources 2008	1 July 2008	Surat Groundwater Source 75,000 ML/y[a]	not applicable (not in the Murray–Darling Basin)
Fractured rock aquifers	Condamine-Balonne Water Resource Plan	1 February 2005	The plan does not currently manage groundwater	Upper Condamine Basalts BDL: 79.0 GL/y[b] SDL: 79.0 GL/y

[a]These are long-term average annual net recharge estimates. Annual extraction limits are calculated from these figures by subtracting the volume of planned environmental water – refer to the Water Sharing Plan for the NSW Great Artesian Basin Groundwater Sources 2008.
[b]The Basin Plan sustainable diversion limit resource unit occurs across two water resource plans, but the correlation in the table is shown with the with the largest overlapping areas
[c]SDL = sustainable diversion limit; BDL = baseline diversion limit. Where a separate value is not shown for a BDL for a sustainable diversion limit resource unit, BDL=SDL
[d]SDL resource unit extends beyond the subregion boundary

Table 10 Groundwater entitlements and extraction

Groundwater system	Is system confined to the subregion Yes/No	Current entitlements (GL/y)	Recent annual extraction[a] (GL/y)	Baseline diversion limit[b] (GL/y)	Long-term average sustainable diversion limit[c] (GL/y)	Basin Plan sustainable diversion limit resource unit - extent beyond subregion Yes/No
Sediments above the GAB: Warrego-Paroo-Nebine[d]	No	0.10	1.21	1.21	99.2	Yes
St George Alluvium: Warrego-Paroo-Nebine[d]	No	0	0.12	0.12	24.6	Yes
St George Alluvium: Condamine-Balonne	No	Shallow: 0 Deep: 12.6	Shallow: 0.77 Deep: 12.6	Shallow: 0.77 Deep: 12.6	Shallow: 27.7 Deep: 12.6	Yes
St George Alluvium: Moonie	Yes	0	0.1	0.01	0.69	No
Sediments above the GAB: Condamine-Balonne	Yes	0.7	0.66	0.66	18.1	No
Sediments above the GAB: Moonie	Yes	0.02	0.10	0.10	32.5	No
Sediments above the GAB: Border Rivers	Yes	0	0.04	0.04	14.4	No
Upper Condamine Alluvium (Central Condamine Alluvium)	Yes	86.15	58.6	81.4	46.0	No
Upper Condamine Alluvium (Tributaries)	Yes	42.00	45.5	45.5	40.5	No
Queensland Border Rivers Alluvium	No	21.97	23.42	14.0	14.0	Yes
Upper Condamine Basalts	Yes	61.1	78.9	79	79.0	Yes
NSW GAB Surat Shallow	No	n/a	n/a	6.57	15.5	Yes
Lachlan Fold Belt	No	n/a	n/a	142.4	259.0	Yes
Queensland Water Resource Plan for the Condamine-Balonne	No	n/a	n/a	n/a	n/a	Yes
Queensland Water Resource Plan Moonie River	Yes	n/a	n/a	n/a	n/a	Yes
Water Resource Plan Border Rivers	Yes	n/a	n/a	n/a	n/a	Yes

Source data: MDBA (2012a) and the MDBA (2012)
n/a = not applicable
[a]Recent annual extraction includes metered extraction volumes from licensed bores, and estimated extraction from authorised stock and domestic bores reported in MDBA (2012a).
[b]Baseline diversion limits represent the Murray–Darling Basin Authority's determination of the limits on groundwater use under existing water management arrangements.
[c]Long-term average sustainable diversion limits come into effect in 2019
[d]SDL resource unit extends beyond subregion boundary.

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1.1.5 Surface water hydrology and water quality

Summary

The Maranoa-Balonne-Condamine subregion includes the river basins of the Condamine-Balonne River (including the Maranoa River), the Moonie River and the portion of the Border Rivers river basin that is located in Queensland. The historical mean annual surface water availability of the subregion is between 1462 and 2670 GL, depending on how much of the surface water from the Border Rivers is included in the Maranoa-Balonne-Condamine subregion. The Murray-Darling Basin Plan outlines water quality and salinity management issues including key causes of water quality degradation, water quality objectives, and water quality targets for a number of locations in the subregion.

Condamine-Balonne river basin

The Condamine-Balonne and Maranoa are the main rivers of the Condamine-Balonne river basin. The Condamine-Balonne River downstream of St George bifurcates into several distributaries that form the Lower Balonne floodplain system, with heavily dissected channels of various sizes. These channels carry a significant proportion of the surface flow during flood events. The upper reaches of the Condamine-Balonne River are highly prone to flooding (major floods occur every two years on average), which can result in widespread inundation of agricultural land, damage to farming properties and loss of livestock. There are four major public water storages in the basin with a combined storage capacity of 208 GL. In comparison, the numerous private offstream water storages in the lower parts of the river basin have an estimated combined storage volume of 1916 GL.

As water quality measurements are carried out at only a few selected reaches of the Condamine-Balonne River, nutrient and turbidity data are generally deficient along the river. In the upper Condamine river basin, stream nutrients are generally within water quality guidelines, while the electrical conductivity (EC) ranges from 100 to 800 µS/cm, which is greater than those found in other Queensland rivers.

There are 42 operational stream gauging stations within the river basin. The eastern part of the basin has more gauging stations than the western part, and there are no small- or medium-sized gauged catchments in the western half. Results from 60% of the modelling with climate change projections indicate a decrease in future runoff.

Moonie river basin

The Moonie river basin is one of most cleared in southern Queensland and is dependent on surface water for most of its irrigation needs. There is no major public water storage in the basin, but it has a number of off-river private storages with an estimated total volume of 29 GL.

Two water quality sampling sites in the Moonie river basin show high total nitrogen, but no trends for EC or turbidity are detected. There are three stream gauging stations in the basin (two with more than 40 years of flow record); all are in the Moonie River. The flow data

indicate loss of streamflow in the middle reaches of the Moonie River. The projected effects of climate change on runoff are similar to those for the Condamine-Balonne river basin.

Border Rivers river basin

The Maranoa-Balonne-Condamine subregion contains only the north-western part of the Border Rivers river basin, which includes the Weir River, Macintyre Brook, Callandoon Creek and the northern flank of the Macintyre-Dumaresq-Barwon river system. Coolmunda Dam in the Macintyre Brook catchment is one of the major public water storage dams in the area with a storage capacity of 69 GL. Surface water sources comprise more than 90% of the water used for irrigation in the Border Rivers river basin.

There are insufficient data to assess the water quality for nutrients, turbidity and EC in most areas. The part of the Border Rivers river basin that is within the Maranoa-Balonne-Condamine subregion has 19 stream gauging stations with varying flow record lengths. The effect of projected climate change on future runoff in the whole of the Border Rivers river basin (including areas that are in the Gwydir subregion) is a likely decrease in runoff by about 9% by 2030.

1.1.5.1 Surface water systems

The Maranoa-Balonne-Condamine subregion includes the river basins of the Condamine-Balonne River (including the Maranoa River), the Moonie River and the part of the Border Rivers river basin (37%) that is almost entirely within Queensland (Figure 27). Since rivers in these three river basins join either at the downstream end of – or outside of – the subregion, any coal mining and coal seam gas developments that directly affect surface flows in any one river basin do not affect the surface water resources of other river basins in the subregion. Consequently, Section 1.1.5 describes the surface water of each of the river basins separately.

1.1.5.1.1 Condamine-Balonne river basin

The area of the Condamine-Balonne river basin is 143,900 km^2, which is 14.4% of the Murray–Darling Basin (Thoms and Parsons, 2003). The major surface water resources in the basin are the Maranoa, Condamine and Balonne rivers, as well as numerous wetlands, natural lakes and man-made reservoirs and dams. The other minor rivers and creeks of the basin are the Cogoon River, Merivale River, Dogwood Creek and Bungil Creek (Figure 27). The Nebine Creek catchment that joins the Culgoa River upstream of Collerina is mostly outside the Maranoa-Balonne-Condamine subregion.

Rising from the Great Dividing Range, the Condamine River becomes the Balonne River downstream of Surat (Figure 27). The Maranoa River flows from the northern Carnarvon Range into the Balonne River upstream of Beardmore Dam. Downstream from St George, the Condamine-Balonne River divides into five separate channels. The Culgoa and Narran rivers are the main channels conveying 35% and 28%, respectively, of the long-term mean annual flow at St George, while the Ballandool and Bokhara rivers and Birrie Creek flow only during higher discharge periods (Thoms et al., 2007). The Culgoa River and other distributaries (e.g. Bokhara, Ballandool and Narran rivers) make up the Lower Balonne floodplain system. The Lower Balonne floodplain is heavily dissected by well-defined channels of various sizes forming a complex floodplain channel system (Thoms et al., 2002). These channels may carry a significant proportion of the surface flow during flood events.

Licensed water harvesting by instream interception and on-farm storage is mainly for irrigation. Although both surface water and groundwater are used for irrigation, about 75% of the irrigation water used within the river basin is sourced from surface water diversions. The three main irrigation areas are the Upper Condamine Irrigation Project, the Chinchilla Weir Irrigation Project and the St George Irrigation Area (Thoms and Parsons, 2003). In the Condamine-Balonne river basin, over 112,000 ha of irrigated crops were grown in 2000 and 63% of this was cotton. The long-term baseline mean diversion limit for surface water in the Condamine-Balonne river basin within Queensland is 978 GL/year, comprising 264 GL/year in interception and 713 GL/year in watercourse diversions (MDBA, 2013a).

The Queensland water resource plans provide the management framework for water resources to achieve a sustainable balance between competing water demands. The Condamine and Balonne water resource plan is one of four water resource plans in the Queensland Murray Darling Basin which will be reviewed and updated by 2019 to be compliant with the Basin Plan (DNRM, 2014).

There are several nationally significant wetlands located on the Lower Balonne river system (see sections 1.1.2 and 1.1.7). The Ramsar-listed Narran Lake Nature Reserve includes the interconnecting Back and Clear lakes and is part of the large terminal wetlands of the Narran River at the end of the Condamine-Balonne river basin. The Narran Lakes system fills more often and holds water for longer than many regional wetlands (NSW Environment and Heritage, 2013). Although the Narran Lakes system is outside the boundary of the subregion, it is located where the Narran River anabranch of the Condamine-Balonne River terminates and is thus potentially susceptible to changes in surface water flow arising in the subregion.

Water infrastructure

The Balonne River is regulated downstream of Beardmore Dam and the Maranoa River is largely unregulated. There are four major public water storages within the river basin. They are Leslie Dam (106 GL, completed 1985) and Chinchilla Weir (10 GL, completed 1974) on the Condamine River, and Beardmore Dam (82 GL, completed 1982) and Jack Taylor Weir (10 GL, completed 1959) on the Balonne River. In addition to these major reservoirs, the Condamine-Balonne river basin has a range of water infrastructure including Cooby Dam and many weirs, for example Talgai, Yarramalong, Lemon Tree, Cecil Plains, Loudon, Warra, Charleys Creek, Chinchilla, Condamine, Surat and Dirranbandi weirs. Most of the weirs are committed to urban, agricultural and irrigation supply schemes (DERM, 2012a).

Connolly Dam and Neil Turner Weir are the other two public water-holding structures. The total volume of major dams, town water supply dams and weirs in the basin is 268 GL. There are, however, numerous private offstream water storages in the lower parts of the river basin with an estimated combined storage volume of 1916 GL (Webb, McKeown and Associates Pty Ltd, 2007). These private storages are used for harvesting streamflow and overland flow at times of higher river flow (CSIRO, 2008a).

The three major irrigation areas have irrigation infrastructure. Although water produced by coal seam gas and mining activities in the subregion is or will be generally of poorer quality (Biggs et al., 2012), after appropriate treatment, the extracted water could use the existing irrigation infrastructure.

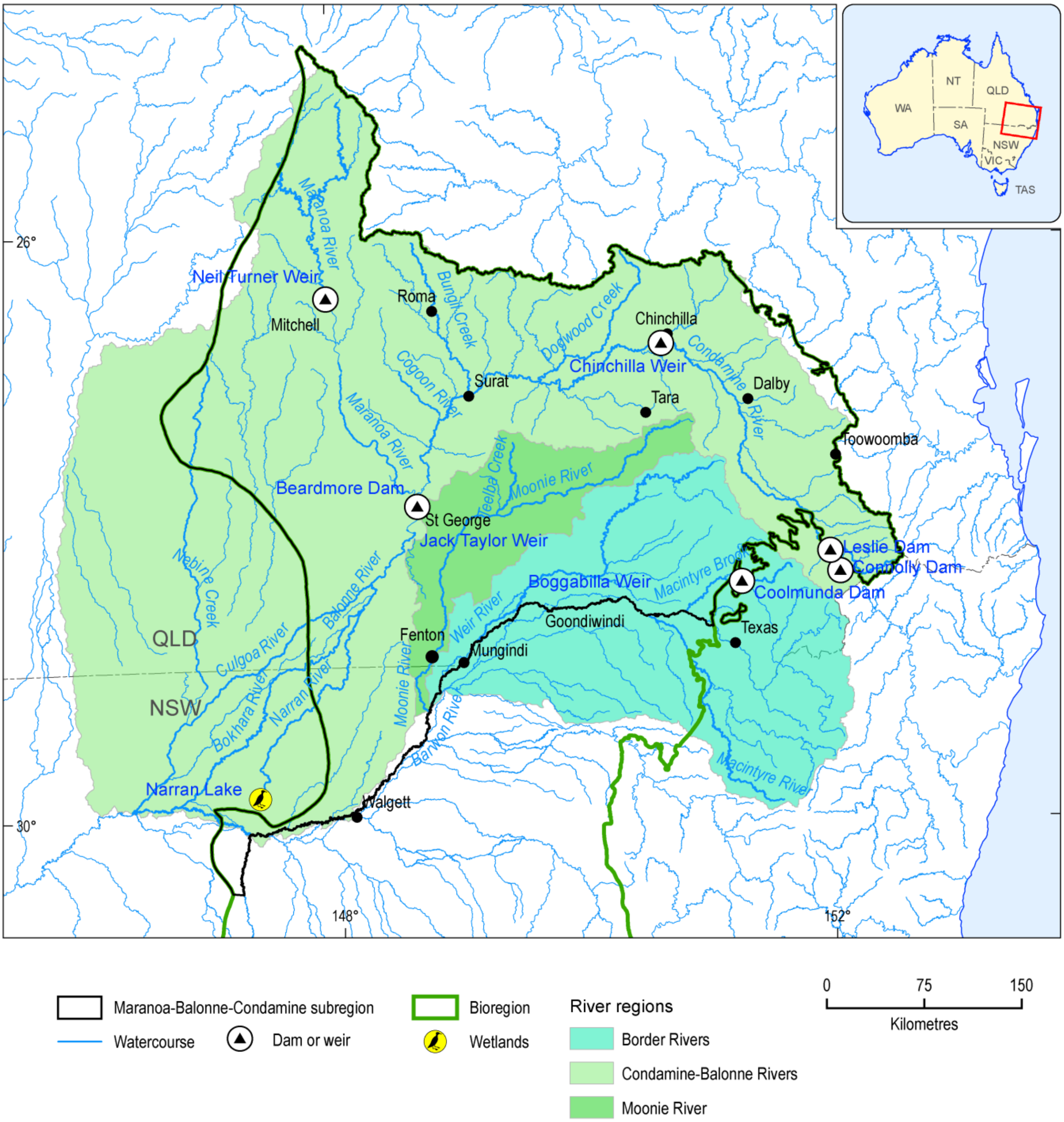

Figure 27 Maranoa-Balonne-Condamine subregion showing stream networks of the Condamine-Balonne, Moonie and Border Rivers river basins, major water infrastructures and towns

Flooding history and flooding potential

Major floods in the Condamine-Balonne River occur, on average, every two years. A major flood is defined as a flood that causes inundation to large areas, isolating towns and cities with major disruptions to road and rail links and that may require evacuation of houses (Bureau of Meteorology, 2011a). Some of the largest recorded floods were in 1942, 1950, 1956, 1975, 1976, 1983 (twice), 1988, 1996, 2010 and 2011 (Bureau of Meteorology, 2011a). Floods in the Condamine-Balonne River can result in widespread inundation of agricultural land, damage to farming properties and loss of livestock. Figure 28 shows the floodplain extent for the Condamine River upstream of Chinchilla (Condamine Alliance, 2014). The Condamine-Balonne and Maranoa rivers can have entirely different flooding patterns in a given year, depending on the distribution of rainfall in the river basin.

In the Condamine-Balonne river basin, minor flooding can result from a widespread 24-hour rainfall event greater than 25 mm, or from 50 mm rainfall events in isolated areas. A widespread rainfall event greater than 50 mm, or isolated rainfall events greater than 75 mm, can result in moderate to major flooding (Bureau of Meteorology, 2011a).

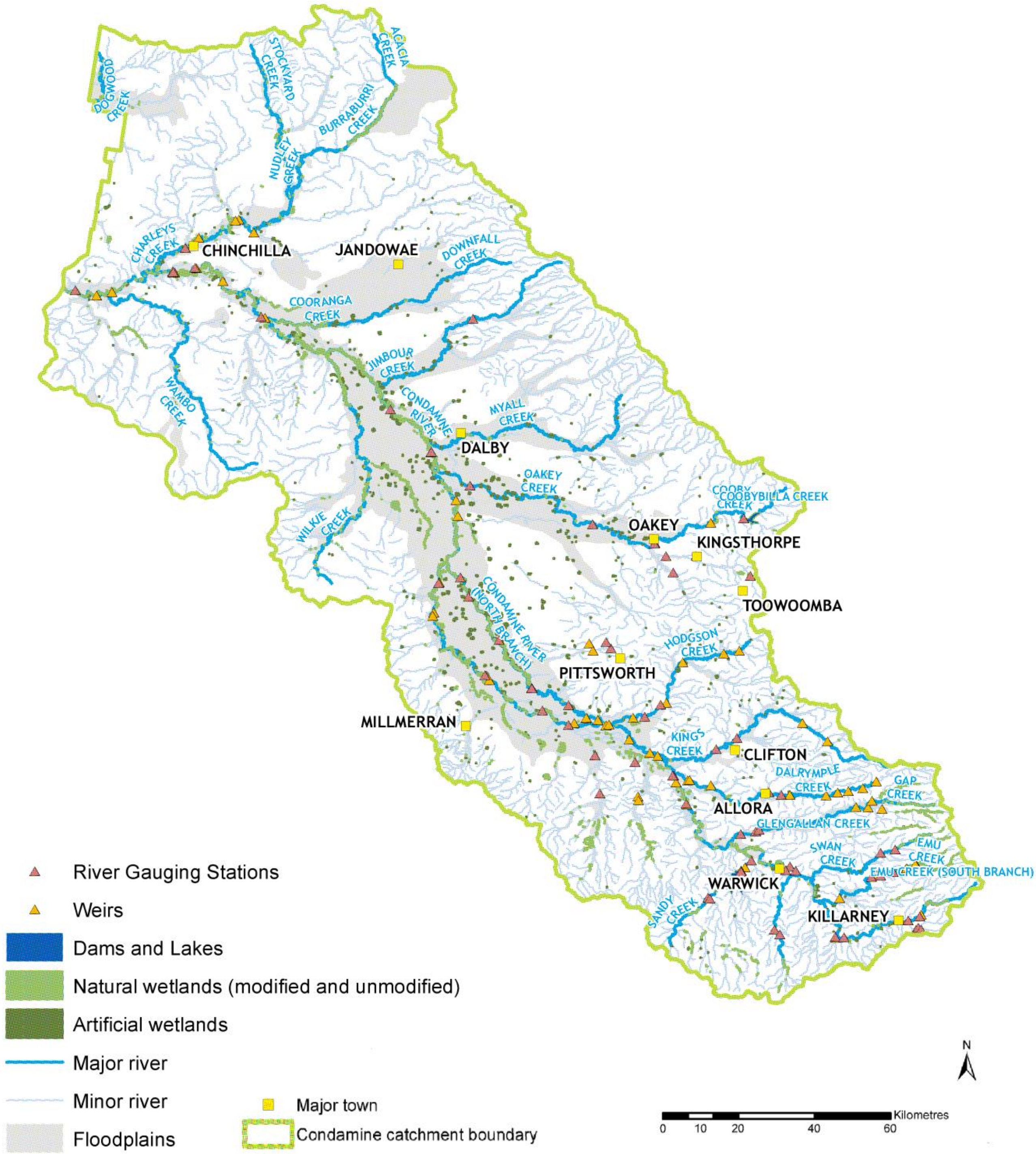

Figure 28 Floodplains in the upper Condamine River

Source: modified from Condamine Alliance (2014)

1.1.5.1.2 Moonie river basin

The Moonie River originates from headwaters east of Tara and flows in a south-westerly direction before crossing the NSW border near Fenton and joining the Barwon River (Figure 27). The Moonie river basin (15,100 km^2) is one of the most heavily cleared areas in southern Queensland (CEWH, 2013). Moonie River is unregulated. Moonie River's tributaries are the Thomby, Bidgel, Farawell, Wongle Wongle, Stephens, Parrie Moolan, Toombilla and Teelba creeks. Teelba Creek is the largest tributary of Moonie River. The Thallon Waterholes, which have been identified as a significant ecological site, are filled by overbank flows from the Moonie River during significant flow events (CEWH, 2013).

Although most of the irrigation in the river basin depends on surface water (CEWH, 2013), the basin uses only 0.2% of the total surface water diverted for irrigation in the Murray–Darling Basin. The long-term mean diversion limit for surface water in the Moonie river basin within Queensland is 84 GL/year, comprising 51 GL/year in interceptions by runoff dams and 33 GL/year in watercourse diversions (MDBA, 2013a). In 2005–06 cotton accounted for 92% of the water used in the region. The environmental water requirement for the region is estimated to be between 49 and 52 GL/year (Bureau of Meteorology, 2013).

The Moonie water resource plan is one of four water resource plans in the Queensland Murray Darling Basin which will be reviewed and updated by 2019 to be compliant with the Basin Plan (DNRM, 2014).

Water infrastructure

The Moonie river basin has no major public storages, but has about 87 private off-river on-farm storages (DERM, 2013). The total volume of these storages is not accurately known but was estimated to be 125 GL, all in hillside dams with their own catchment within the river basin (Webb, McKeown and Associates Pty Ltd, 2007). Thallon Weir, upstream of Fenton, has a capacity of 185 ML and supplies water to Thallon. Although irrigated agriculture exists in the river basin, data on irrigation related infrastructure are not readily available.

Flooding history and flooding potential

Teelba Creek, together with other tributaries upstream of Flinton, contributes to major flooding with potential to inundate large areas of low-lying land (Bureau of Meteorology, 2011b). The Bureau of Meteorology assessment of flood potential in the Moonie River suggests that 50 mm rainfall in 24 hours will cause isolated flooding in the immediate area of the heavy rain. Meanwhile, a rainfall event of 50 mm or more in 24 hours over a wide area will most likely cause major flooding, particularly in the middle to lower reaches downstream of Tartha (Bureau of Meteorology, 2011b). The highest flood on record occurred in March 2010, with flood heights of 4.65 and 5.50 m at Nindigully and Thallon gauging stations, respectively.

1.1.5.1.3 Border Rivers river basin

The Maranoa-Balonne-Condamine subregion contains the north-western part of the Border Rivers river basin (Figure 27). The major surface water resources of the basin that are within the subregion are Weir River, Macintyre Brook, Callandoon Creek and the Macintyre-Dumaresq-Barwon river system.

Weir River is a major unregulated river that joins the Macintyre River upstream of Mungindi. The current surface water availability in the Macintyre and Dumaresq rivers is 242 GL/year and in Weir River it is 242 GL/year (CSIRO, 2007). At Newinga, the Weir and Macintyre rivers almost join and during high flows water can pass to and from these two rivers. Downstream of Mungindi, the Macintyre River becomes the Barwon River.

Surface water sources comprise more than 90% of the water used for irrigation in the Border Rivers river basin. For the Queensland part of the Border Rivers river basin, the estimated baseline surface water diversion limit is 320 GL/year, comprising 77 GL/year in interceptions by runoff dams and 242 GL/year in watercourse diversions (MDBA, 2013b).

The Border Rivers water resource plan is one of four water resource plans in the Queensland Murray Darling Basin which will be reviewed and updated by 2019 to be compliant with the Basin Plan (DNRM, 2014).

Water infrastructure

Coolmunda Dam in the Macintyre Brook creates one of the major public water storage reservoirs in the river basin, with a storage capacity of 69 GL. Macintyre Brook is a regulated stream and supplies medium security water entitlements estimated to be 6.4 GL/year for irrigators from the Coolmunda system (CSIRO, 2007). The other water storage structures in the area are Boggabilla and Goondiwindi weirs in the Macintyre River, and Greenup, Whetstone and Ben Dor weirs in the Macintyre Brook. The total volume of all major reservoirs, weirs and farm storages is estimated to be about 578 GL for the whole of the Border Rivers river basin, including areas outside of the subregion (Webb, McKeown and Associates Pty Ltd, 2007).

Flooding history and flooding potential

The town of Goondiwindi, downstream of the junction of the Macintyre and Dumaresq rivers, has experienced more than 60 major floods since 1886 including in 1956 (three major floods within six months), 1996 and 2011 (with a record flood level of 10.64 m) (Bureau of Meteorology, 2011c). For the Macintyre and Weir rivers, 50 mm of rainfall in 24 hours over isolated areas or 25 mm of rainfall over more extensive areas will cause stream rises and the possibility of minor flooding. A rainfall event of 25 mm over 24 to 72 hours can cause moderate to major flooding and a 50 mm rainfall in 24 hours will cause isolated flooding in the immediate area of the heavy rain. Generally, rainfall in excess of 50 mm in 24 hours over a large area will most likely cause major flooding, particularly in the lower reaches of the Macintyre and Dumaresq rivers, the Macintyre Brook and the Weir River (Bureau of Meteorology, 2011c).

1.1.5.2 Surface water quality

Queensland has a surface water quality network of about 240 stations monitoring in situ measurements using manual sampling as well as continuous water quality measurements (167 stations). These measurements generally include electrical conductivity (EC) at 25 °C, temperature, pH, turbidity, nutrients, dissolved oxygen and total alkalinity (DERM, 2012b). The manual water sampling frequency for all stations in the subregion is four times a year, except in the Oakey Creek (tributary of the Condamine River) which is sampled 12 times a year (DERM, 2012b).

Chapter 9 of the Murray–Darling Basin Plan outlines water quality and salinity management issues, including key causes of water quality degradation in the Basin (MDBA, 2012). It also contains water quality targets for different water use purposes such as irrigation, fresh water-dependent ecosystems for different ecosystem types and recreational water.

1.1.5.2.1 Condamine-Balonne river basin

Water quality data are gathered in the Condamine-Balonne river basin for a range of water quality markers including total nitrogen, total phosphorus, total suspended solids and many other chemicals, such as cadmium, copper, the herbicides Atrazine and Diuron, and the insecticide Dieldrin (DERM, 2011). In the upper Condamine river basin nutrient levels were found to be generally within the guidelines at the nutrient monitoring sites. EC was relatively high in the upstream parts of the Condamine River. The EC measured on the Condamine River at Chinchilla Weir showed values ranging from 800 µS/cm during low flows to 100 to 180 µS/cm during high flows. These results indicate that the Condamine River is relatively saline compared to other rivers in Queensland. Nutrient and turbidity data are generally deficient along the Condamine-Balonne River (DERM, 2011).

An ambient surface water quality summary report by the Department of Environment and Resource Management only reports the direction of water quality trends due to data limitations in most Queensland catchments; they note that reporting on magnitude would not be sufficiently reliable or meaningful (DERM, 2011, p.10). EC and turbidity trends in some of the Condamine-Balonne river basin catchments are summarised in Table 11. Trend data for other water quality indicators are unavailable.

Table 11 Electrical conductivity and turbidity trends in the Condamine-Balonne river basin

Locations	Electrical conductivity	Turbidity
Condamine River at Warwick	Falling	No trend detected[a]
Culgoa River at Whyenbah	Falling	Possibly rising
Condamine River at Chinchilla	Stable	No trend detected[a]
Balonne River at Weribone	No trend detected[a]	No trend detected[a]
Narran River at Dirranbandi Hebel Rd	No trend detected[a]	Unreported
Bokhara River at Hebel	No trend detected[a]	Unreported

[a]with available data
Source data: DERM (2011)

1.1.5.2.2 Moonie river basin

The two streamflow gauging stations in the Moonie river basin (at Nindigully and Fenton) have high concentrations of total nitrogen, which requires management action (DERM, 2011). However, no trends for EC and turbidity are apparent.

1.1.5.2.3 Border Rivers river basin

Sites in Border Rivers river basin in Queensland (not all within the subregion) are monitored on a monthly basis by the NSW Office of Water on behalf of Dumaresq Barwon Border Rivers Commission for electrical conductivity, nutrients, turbidity, total suspended solids and water temperature. Summary statics of the samples are reported for electrical conductivity, total phosphorus, total nitrogen and turbidity (DBBRC, 2012a). DBBRC (2012b) reports that median salinity level in the Border Rivers basin are below the low salinity guidelines for irrigation water. Macintyre Brook however had the salinity level above the guidelines for protection of aquatic ecosystems in upland streams. Turbidity levels in the Border Rivers river basin showed a gradual increase downstream along the waterway towards Mungindi. The Weir River is the most turbid and most nutrient rich (DBBRC, 2012b).

The DERM (2011) however reports that the streamflow gauging station in the Weir River has insufficient water quality data to assess levels and trends of EC, nitrogen, phosphorus and turbidity. In Macintyre Brook, EC is within the guidelines, while data for nitrogen, phosphorus and turbidity are insufficient for meaningful assessment (DERM, 2011).

1.1.5.3 Surface water flow

1.1.5.3.1 Condamine-Balonne river basin

The Condamine-Balonne river basin contributes about 8.5% of the total runoff and uses 3% of the surface water diverted for irrigation in the Murray–Darling Basin (CSIRO, 2008a). The mean annual rainfall for the Condamine-Balonne river basin is 514 mm, ranging from 1200 mm in the east to 400 mm in the west (NWC, 2013). Most of the rainfall occurs during the summer months of October to March and runoff is highest in summer and early autumn.

The long-term (1895 to 2006) mean annual modelled runoff over the entire Condamine-Balonne river basin is 19 mm (runoff ratio = 3.7%). However, the runoff for a recent ten-year period (1997 to 2006) was 23% lower than the long-term mean. Given the inter-annual variability, this difference is statistically insignificant (CSIRO, 2008a). Droughts and floods are common in the basin (NWC, 2013).

Forty-two stream gauging stations are still operational in the Condamine-Balonne river basin within the Maranoa-Balonne-Condamine subregion (Table 12). These stations are managed by the Queensland Department of Natural Resources and Mines and have record lengths ranging from a few years to more than 90 years (on the Balonne River at St George). There are several others with more than 40 years of recorded data, including the Condamine River at Chinchilla (58 years) and the Balonne River at Weribone (44 years). The eastern half of the Condamine-Balonne river basin has more gauged catchments than the western half, which has no small- or medium-sized gauged catchments. This would have implications for rainfall-runoff modelling at smaller scales in the western half of the river basin. The Queensland Government provides summary statistics from streamflow gauging stations in the Condamine-Balonne river basin in Queensland Government (2013).

The impact of climate change by the South Eastern Australian Climate Initiative (SEACI) for Condamine-Balonne river basin indicated that 11 of 15 global climate models (GCMs) projected a decrease in future rainfall showing a median reduction of 13% and 21% in future runoff under 1 and 2 degree global warming, respectively (Post et al., 2012). See Section 1.12.4 (Geography: Climate change and impacts) for further details. An earlier modelling using climate change projections for 2030 conditions based on input from nine of 15 GCMs also indicated a decrease in future runoff in Condamine-Balonne river basin (CSIRO, 2008a).

Table 12 List of open stream gauging stations within the Condamine-Balonne river basin. Some of the stations are re-sited and have a longer record length than listed here

Site number	Station name and location	Record length (y)	Start year	Catchment area (km²)	Mean monthly flow (GL)	Mean annual flow (mm)
422201F	Balonne River at St. George	93	1920	75,370	10.5	1.7
422202B	Dogwood Creek at Gilweir	64	1949	3,010	6.8	27.2
422204A	Culgoa River at Whyenbah	48	1965	79,330	39.2	5.9
422205A	Balonne-minor River at Hastings	48	1965	79,330	57.8	8.7
422206A	Narran River at Dirranbandi Hebel Road	48	1965	80,110	19.8	3.0
422207A	Ballandool River at Hebel Bollon Road	48	1965	80,185	5.4	0.8
422208A	Culgoa River at Woolerbilla	48	1965	80,405	42.3	6.3
422209A	Bokhara River at Hebel	48	1965	80,030	5.6	0.8
422210A	Bungil Creek at Tabers	47	1966	710	1.8	29.9
422211A	Briarie Ck at Woolerbilla-Hebel Rd	46	1967	410	8.8	256.7
422213A	Balonne River at Weribone	45	1969	51,540	106.8	24.9
422219A	Yuleba Creek at Forestry Station	41	1972	1,475	2.7	21.9
422220A	Balonne River at Surat	9	2004	47,251	113.4	28.8
422306A	Swan Creek at Swanfels	94	1919	83	0.8	121.2
422308C	Condamine River at Chinchilla	58	1955	19,190	49.3	30.8
422310C	Condamine River at Warwick	53	1960	1,360	7.9	69.5
422313B	Emu Creek at Emu Vale	41	1972	148	1.5	123.1
422316A	Condamine River at Cecil Weir	66	1947	7,795	29.3	45.0
422317C	Glengallan Creek at Rocky Ridge	2	2011	474	5.4	135.6
422319B	Dalrymple Creek at Allora	45	1968	246	1.6	80.1
422321B	Spring Creek at Killarney	41	1972	35	0.8	282.5
422323A	Condamine River at Tummaville	52	1961	6,475	20.0	37.1
422325A	Condamine River at Cotswold	47	1966	28,930	63.7	26.4
422326A	Gowrie Creek at Cranley	44	1969	47	0.8	200.7
422332B	Gowrie Creek at Oakey	21	1992	142	1.5	129.0
422333A	Condamine Riv. at Loudouns Bridge	45	1969	12,380	29.6	28.7
422334A	Kings Creek at Aides Bridge	45	1969	516	2.1	48.0
422336A	Condamine River at Brigalow	41	1972	18,000	43.0	28.7
422338A	Canal Creek at Leyburn	42	1972	395	1.1	32.8
422341A	Condamine River at Brosnans Barn	37	1976	92	1.5	196.6
422343A	Charleys Creek at Chinchilla	11	2002	3,461	8.6	29.9
422344A	Condamine River at Bedarra	6	2007	24,344	109.3	53.9

Site number	Station name and location	Record length (y)	Start year	Catchment area (km²)	Mean monthly flow (GL)	Mean annual flow (mm)
422345A	North Condamine Riv. at Lone Pine	35	1978	710	1.7	27.9
422347B	North Condamine River at Pampas	26	1988	378	1.2	39.3
422350A	Oakey Creek at Fairview	33	1980	1,970	4.0	24.5
422352A	Hodgson Creek at Balgownie	26	1987	560	3.1	66.2
422355A	Condamine Riv. at Talgai Tailwater	24	1989	3,105	10.7	41.3
422359A	Oakey Creek at Jondaryan	2	2011	1,353	5.5	48.8
422394A	Condamine River at Elbow Valley	41	1972	325	3.3	120.9
422404A	Maranoa River at Cashmere	44	1969	19,490	14.3	8.8
422501A	Wallam Creek at Cardiff	14	1999	4,698	3.6	9.3
422502A	Nebine Creek at Roseleigh	6	2007	17,906	3.0	2.0

Source data: Queensland Government (2013)

1.1.5.3.2 Moonie river basin

The Moonie river basin has a summer-dominated rainfall with an annual mean of 528 mm ranging from 700 mm in the east to 450 mm in the west. The mean annual rainfall has remained relatively consistent over the last 100 years. The Moonie river basin contributes less than 1% of the total runoff in the Murray–Darling Basin. The long-term (1895 to 2006) modelled mean annual runoff is 17 mm and the mean annual runoff ratio is 3.2% (CSIRO, 2008b).

There are three stream gauging stations in the Moonie river basin, all on the Moonie River. Two of the gauging stations have more than 40 years of flow records (Table 13). The mean observed monthly flows downstream from Flinton (417205A), Nindigully (417201B) and Fenton (417204A) are 13.2, 11.8 and 14 GL respectively, indicating a loss of flow in the middle reaches.

Table 13 List of open stream gauging stations within the Moonie river basin. Some of the stations are re-sited and have a longer record length than listed here

Site number	Station name and location	Record length (y)	Start year	Catchment area (km²)	Mean monthly flow (GL)	Mean annual flow (mm)
417205A	Moonie river at Flinton	8	2006	5,378	13.245	29.6
417201B	Moonie River at Nindigully	45	1969	12,030	11.822	11.8
417204A	Moonie River at Fenton	42	1971	14,050	14.161	12.1

Source data: Queensland Government (2013)

The impact of climate change by the South Eastern Australian Climate Initiative (SEACI) for Moonie river basin indicated that 11 of 15 GCMs projected a decrease in future rainfall showing a median reduction of 12% and 20% in future runoff under 1 and 2 degree global warming, respectively (Post et al., 2012). See Section 1.12.4 (Geography: Climate change and impacts) for further details.

An earlier modelling using climate change projections for 2030 conditions based on input from nine 15 GCMs also indicated a decrease in future runoff in the Moonie river basin (CSIRO, 2008b).

1.1.5.3.3 Border Rivers river basin

The subregion within Border Rivers river basin has a summer-dominated rainfall and ranges from 800 to 500 mm from east to west (see Section 1.1.2.3). The modelled mean annual runoff is 32 mm over the entire basin generating 4.7% of the total runoff of the Murray–Darling Basin (CSIRO, 2007).

There are 19 stream gauging stations in the Border Rivers river basin within the Maranoa-Balonne-Condamine subregion. They are managed by the Queensland Department of Natural Resources and Mines (Table 14). The lengths of flow records vary from a few years to 96 years (for Macintyre River at Goondiwindi). The mean annual runoff for Callandoon Creek at Carana Weir is noted to be unusually high (3863 mm), which might be due to either an error in the estimated catchment area or in the measurement of flow volume.

The impact of climate change by the South Eastern Australian Climate Initiative (SEACI) for whole of Border Rivers river basin (including areas that are outside the subregion) indicated that 11 of 15 GCMs projected a decrease in future runoff showing a median reduction of 14% and 25% under 1 and 2 degree global warming, respectively (Post et al., 2012). See Section 1.12.4 (Geography: Climate change and impacts) for further details. The CSIRO (2007) study also indicated the effect of projected climate change on future runoff in the whole of the Border Rivers river basin is a likely decrease of runoff of about 9% for 2030 climate based on a median estimate. Surface water – groundwater exchange under the median 2030 climate is projected to be unaffected.

Table 14 List of open stream gauging stations in the Border Rivers river basin within the Maranoa-Balonne-Condamine subregion. Some of the stations are re-sited and have a longer record length than listed here

Site number	Station name and location	Record length (y)	Start year	Catchment area (km^2)	Mean monthly flow (GL)	Mean annual flow (mm)
416201A	Macintyre River at Goondiwindi	96	1917	23,090	80.1	41.6
416201B	Macintyre River at Goondiwindi Weir	17	1997	23,090	52.5	27.3
416202A	Weir River at Talwood	64	1949	12,070	13.1	13.1
416203A	Callandoon Creek at Carana Weir	18	1996	16	5.2	3863.3
416204A	Weir River at Gunn Bridge	14	1999	4,423	6.0	16.3
416205A	Weir River at Jericho	11	2002	12,348	18.7	18.2
416206A	Callandoon Creek at Oonavale	8	2005	115	5.7	593.1
416207A	Weir River at Mascot	7	2007	13,495	21.0	18.7
416305B	Brush Creek at Beebo	45	1968	335	0.7	25.1
416309B	Pike Creek at Glenlyon Dam T/W	40	1973	1,320	5.4	48.7
416310A	Dumaresq River at Farnbro	51	1962	1,310	6.9	62.8
416312A	Oaky Creek at Texas	45	1969	422	1.3	37.8
416315A	Pike Creek at Glenlyon Dam Headwater	37	1977	1,295	1.1	10.6
416317A	Broadwater Creek at Barkers	26	1987	108	0.4	45.0
416318A	Severn River at Ballandean	14	1999	621	2.3	43.7
416319A	Quart Pot Creek at Stanthorpe	8	2005	230	1.8	91.7
416320A	Accomodation Creek at Wallaces Dump	8	2006	240	1.5	74.7
416402C	Macintyre Brook at Inglewood	33	1981	3,430	7.9	27.6
416415A	Macintyre Brook at Booba Sands	27	1987	4,092	8.7	25.4

Source data: Queensland Government (2013)

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1.1.6 Surface water – groundwater interactions

Summary

Detailed studies of surface water – groundwater interactions have been undertaken in specific areas of the Maranoa-Balonne-Condamine subregion but not for the subregion as a whole. General studies have shown that major watercourses in the subregion vary between gaining and losing systems along their reaches both naturally and in response to anthropogenic stresses (e.g. groundwater extraction in the Condamine Alluvium). Connectivity characteristics have been shown to vary seasonally in places.

1.1.6.1 Connectivity between groundwater and surface water

Although some useful general information about connectivity in the Maranoa-Balonne-Condamine subregion is available for specific locations, details are lacking in many areas and available information appears contradictory in places. Most of the findings described below are based on river and groundwater levels either at a single point in time (e.g. CSIRO, 2007) or for a single season (e.g. Baskaran, 2009). Since connectivity between streams of the Condamine-Balonne river system and the alluvial aquifers is spatially and temporally variable (Moran and Vink, 2010), these studies do not provide insights into the seasonal changes in surface water – groundwater interactions.

Regional assessments of surface water – groundwater connectivity were undertaken as part of the Murray-Darling Basin Sustainable Yields Project (Parsons et al., 2008). In the Maranoa-Balonne-Condamine subregion, connectivity was assessed in the Border Rivers, Barwon River and Condamine-Balonne river systems. The Maranoa River and the Moonie river basin (see Figure 28) were excluded from the assessment because the degree of connection between streams and aquifers is largely unknown (CSIRO, 2008a). Connectivity mapping was based on a snapshot in time of fluxes to or from the major rivers. The study used data from June 2006 in the Border Rivers and Barwon-Darling river basins and from March 2006 in the Condamine-Balonne river basin, times that represented historically low-flow periods in these areas (CSIRO, 2007, 2008a, 2008b and 2008c). Results are shown in Figure 29.

The north branch of the Condamine River and its Oakey Creek tributary were classified as ‘maximum losing’, the watertable being separated from the stream by an unsaturated zone. CSIRO (2008b) attribute this to large-scale groundwater extraction in the area. Since the groundwater is already significantly depleted, the flow is unlikely to be changed by any further drawdown in the water level (Moran and Vink, 2010). The upper reaches of the river are mostly classified as ‘medium losing’, changing to gaining conditions in the area of Chinchilla Weir. CSIRO (2008b) state that gaining conditions may seasonally extend further downstream. Downstream from Werribone Weir, the Balonne-Culgoa River is classified as ‘medium losing’ to the border with NSW, beyond which it changes to ‘low losing’. CSIRO (2008b) note that the Condamine-Balonne system is seasonally variable in character from Chinchilla Weir to the border. The pattern of gaining and losing stream reaches in Figure 29 is generally supported by the groundwater contours on Figure 25 and Figure 23.

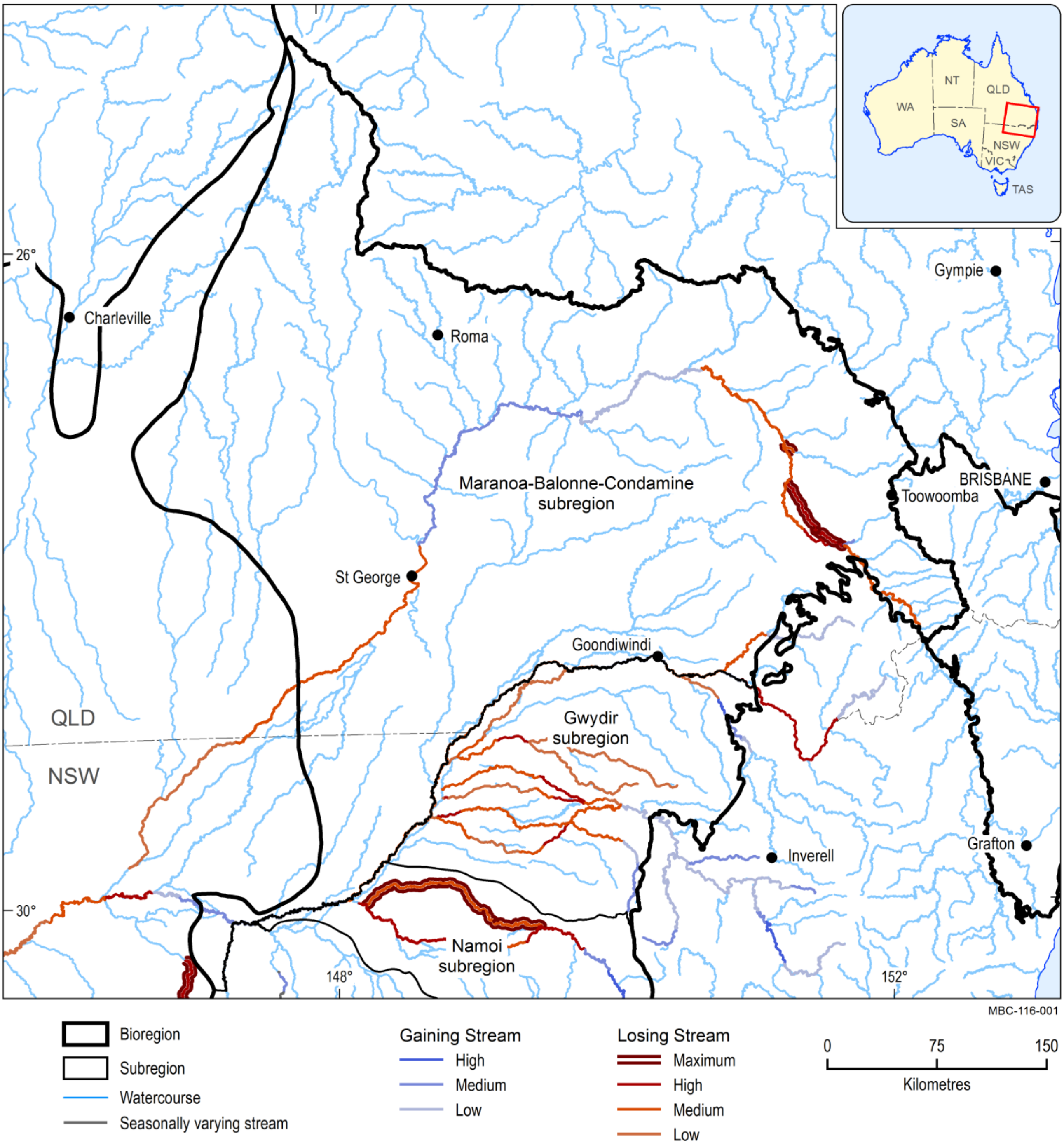

Figure 29 Surface water – groundwater connectivity in the Maranoa-Balonne-Condamine subregion

Not all watercourses are classified. Maximum losing conditions occur where the watertable is separated from the streambed by an unsaturated zone. The additional classification of high, medium or low losing for these reaches refers to the flux from streambed to watertable

Source data: derived from data presented in CSIRO, 2007, 2008a, 2008b and 2008c.

1.1.6.1.1 Condamine Alluvium area

Interactions between surface water and groundwater in the Condamine River valley are predominantly through the Condamine Alluvium unconfined to semi-confined aquifer. The Condamine Alluvium comprises stratified sand, gravel, and clay lenses deposited in a fluvial setting by the Condamine River and its tributaries (Huxley, 1982).

Intensive groundwater extraction for irrigation since the 1960s has lowered the potentiometric surface and is believed to have caused groundwater across the main body of the Condamine Alluvium to be largely disconnected from surface water. In the upper regions of the alluvium (Killarney-Warwick area), reasonable connectivity between surface water and groundwater is thought to exist and groundwater levels are consequently influenced by river levels (J Chavasse, 2013, pers. comm.). Evidence for this includes a considerable decrease in the level of the modelled potentiometric surface relative to the topographic surface moving from the upper catchment into the central reaches of the alluvium. In addition, electrical conductivity in the Condamine River is comparable to that of groundwater in the alluvium in the upper catchment but not in the central and lower regions of the Condamine Alluvium, where groundwater has become significantly more saline. Decline in hydraulic head in the Condamine Alluvium due to extraction of groundwater over the past 40 years has induced an upwards hydraulic gradient from the underlying Walloon Coal Measures, resulting in the influx of saline waters (Barnett and Muller, 2008; Hillier, 2010).

A study commissioned by Queensland Department of Environment and Resource Management (DERM), reporting on the conceptual hydrogeology of the Central Condamine Alluvium, undertook an analysis of groundwater and stream gauge transects which confirmed that steambed recharge from the Condamine River and North Branch is potentially occurring along the entire length of the Condamine River (Figure 20) (KCB 2010). The study also considered that the maximum losing reach of the Condamine River (Figure 30) reported by CSIRO (2008b) extends further downstream and that although disconnected surface water – groundwater conditions are inferred for most of the Central Condamine River Alluvium, the actual mechanisms governing stream loss are complex, and a dynamic zone of variable saturation is likely to exist between surface water and groundwater (KCB 2010).

A subsequent DERM water balance study considered Condamine River streambed recharge estimates, concluding that the most likely values are those calculated by Lane (1979) who reported stream loss values ranging from 38.5 ML/annum/km to 115 ML/annum/km (KCB, 2011).

Comparison of hydrographs from the Condamine River with bore hydrographs at different locations in the river basin indicates large variation in connectivity between surface water and groundwater across the alluvium (Figure 31). Figure 31 shows a hydrograph from the gauging station at Loudouns Bridge (Central Condamine Alluvium) on the Condamine River superimposed on a bore hydrograph from a monitoring bore approximately 100 m east of the river and 9 km upstream (Registered Number 42230152).

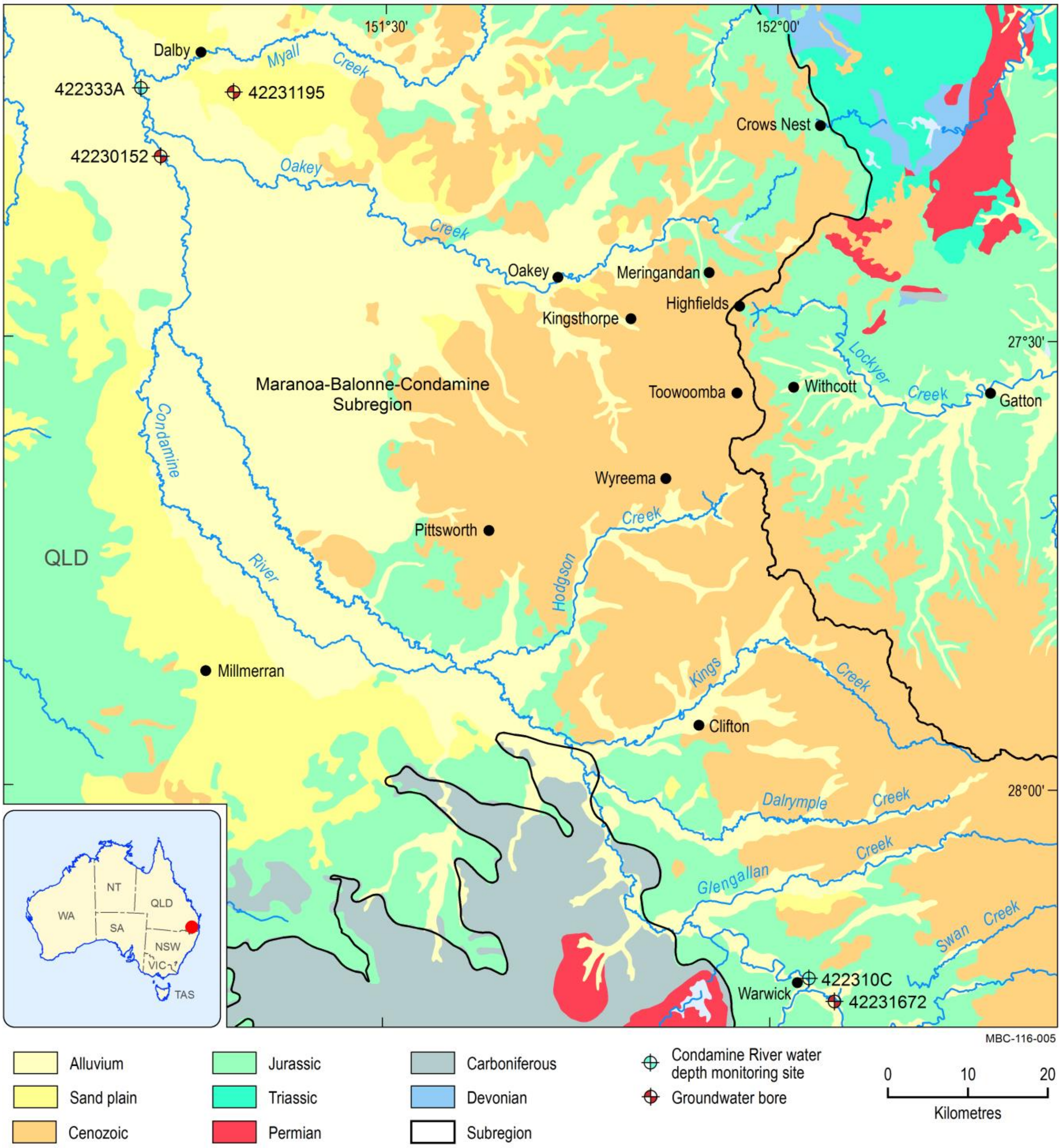

Figure 30 Surface geology of the Condamine Alluvium area showing the location of selected river gauging stations and groundwater monitoring sites

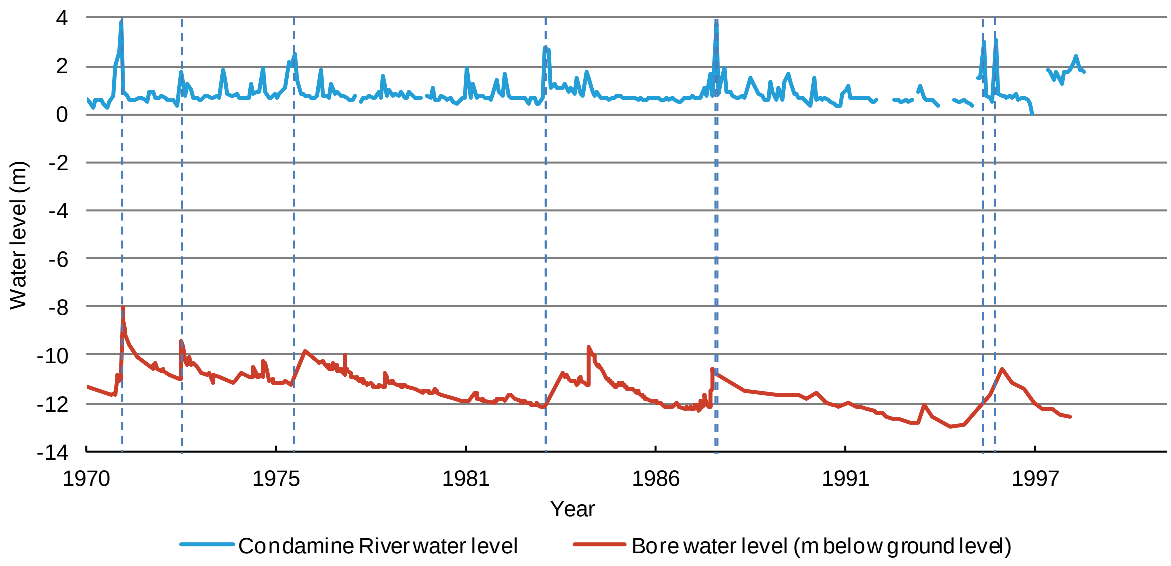

Figure 31 Hydrograph from the gauging station at Loudouns Bridge (Central Condamine Alluvium) on the Condamine River and bore hydrograph from a monitoring bore approximately 9 km upstream (Registered Number 42230152)

Locations of these stations are shown in Figure 30

The bore hydrograph correlates strongly with river water levels for some flood events. However, on close inspection there is a lag of at least several weeks between most of the flood peaks in the river and response in groundwater levels suggesting slow percolation rates. Some flood events (e.g. 1983) appear to have no influence on groundwater levels, but this could be the result of intensive extraction over-riding the flood signal. Figure 32 compares the same hydrograph from Loudouns Bridge monitoring station on the Condamine River with a bore hydrograph approximately 13 km east from the river, in the Condamine Alluvium (Registered Number 42231195). No correlation appears to exist between surface water and groundwater levels at this distance from the river. This suggests that in the Central Condamine Alluvium, the Condamine River is an important source of recharge to the groundwater resources of the Condamine Alluvium within close proximity of the river, but more distal areas are probably recharged via other mechanisms.

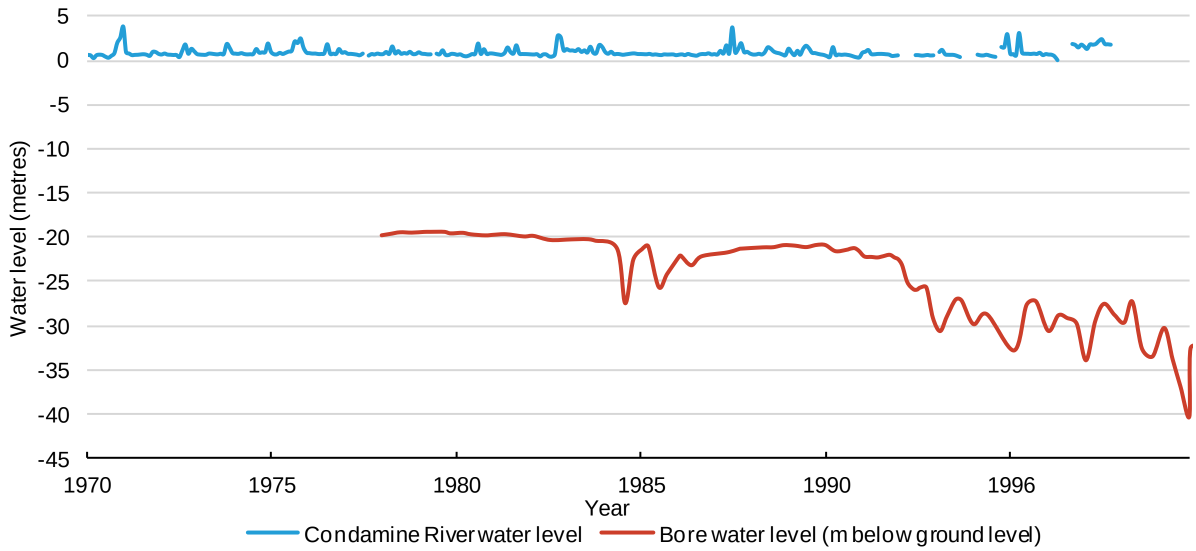

Figure 32 Hydrograph from the gauging station at Loudouns Bridge (Central Condamine Alluvium) on the Condamine River and bore hydrograph from a monitoring bore approximately 13 km east of the river in the Condamine Alluvium (42231195)

Locations of these stations are shown in Figure 30

Figure 33 shows a hydrograph from the gauging station at Warwick (upper reaches of Condamine Alluvium) on the Condamine River superimposed on a bore hydrograph from a monitoring bore approximately 4 km away (Registered Number 42231672). These hydrographs are plotted at a different time scale to those in Figure 31 and Figure 32 due to data availability (2 years, in comparison to 20 to 30 years). Surface water is clearly contributing to the groundwater recharge, as evidenced by high river level events being mirrored by groundwater levels of subdued magnitude. The lag between surface water and groundwater peaks is approximately one week for the two major flood events, a significantly more rapid response than that inferred from the hydrographs of the Central Condamine Alluvium (Figure 31). Other processes are obviously affecting groundwater levels in this area of the alluvium; extraction for irrigation being the most likely. Note the separate vertical axes for the two water levels. The magnitude in variation of groundwater levels appears to be greater than that of surface levels but they are in fact 0.35 m and 1 m, respectively, when the different axes are taken into account. Similarly, it is important to note that these groundwater levels are always below the surface water levels.

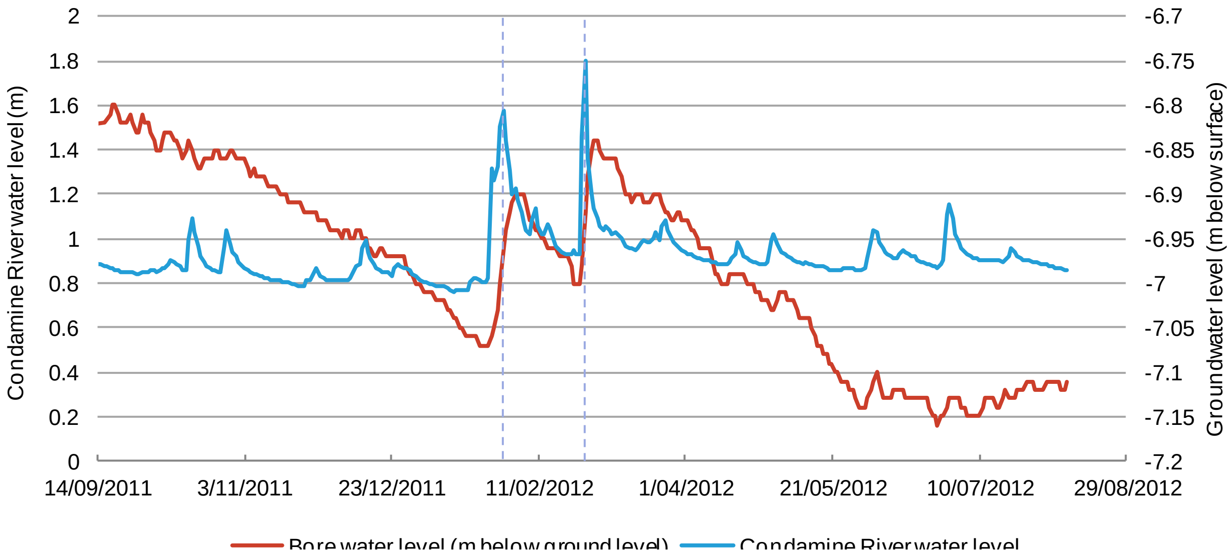

Figure 33 Hydrograph from the gauging station at Warwick (upper reaches of Condamine Alluvium) on the Condamine River and bore hydrograph from a monitoring bore approximately 4 km away in the Condamine Alluvium (42231672)

Locations of these stations are shown in Figure 30. Note the separate vertical axis for the two water levels

1.1.6.1.2 Lower Balonne area

A study by Kellett et al. (2006) investigating salinity using airborne electromagnetics in the Lower Balonne area reported evidence of surface water – groundwater interaction based on water level and airborne electromagnetic data.

Figure 34 shows a groundwater mound along the axis of the Balonne River north of Whyenbah, interpreted by Kellett et al. (2006) as river bed underflow leakage, acting as a line source of recharge to the upper alluvial aquifer. These authors also proposed that the northern and western margins of Lake Kajarabie (on the Balonne River north-west of St George) were important sources of recharge for the upper alluvial aquifer. Further, groundwater with Na-HCO3-Cl type major ion chemistry, suggesting local river recharge, occurs in bores adjacent to the Maranoa and Balonne rivers upstream of St George, the Balonne River at Whyenbah and the Narran and Culgoa rivers to the west and south-west of Dirranbandi (Kellett et al., 2006).

Kellett et al. (2006) speculated that recharge to the lower alluvial aquifer occurs via bed underflow leakage from both the Balonne and Maranoa rivers. Specifically this occurs where the Dirranbandi paleovalley extends beneath the Balonne River upstream of Beardmore Dam and the lower alluvial aquifer becomes unconfined, and beneath the Maranoa River immediately upstream of its confluence with the Balonne River.

The conclusion of bed underflow leakage via the Maranoa River is supported by the airborne electromagnetic conductivity 30 to 40 m depth slice shown in Figure 35 which depicts a resistive lobe associated with the lower alluvial aquifer, which is likely to be a result of inflow of fresh, low conductivity water from the river.

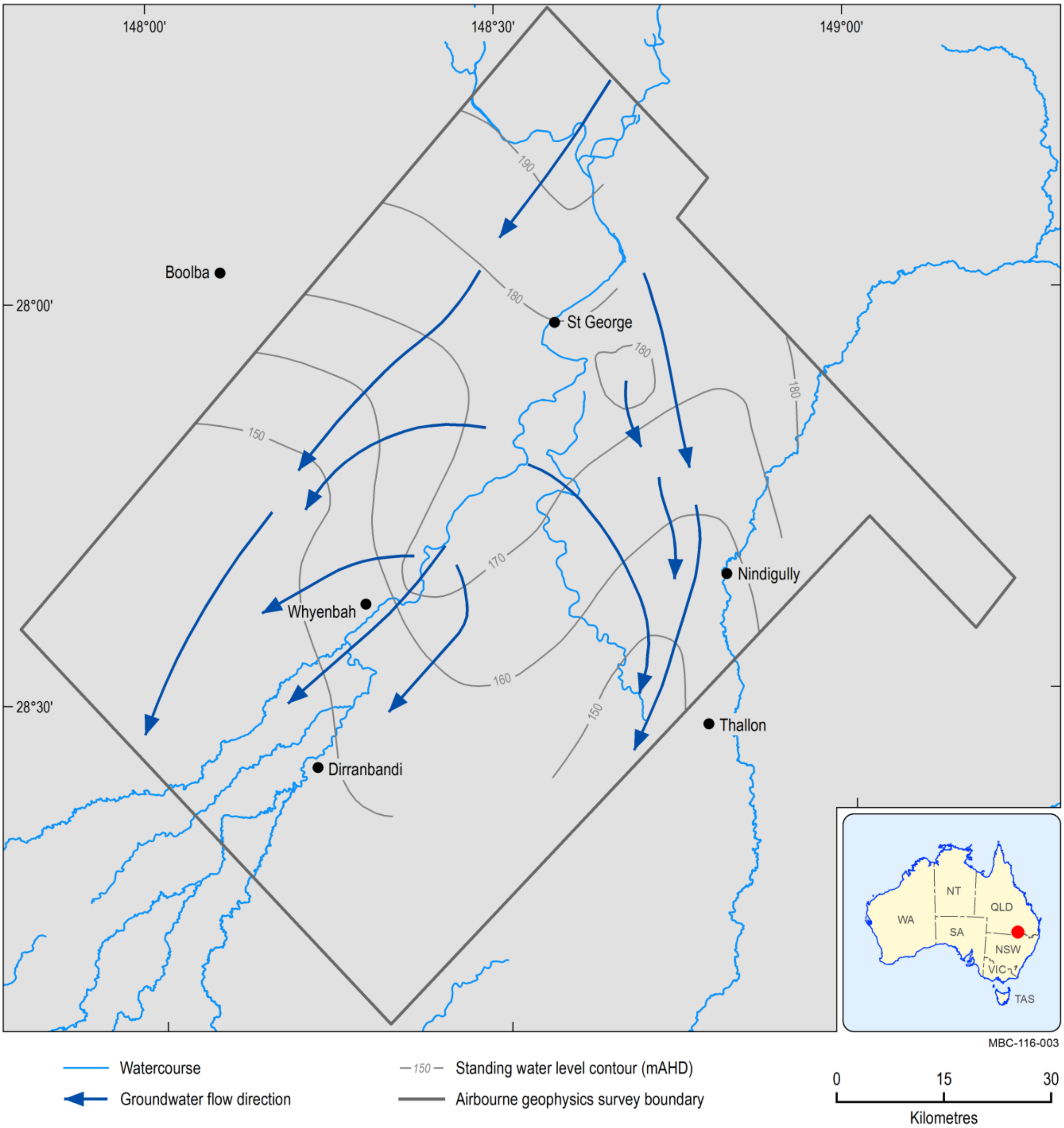

Figure 34 Watertable contours and groundwater flow directions, upper alluvial aquifer

Source data: derived from data presented in Kellett et al. (2006)

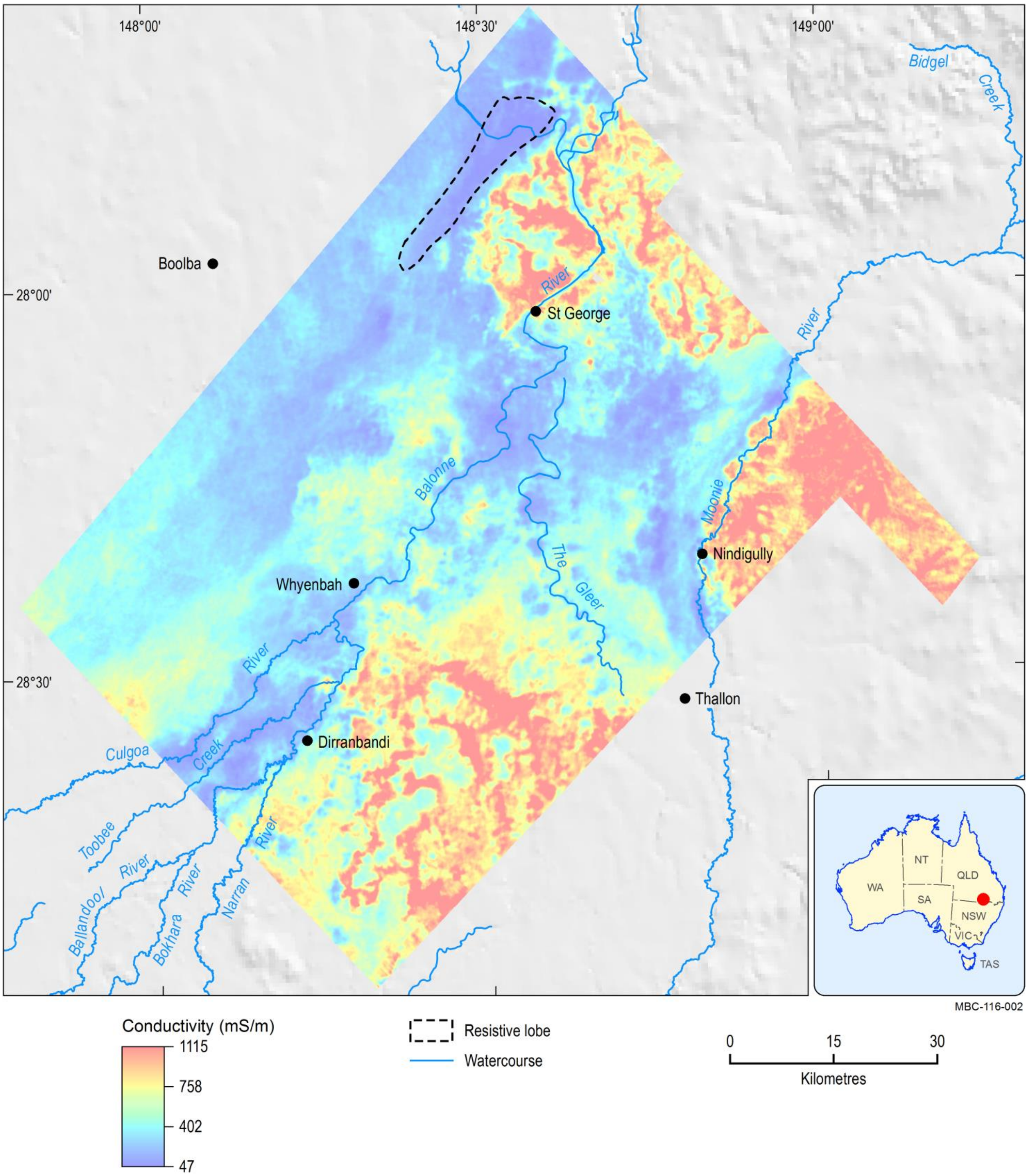

Figure 35 Representative 30 to 40 m airborne electromagnetic conductivity slice, showing a resistive lobe in the north

Source data: derived from data presented in Kellett et al. (2006)

1.1.6.1.3 Border Rivers area

In the south of the subregion, the Dumaresq and Macintyre rivers and the Macintyre Brook are mostly classified by CSIRO (2007) as 'losing' in the groundwater extraction area of the Queensland Border Rivers Alluvium. CSIRO (2007) indicate that comparisons between river levels and groundwater levels over time at select locations commonly show that the surface water – groundwater level relationships in Figure 29 in the Border Rivers area are maintained. However, gaining conditions in some stream reaches could be reversed over short time periods in response to flood events.

In contrast to CSIRO (2007), Kelett and Stewart (2013) note that recharge to groundwater from the Dumaresq River and Macintyre Brook is not strongly manifested in the groundwater surface (see Figure 23) which generally suggests either no interaction with streams or discharge to them in many areas, although the area near Goondiwindi does show groundwater mounding near the Border Rivers.

Baskaran et al. (2009) undertook an assessment of river–groundwater interactions in the Border Rivers area using heat tracers. They concluded that the Dumaresq River immediately downstream of Bonshaw Weir (about 25 km east of where the Dumaresq River exits the Maranoa-Balonne-Condamine subregion) gains groundwater during the high-flow (high rainfall) season but recharges groundwater during the low-flow season. This area was classified by CSIRO (2007b) as 'high losing'. In contrast, temperature tracer studies near Goondiwindi (at the west of the NSW Border Rivers Alluvium sustainable diversion limit resource unit) and Kanowna (downstream from Goondiwindi outside of the NSW Border Rivers Alluvium sustainable diversion limit resource) suggested that the river loses water to groundwater during both high- and low-flow seasons, a feature supported by measured hydraulic gradients.

Kellett and Stewart (2013) note that the configuration of the shallow GAB groundwater surface (see Figure 25) suggests that there is likely to be upward leakage from the GAB to the Border Rivers area drains for GAB groundwater that may in turn contribute a component of baseflow to the river.

The Barwon River is classified as variably 'medium losing' or 'low losing' from the NSW border to the area near Walgett. In these upper reaches, CSIRO (2008c) state that groundwater levels deepen and the river behaves as a 'maximum losing' or disconnected system but this is not recorded on accompanying figures (on which Figure 29 is based). Downstream of Walgett the classification changes to 'low gaining' and ultimately to 'medium gaining' before the river exits the subregion. CSIRO (2008c) indicate that analysis at several locations showed that most river reaches maintained the relationships shown Figure 29 over time. They note the limitations of the classification method used, stating that some of the classifications in the Barwon-Darling river basin are contradicted in the literature (these areas fall outside the subregion). The groundwater contours on Figure 24 suggest that the Barwon River is a gaining system within the subregion.

1.1.6.1.4 Impacts of future developments

The impact of 2030 climate change on surface water – groundwater interaction is predicted to be relatively small for current development scenarios (CSIRO, 2007). However, the nature of these interactions changes depending on water levels in the river, which may vary under coal seam gas or mining development. These changes are in addition to any effects caused by future climate change.

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1.1.7 Ecology

Summary

The Maranoa-Balonne-Condamine subregion intersects the Condamine-Balonne, Border Rivers and Moonie river basins. The subregion spans the high country in the upper Condamine catchment and Border Rivers in the east, to the wide alluvial western plains in the lower portions of the river basins, and is typified by three distinct landforms: the tablelands, slopes and plains. The Maranoa-Balonne-Condamine subregion includes three Interim Biogeographic Regionalisation for Australia (IBRA) bioregions: Brigalow Belt South, Darling Riverine Plains and Mulga Lands, with most of the Maranoa-Balonne-Condamine subregion represented by the Brigalow Belt South IBRA bioregion. Extensive areas of the Brigalow Belt South IBRA bioregion within the Maranoa-Balonne-Condamine subregion have been cleared for agriculture and the native remnant vegetation is influenced by floodplains and alluvial fans. The main vegetation types across the Maranoa-Balonne-Condamine subregion are grassy woodlands (e.g. poplar box) across the uplands, while the riparian vegetation is dominated by river red gum, coolibah and river oak, with weeping bottlebrush a common understorey. The total area of wetlands listed in the Australian Wetlands Database in the Maranoa-Balonne-Condamine subregion is approximately 4000 km^2 and incorporates seasonal, semi-permanent and permanent wetlands and lagoons, three of which are listed nationally. The subregion is ecologically significant because it comprises a large range of landforms and associated ecosystems containing many important species. There are 85 species listed under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999*. The seven nationally threatened ecological communities include the critically endangered Natural grasslands on basalt and fine-textured alluvial plains and White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland. Recent mapping of groundwater dependent ecosystems across most of the Maranoa-Balonne-Condamine subregion identified 14 distinct types of systems that potentially support ecosystems with some level of groundwater dependency. These systems cover a diverse range of landforms including; alluvia, permeable geologies, spring complexes and inland sand ridges.

1.1.7.1 Ecological systems

The Maranoa-Balonne-Condamine subregion, in southern Queensland and western NSW, is based around the Border Rivers, Maranoa-Balonne and Condamine natural resource management regions and a small eastern portion of the South West Queensland natural resource management region. The Maranoa-Balonne-Condamine subregion covers an area of 144,890 km^2. The subregion extends south towards the terminal lakes and wetlands of the Narran River (Figure 36). The major river basins of the Maranoa-Balonne-Condamine subregion are the Condamine-Balonne, Border Rivers and Moonie (Section 1.1.5). The dominant land use is agriculture based around a mixture of cropping and grazing (Figure 11).

The subregion spans the high country in the upper Condamine catchment and Border Rivers in the east to the wide alluvial western plains in the lower portions of the river basins (Figure 5). The topography contains three distinct landforms: the tablelands, slopes and plains. The north-eastern portion of the Maranoa-Balonne-Condamine subregion rises in the Great Dividing Range near Toowoomba at about 1400 mAHD within the Condamine river basin and falls to the lower Balonne floodplain wetland complex at about 200 mAHD. Similarly, the Border Rivers river basin comprises the tablelands in the east at about 1400 mAHD elevation, characterised by granite and basalt tablelands, grading into the slopes region characterised by undulating country with numerous permanent and semi-permanent billabongs. The plains region is downstream from the township of Boggabilla, where the terrain is undulating to flat. Floodplains stretch west towards Mungindi. The majority of river flows within the Maranoa-Balonne-Condamine subregion discharge either to the Barwon River south through NSW (via the Culgoa and Bokhara rivers) or toward the terminal lakes and wetlands of the Bokhara and Narran rivers (Figure 28).

1.1.7.2 Terrestrial species and communities

The Maranoa-Balonne-Condamine subregion includes three Interim Biogeographic Regionalisation for Australia (IBRA) bioregions: Brigalow Belt South, Darling Riverine Plains and the Mulga Lands (Figure 36). Table 15 provides a brief overview of the major landforms and biodiversity values across the three main biogeographic regions.

Table 15 Brief description of the Interim Biogeographic Regionalisation for Australia bioregions occurring in the Maranoa-Balonne-Condamine subregion

Interim Biogeographic Regionalisation for Australia bioregion	Landform	Biodiversity values
Brigalow Belt South	Landscapes derived from extensive basalt flow and quartz sandstones, variable soils and vegetation types	Supports a variety of forests and woodlands including a number of endangered ecological communities, plant and animal species
Darling Riverine Plains	Occupies most of the upper catchment of the Darling in southern Queensland and is a series of overlapping, low gradient alluvial fans that include the channels and floodplains of the lower reaches of these catchments	River channels support red gum communities, with coolibah and black box communities on floodplains
Mulga Lands	The Mulga Lands are dominated by horizontal Cretaceous sandstones and claystones and occupy the western portion of the subregion	Predominant vegetation of the bioregion is mulga (*Acacia aneura),* which supports several endangered plant and animal species

Source data: Department of the Environment (2013b).

The vegetation communities of the Maranoa-Balonne-Condamine subregion are mostly fragmented remnants of forest grading into woodland further west (Figure 9, Figure 11). More than 30% of the region is remnant native vegetation with a substantial area also under regrowth woodlands and grass-based native pastures (QMDC, 2011). The native grasslands that once made up about 3900 km^2 around the Darling Downs have been reduced to just over 1% of that region's original grasslands extent, making these sparsely timbered plains one of the most endangered ecosystems in Queensland (QMDC, 2013).

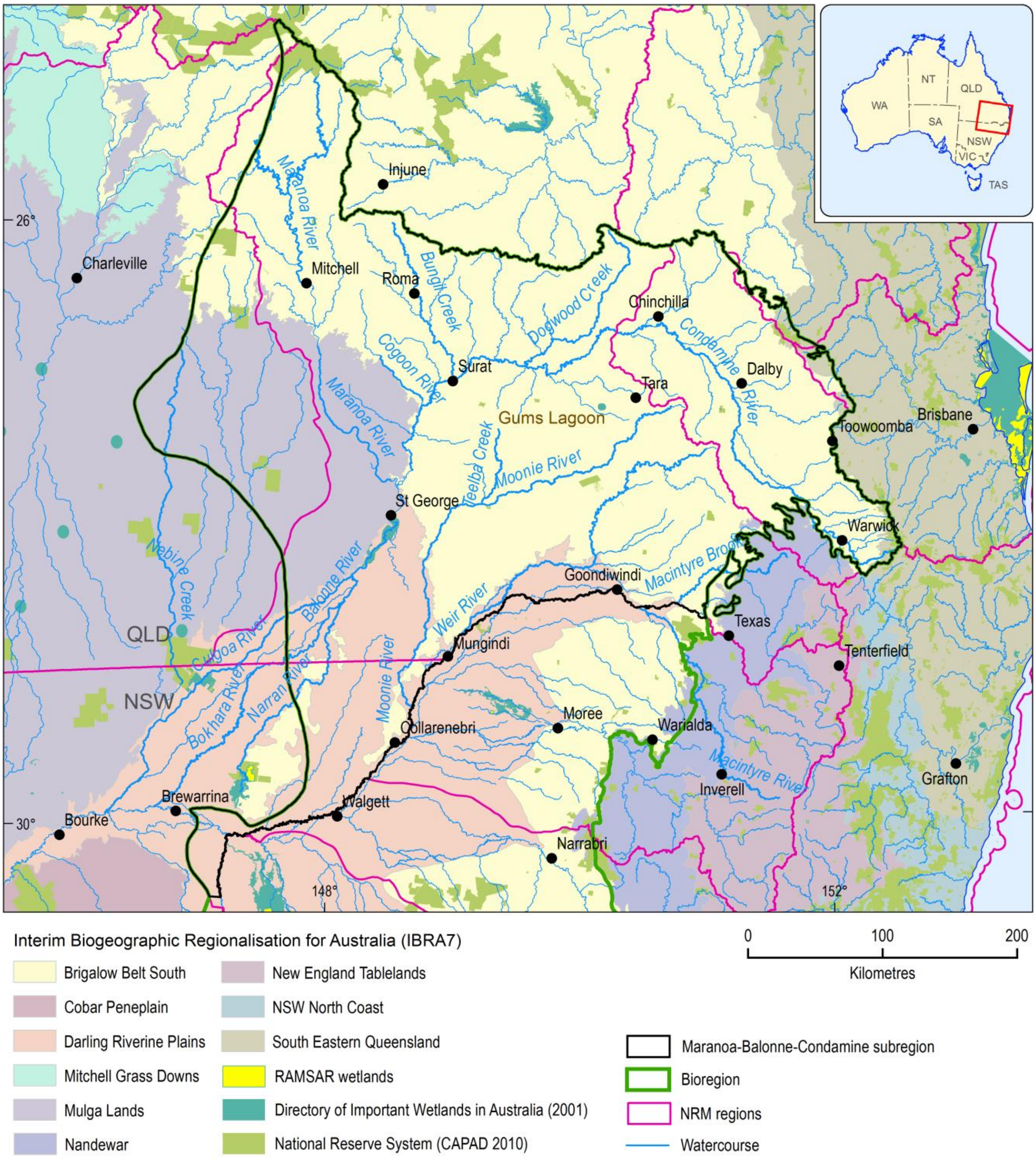

Figure 36 Major river systems, nationally and internationally recognised wetlands and relevant catchment management boundaries in the Maranoa-Balonne-Condamine subregion

The Brigalow Belt South IBRA bioregion encompasses most of the subregion (Figure 36). It is dominated by stony red earth soils in the upper river basin and deeper clay soils in the lower river basin. The main vegetation type is grassy woodlands of poplar box (*Eucalyptus populnea*), wilga (*Geijera parviflora*), white cypress pine (*Callitris glaucophylla*), budda (*Eremophila mitchellii*), ironwood (*Backhousia myrtifolia*) and belah (*Casuarina cristata*) with mixed grasses (CSIRO, 2008). Extensive areas of the Brigalow Belt South IBRA bioregion (up to 85%) have been cleared for agriculture, and the native remnant vegetation is influenced by floodplains and alluvial fans (Green et al., 2012; Green et al., 2011). The riparian vegetation of the Darling Riverine Plains IBRA bioregion is dominated by river red gum (*Eucalyptus camaldulensis*), coolibah (*Eucalyptus coolibah*) and river oak (*Casuarina cunninghamiana*), with weeping bottlebrush (*Callistemon viminalis*) a common understorey. Other communities occurring on the higher parts of the floodplains include poplar box woodlands, wilga, brigalow, white cypress and silver leaf ironbark (Border Rivers - Gwydir CMA, 2007). Based on 2009 wetland mapping by the Queensland Government, the total area of wetlands in the Murray–Darling drainage division (which incorporates an area slightly larger than the Maranoa-Balonne-Condamine subregion) is approximately 4000 km^2 and includes seasonal, semi-permanent and permanent wetlands and lagoons (DEH, 2014a), three of which are listed nationally (Figure 36) (Environment Australia, 2001). There are numerous protected areas covered by local and state reserve systems and several national parks within the Maranoa-Balonne-Condamine subregion (Figure 36) (Department of the Environment, 2010).

1.1.7.2.1 Matters of state, national and international environmental significance

The subregion is an ecologically significant area because it comprises a large range of landforms and ecosystems containing many important species. The historical land uses, particularly clearing and fragmentation of remnant vegetation for grazing, agriculture, mining and urban development, have been major drivers of the current occurrence of the flora and fauna within the subregion (QMDC, 2011). In the Condamine natural resource management region, there has been no detailed and systematic fauna and flora survey. Significant ecological assets of the subregion include:

- three entries listed in the Directory of Important Wetlands in Australia (Environment Australia, 2001)
- critically endangered ecological communities, including natural grasslands on basalt and fine-textured alluvial plains, White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland (Table 16)
- several important threatened species including Corben’s long-eared bat (*Nyctophilus corbeni*), yakka skink (*Egernia rugosa*), painted honeyeater (*Grantiella picta*), Brigalow scaly-foot (*Paradelma orientalis*) and rough collared frog (*Cyclorana verrucosa*)
- threatened species associated with aquatic ecosystems including silver perch (*Bidyanus bidyanus*), Australian painted snipe (*Rostratula australis*) and Murray cod (*Maccullochella peelii*)
- Lake Broadwater Conservation Park, which is the only large, naturally occurring freshwater lake on the Darling Downs that acts as an important refuge for waterbirds and other wildlife
- Southwood National Park, which is a 7120 ha remnant of brigalow - belah and poplar box woodlands.

There are many state and nationally important species found in the subregion listed under Queensland’s *Nature Conservation Act 1992* and the Commonwealth’s *Environment Protection and Biodiversity Conservation Act 1999* (EPBC). Under Queensland legislation there are 78 species listed as vulnerable or endangered. There are 85 species listed as vulnerable or endangered under the EPBC Act and include fishes (two species), mammals (14 species), reptiles (6 species), birds

(14 species), and plants (49 species). Table 3 lists the seven threatened ecological communities listed under the EPBC Act.

The ‘Back on Track’ programme has identified the major and minor threats to 36 and 42 species classified as management priorities for the Condamine and Border Rivers Maranoa- Balonne regions respectively (DERM, 2010a; DERM 2010b). Both reports identified the major threats to these species as clearing of vegetation, and inappropriate fire and grazing regimes. Mining was also identified as a threat in the Border Rivers Maranoa-Balonne natural resource management region (DERM, 2010a). These processes also pose significant threats to the Brigalow Belt South ecological communities (Benson et al., 2006). There are over 50 feral species listed for the Maranoa-Balonne-Condamine subregion and these include many pests associated with key threatening processes in the EPBC Act. The ongoing degradation of remnant vegetation and the low level of protection for regional species and ecosystems also pose a significant threat. Some dryland salinity occurs in the Border Rivers alluvial landscape and the interface with the Brigalow Plains to the north is identified as a key hazard area. The extensive irrigation of sodic and saline clays in some areas could increase salt leaching and elevate watertables.

Table 16 Threatened ecological communities in the Maranoa-Balonne-Condamine subregion

Threatened ecological community	Status under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999*	Description
Brigalow (*Acacia harpophylla* dominant and co-dominant)	Endangered	Low woodland or forest community dominated by brigalow (*Acacia harpophylla*), with pockets of belah (*Casuarina cristata*) and poplar box (*Eucalyptus populnea* subsp. *bimbil*)
Coolibah - Black Box Woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregions	Endangered	Semi-arid to humid subtropical woodland where coolibah (*Eucalyptus coolibah* subsp. *coolibah*) and/or black box (*Eucalyptus largiflorens*) are the dominant canopy species and where the understorey tends to be grassy. The ecological community is associated with the floodplains and drainage areas
Natural Grasslands of the Queensland Central Highlands and the northern Fitzroy Basin	Endangered	Native tussock grasslands dominated by bluegrasses (*Dichanthium* spp.), with tropical three-awned grasses (*Aristida* spp.) and panic grasses (*Panicum* spp.) also a major component
Natural grasslands on basalt and fine-textured alluvial plains of northern NSW and southern Queensland	Critically endangered	Native tussock grasslands with bluegrass (*Dichanthium sericeum*) tend to be the dominant grass species in this area
Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar Bioregions	Endangered	A low, dense form of dry rainforest generally less than 10 m high, made up of vines and rainforest trees as well as some shrubs
Weeping Myall Woodlands	Endangered	Low woodland and low open woodland to low sparse woodland or open shrubland. The tree layer grows up to a height of about 10 m and invariably includes weeping myall or boree (*Acacia pendula*) as one of the dominant or only tree species present
White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland	Critically endangered	Dominance of white box (*Eucalyptus albens*), yellow box (*Eucalyptus melliodora*) or Blakely's red gum (*Eucalyptus blakelyi*) and a species-rich understorey of native tussock grasses, herbs and scattered shrubs

Source data: Department of the Environment (2013c).

1.1.7.3 Aquatic species and communities

The Maranoa-Balonne-Condamine subregion is included in the Queensland Murray–Darling Freshwater Biogeographic Province (Marshall et al., 2006). This province was identified using the response of its biota, and shows a high degree of dependence on the majority of biophysical processes (e.g. climate, hydrology and habitat factors) used in the assessment (DEH, 2013c). The majority of the Maranoa-Balonne-Condamine subregion was assessed as part of the Aquatic Conservation Assessments in 2011, an analysis that used multiple criteria to determine conservation values of wetlands in the Queensland portion of the Murray–Darling Basin (including the Border Rivers river basin in NSW) (Fielder et al., 2011). The assessment provides baseline ecological and conservation information for the region based on aquatic naturalness, catchment naturalness, diversity and richness, threatened species, special features and representativeness (Fielder et al., 2011). The report found that approximately half of the area assessed received a 'medium' score across the assessment criteria and noted that the Maranoa-Balonne-Condamine river basins are relatively data rich in comparison to those further west (Fielder et al., 2011).

Based on 2009 wetland mapping for the Queensland portion of the Murray–Darling Basin, of the the 4000 km^2 of wetlands approximately one-third are palustrine – vegetated, non-riverine or non-channel systems; one-third are riverine – systems associated within a channel and the remaining third being either lacustrine – wetlands or lakes dominated by open water or artificial and highly modified systems (DEH, 2014a). From 2001 to 2009, the areal extent of riverine and palustrine wetland systems have been reduced by approximately 15% and 11% respectively. During the same period artificial and highly modified systems increased by around 50% (DEH, 2014a).

There are three nationally significant wetlands included in the Maranoa-Balonne-Condamine subregion listed under the Directory of Important Wetlands (Department of the Environment, 2013a). The Gums Lagoon is in the northern part of the Maranoa-Balonne-Condamine subregion (Figure 36) and is a relatively undisturbed wooded swamp in a small (340 ha) reserve of similarly undisturbed woodlands and open forest (Figure 36). The lagoon supports a low open forest of river red gum (*Eucalyptus camaldulensis*) over perennial tussock grasses (species such as *Chloris* spp. and *Leptochloa digitata*) (Department of the Environment, 2013a). Ephemeral semi-aquatic plants (e.g. *Marsilea* spp. and *Cyperaceae* spp.) occur during periods of inundation. Large numbers of waterbirds and fish are known to use the lagoon when it is full (Department of the Environment, 2013a).

The Balonne River floodplain is an aggregation of permanent and ephemeral freshwater billabongs and swamps on an inland floodplain in the western part of the Maranoa-Balonne-Condamine subregion (Figure 37). Coolibah (*Eucalyptus coolibah*) open woodland is the dominant community fringing billabongs and swamps, and on the floodplain (Department of the Environment, 2013a). Occasional black box (*Eucalyptus largiflorens*) and river red gum (*Eucalyptus camaldulensis*) also occur in this community (Department of the Environment, 2013a). Open water areas support a variety of aquatic vegetation, and large numbers of waterbirds are known to use the wetlands (Department of the Environment, 2013a). Despite major agricultural disturbance in recent years, the fringing and aquatic vegetation of the wetlands appears to be reasonably intact (Department of the Environment, 2013a).

Lake Broadwater is situated within a conservation park at the edge of the broad valley of the Condamine River and lies to the west of the associated Long Swamp (Figure 36; Department of the Environment, 2013a). The lake has been enhanced by minor levee construction to a height of approximately 0.75 m. Lake Broadwater is a good example of a semi-permanent freshwater lake in an area where these types of water bodies are rare. Four wetland communities are recognised as being associated with the lake:

- open water communities – dominated by a range of species including shiny nardoo (*Marsilea mutica*) and swamp lily (*Ottelia ovalifolia*)
- lake edge communities – dominated by river red gum (*Eucalyptus camaldulensis*) with an understorey of grasses and sedges
- marsh communities
- riparian communities of similar structure to the lake edge communities (Department of the Environment, 2013a).

There are various other wetland and instream environments scattered across the subregion. The ecological values of the Moonie River instream environments are not well described (CSIRO, 2008). The Thallon waterholes (along the Moonie River) have been identified as significant for waterbirds in the Murray–Darling Basin. The waterholes can support between 10,000 and 20,000 waterbirds (Kingsford et al., 1997).

The Morella Watercourse, Boobera Lagoon and Pungbougal Lagoon are located on the Macintyre River floodplain within the Border Rivers river basin. This area floods from the river approximately once in ten years on average (Environment Australia, 2001). Boobera Lagoon is considered to be one of the most important Indigenous places in eastern Australia. The floodplain between Goondiwindi and Mungindi contains large areas of anabranches and billabongs. When flooded, these provide large amounts of organic carbon, and a major energy input to the aquatic ecosystem. Downstream from Goondiwindi small effluent creeks such as Boomi, Callandoon, Dingo and Whalan creeks break off from the main channel and meander across the landscape forming a complex floodplain of billabongs and wetlands that rely on overbank flows (Kingsford, 1999). These wetlands support the breeding of waterbirds listed under the NSW *Threatened Species Conservation Act 1995* including: brolgas (*Grus rubicunda*), black-necked storks (*Ephippiorhynchus asiaticus*) and magpie geese (*Anseranas semipalmata*).

1.1.7.4 Groundwater-dependent ecosystems

The Queensland Government recently produced groundwater-dependent ecosystem mapping of the Murray–Darling drainage basin that encompasses most of the Maranoa-Balonne-Condamine subregion (DSITIA, 2012). The mapping integrated existing regional ecosystem and wetland mapping with expert knowledge to develop mapping rules to identify groundwater dependent ecosystems. There are three classes of groundwater dependent ecosystems provided by the mapping based on the surface expression of groundwater; terrestrial ecosystems dependent on the subsurface presence of groundwater; and aquifer and cave ecosystems (Figure 37). The majority of groundwater dependent ecosystems associated with channels on alluvia with seasonal baseflow or groundwater connectivity are found in the eastern and northern portions of the subregion (Figure 37). A greater proportion of the terrestrial ecosystems that potentially contain surface expressions of groundwater dependent ecosystems are located in the southern portion of the subregion along the floodplains of the Maranoa, Balonne, Moonie and Border rivers. Springs are clustered around the eastern part of the subregion, south of Toowoomba, in the northern reaches of the Maranoa and the plains near the Balonne River. Specifically the groundwater-dependent ecosystem mapping identified 14 distinct types of systems that potentially support ecosystems with some level of groundwater dependency. The hydrogeology associated with groundwater dependent ecosystems in the Queensland Murray–Darling Basin can be summarised as:

- alluvia
- those systems associated with sandstones, limestone and basalt contact zones
- permeable geologies associated with basalt
- catchment constrictions arising from a narrowing in the width and/or depth of the catchment
- Goondoola Basin, an ancient lakebed characterised by a shallow saline watertable
- inland sand ridges (DEH, 2013a).

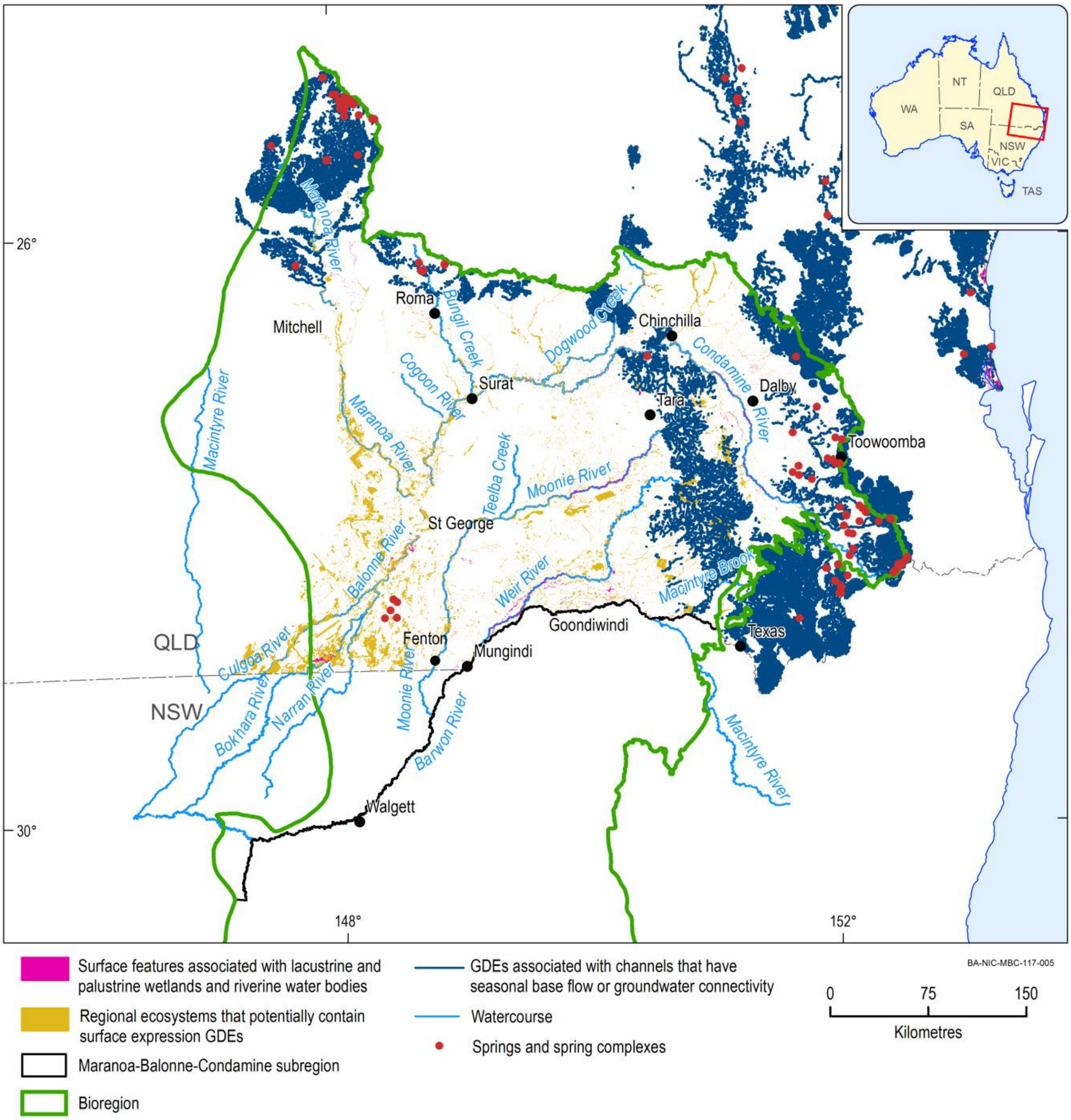

Figure 37 Groundwater-dependent ecosystems in the Queensland portion of the Murray–Darling Basin drainage division

Source data: Queensland groundwater dependent ecosystems (DSITIA, 2013).

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