Australian Government

BIOREGIONAL ASSESSMENTS

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

Current water accounts and water quality for the Maranoa-Balonne-Condamine subregion

Product 1.5 for the Maranoa-Balonne-Condamine subregion from the Northern Inland Catchments Bioregional Assessment

16 October 2015

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

The Bioregional Assessment Programme

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

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

Department of the Environment

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Cover photograph

Condamine river weir on Darling Downs in Queensland, 2005

Credit: Arthur Mostead © Commonwealth of Australia (Murray–Darling Basin Authority)

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Contents

Figures

Tables

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Introduction

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

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

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

The Bioregional Assessment Programme

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

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

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

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

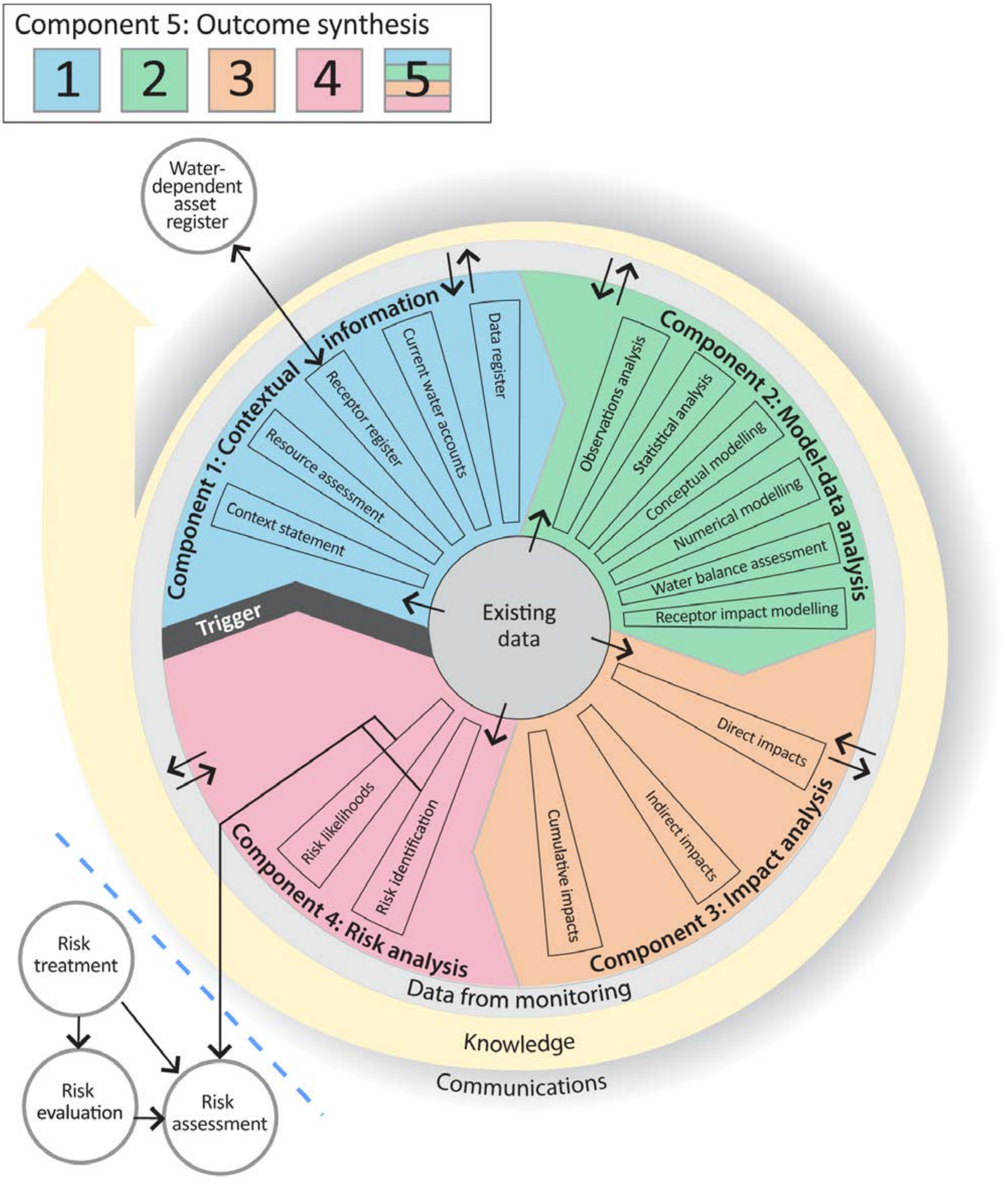

Figure 1 Schematic diagram of the bioregional assessment methodology

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

Methodologies

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

Table 1 Methodologies and associated technical products listed in Table 2

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

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

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

Technical products

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

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

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

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

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

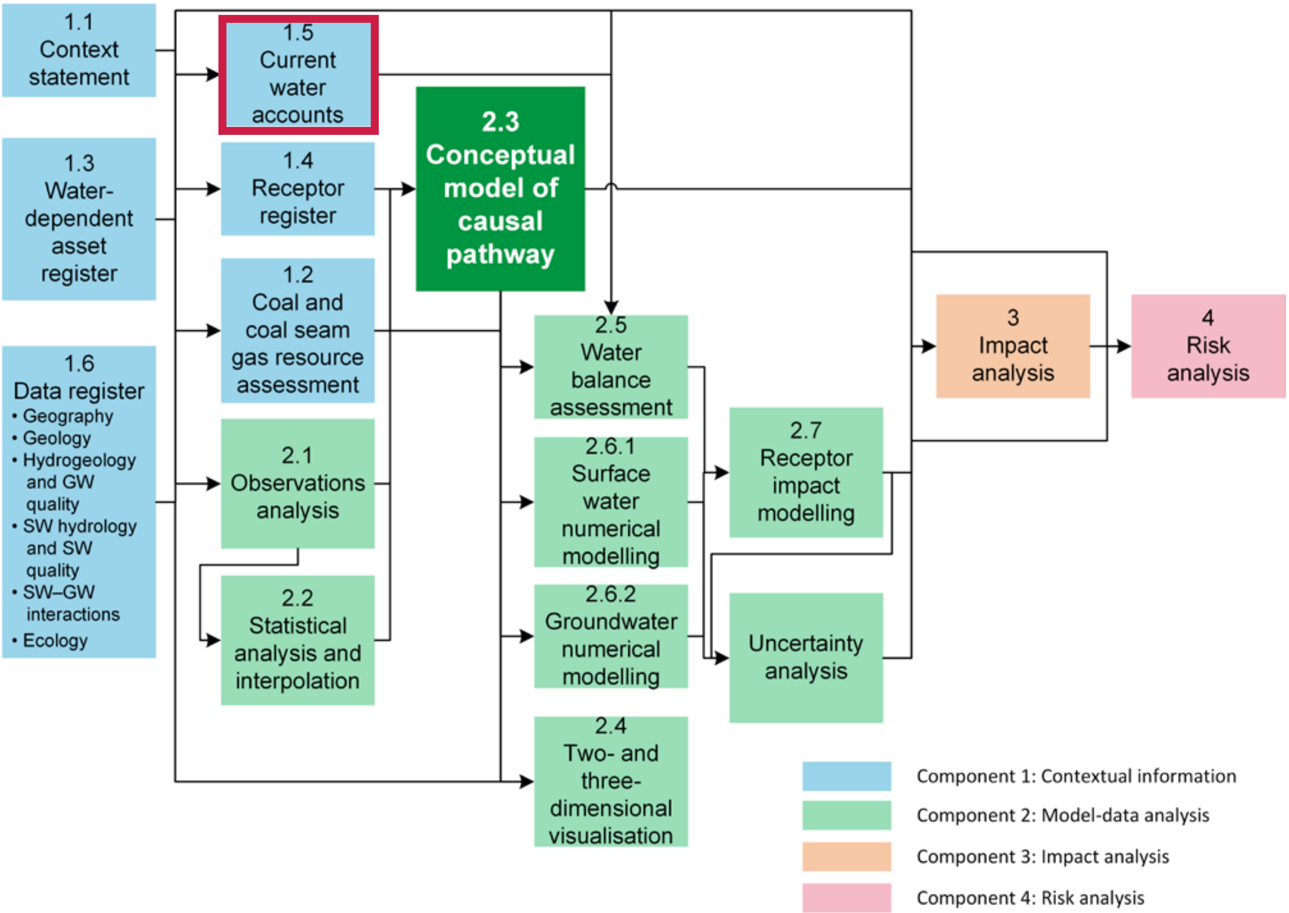

Figure 2 The simple decision tree indicates the flow of information through a bioregional assessment

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

Table 2 Technical products delivered by the Northern Inland Catchments Bioregional Assessment

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

Component	Product code	Title	Section in the BA methodology[b]	Type[a]
Component 1: Contextual information for the Maranoa-Balonne-Condamine subregion	1.1	Context statement	2.5.1.1, 3.2	PDF, HTML
	1.2	Coal and coal seam gas resource assessment	2.5.1.2, 3.3	PDF, HTML
	1.3	Description of the water-dependent asset register	2.5.1.3, 3.4	PDF, HTML, register
	1.4	Description of the receptor register	2.5.1.4, 3.5	PDF, HTML, register
	1.5	Current water accounts and water quality	2.5.1.5	PDF, HTML
	1.6	Data register	2.5.1.6	Register
Component 2: Model-data analysis for the Maranoa-Balonne-Condamine subregion	2.1-2.2	Observations analysis, statistical analysis and interpolation	2.5.2.1, 2.5.2.2	PDF, HTML
	2.3	Conceptual modelling	2.5.2.3, 4.3	PDF, HTML
	2.5	Water balance assessment	2.5.2.4	Not produced
	2.6.1	Surface water numerical modelling	4.4	Not produced
	2.6.2	Groundwater numerical modelling	4.4	PDF, HTML
	2.7	Receptor impact modelling	2.5.2.6, 4.5	Not produced
Component 3: Impact analysis for the Maranoa-Balonne-Condamine subregion	3-4	Impact analysis	5.2.1	PDF, HTML
Component 4: Risk analysis for the Maranoa-Balonne-Condamine subregion		Risk analysis	2.5.4, 5.3	
Component 5: Outcome synthesis for Northern Inland Catchments bioregion	5	Outcome synthesis	2.5.5	PDF, HTML

[a]The types of products are as follows:

- 'PDF' indicates a PDF document that is developed by the Northern Inland Catchments Bioregional Assessment using the structure, standards, and look and feel specified by the programme.
- 'HTML' indicates the same content as in the PDF document, but delivered as webpages.
- 'Register' indicates controlled lists that are delivered using a variety of formats as appropriate.
- 'Cross-reference' indicates material that does not use the same structure, standards, and look and feel specified by the programme. This material is typically developed externally or through aligned research projects funded by the Department of the Environment. A webpage links to this material and explain how it fits into the Assessment.
- 'Not produced' indicates that the product was not developed. A webpage explains why and points to relevant submethodologies (Table 1).

[b]*Methodology for bioregional assessments of the impacts of coal seam gas and coal mining development on water resources* (Barrett et al., 2013)

About this technical product

The following notes are relevant only for this technical product.

- All reasonable efforts were made to provide all material under a Creative Commons Attribution 3.0 Australia Licence.
- All maps created as part of this BA for inclusion in this product used the Albers equal area projection with a central meridian of 151.0° East for the Northern Inland Catchments bioregion and two standard parallels of –18.0° and –36.0°.
- Contact bioregionalassessments@bom.gov.au to access metadata (including copyright, attribution and licensing information) for all datasets cited or used to make figures in this product. At a later date, this information, as well as all unencumbered datasets, will be published online.
- The citation details of datasets are correct to the best of the knowledge of the Bioregional Assessment Programme at the publication date of this product. Readers should use the hyperlinks provided to access the most up-to-date information about these data; where there are discrepancies, the information provided online should be considered correct. The dates used to identify Bioregional Assessment Source Datasets are the dataset's published date. Where the published date is not available, the last updated date or created date is used. For Bioregional Assessment Derived Datasets, the created date is used.

References

Barrett DJ, Couch CA, Metcalfe DJ, Lytton L, Adhikary DP and Schmidt RK (2013) Methodology for bioregional assessments of the impacts of coal seam gas and coal mining development on water resources. A report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of the Environment. Department of the Environment, Australia. Viewed 27 November 2015, http://www.iesc.environment.gov.au/publications/methodology-bioregional-assessments-impacts-coal-seam-gas-and-coal-mining-development-water.

1.5 Current water accounts and water quality for the Maranoa-Balonne-Condamine subregion

This product provides current water account and water quality information that will be used in subsequent products in the bioregional assessment.

The water accounts include information about water stores, flows, allocations and use that will be required in the numerical modelling (product 2.6.2).

This product also provides information about surface water and groundwater quality that will be required for the impact analysis (product 3) and risk analysis (product 4).

1.5.1 Current water accounts

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 GL and 2670 GL (Welsh et al., 2014). There are four major public water storages in the Condamine-Balonne river basin with a combined storage capacity of 219.2 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. The Moonie river basin is one of the 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 there are estimated to be 87 private off stream water storages with an estimated total volume of 125 GL. 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 on Macintyre Brook is one of the major public water storage dams in the area with a storage capacity of 69 GL. Surface water provides more than 90% of the water used for irrigation in the Border Rivers river basin.

Groundwater is used for agriculture, stock and domestic, industrial and urban water uses in Maranoa-Balonne-Condamine subregion. This report considers groundwater use within the Surat Cumulative Management Area identified in the Underground Water Impact Report (QWC, 2012), which covers 65% of the Maranoa-Balonne-Condamine subregion. Estimated total non-petroleum and non-CSG water extraction in the Surat Cumulative Management Area is 215 GL/year from about 21,200 water bores (QWC, 2012). This is comprised of 85 GL/year from GAB aquifers and 130 GL/year from other aquifers. Approximately 1800 ML/year of water is extracted by conventional petroleum activites. The mean water production for coal seam gas activities over the period 2005 to 2013 was 13,476 ML/year with an increasing trend over the years. Water extraction for petroleum and CSG activities accounts for 7.1% of the average annual extraction for non-petroleum and non-gas activities.

The Maranoa-Balonne-Condamine subregion partially or fully overlaps the following Water Resource Plans (WRP) managed under Queensland's *Water Act* 2000: Condamine and Balonne, Moonie Basin, Border Rivers, Warrego-Paroo-Bulloo-Nebine, Cooper Creek and Fitzroy catchments and the Great Artesian Basin (GAB). The extent of the surface water catchments defines the areal extent of the WRPs, with the exception of the GAB aquifers, which are managed under the GAB WRP in Queensland and the Great Artesian Basin shallow groundwater sources water sharing plan in New South Wales.

1.5.1.1 Surface water

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 3). More information about these river basins are available in companion product 1.1 for the Maranoa-Balonne-Condamine subregion (Welsh et al., 2014). The water accounts for these three river basins are described in the subsequent sections.

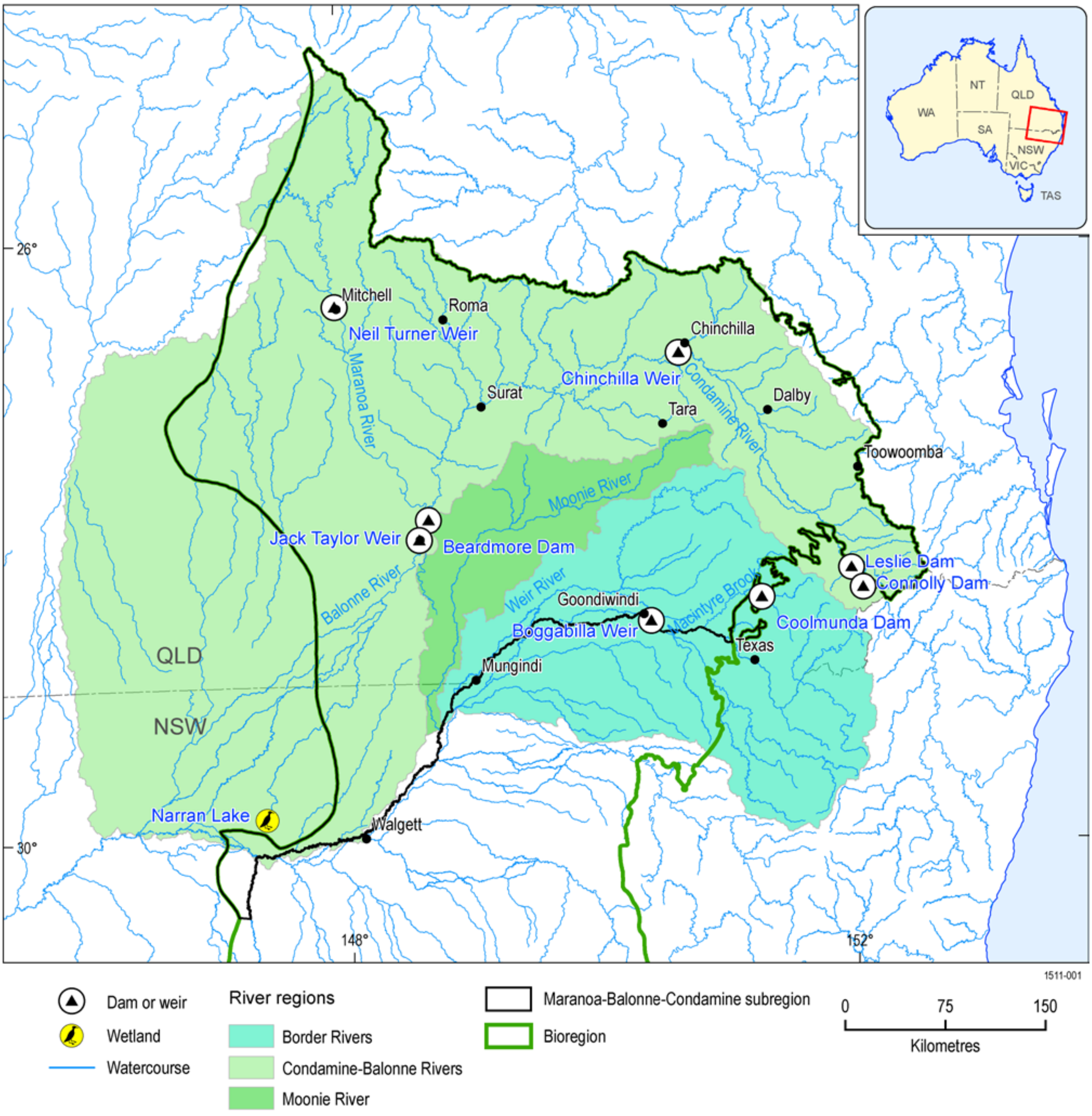

Figure 3 Maranoa-Balonne-Condamine subregion map showing stream networks of the Condamine-Balonne, Moonie and Border Rivers river basins, major water infrastructure and towns

Data: Bioregional Assessment Programme (Dataset 1), Bureau of Meteorology (Dataset 2), Australian Government Department of the Environment (Dataset 3)

1.5.1.1.1 Water accounts in the Condamine-Balonne river basin

The major surface water resources in the Condamine-Balonne river basin (Figure 4) are the Maranoa, Condamine and Balonne rivers, as well as numerous wetlands, natural lakes and reservoirs and dams. One of the major tributaries of the Condamine-Balonne river is the Condamine River, which has mean annual flow (MAF) of between 18 GL at Brosnans Barn (422341A) and 1312 GL at Bedarra (422344A) (Welsh et al., 2014). The Balonne River is another major tributary of the Condamine-Balonne river basin that has MAF of between 126 GL at St George (422201F) and 1361 GL at Weribone (422213A). The Maranoa River has MAF of 172 GL at Cashmere (422404A) (Welsh et al., 2014).

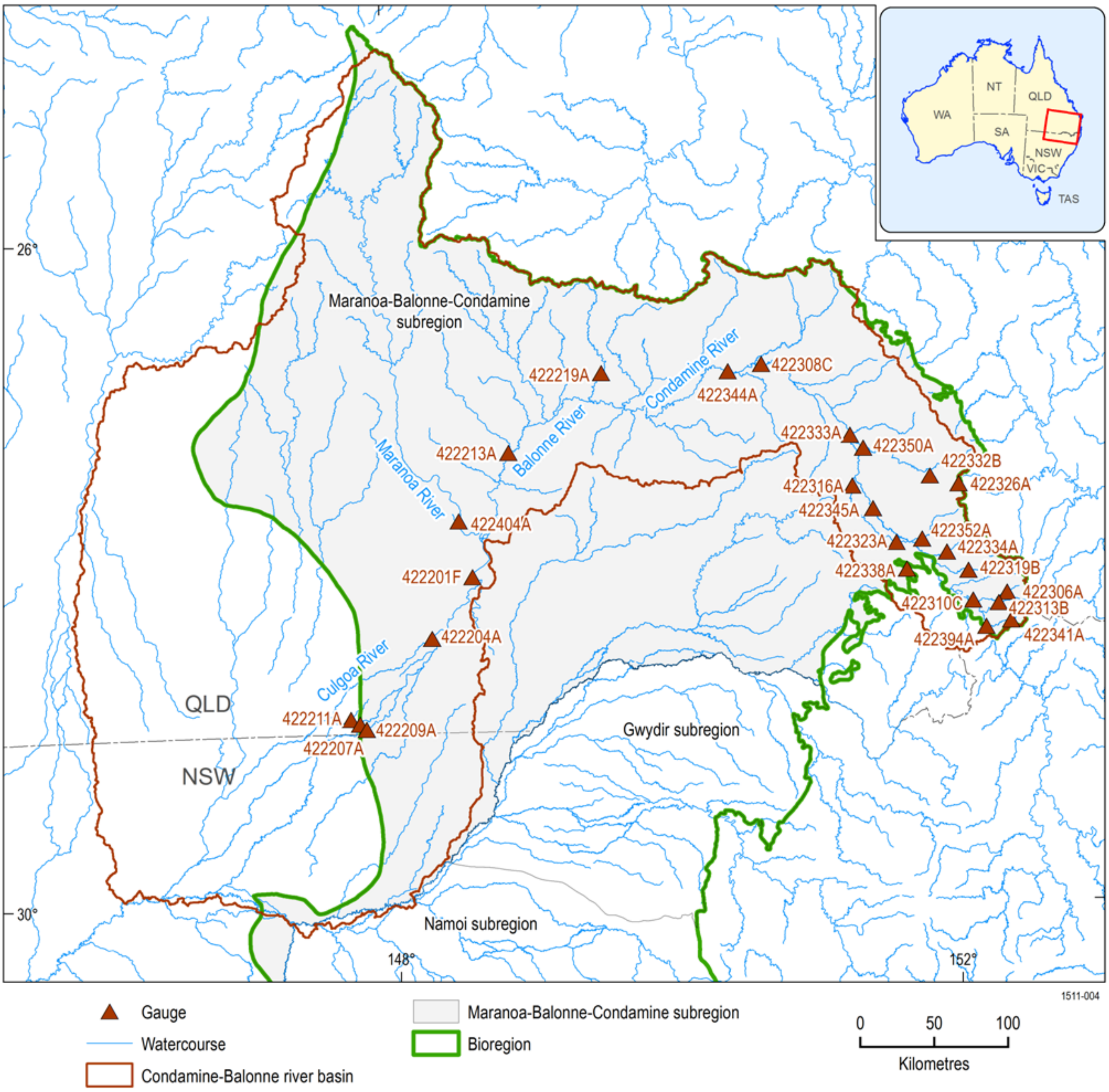

Figure 4 Tributaries of the Condamine-Balonne river basin and streamflow stations

Data: Bureau of Meteorology (Dataset 2, Dataset 4)

There are four major public water storages within the river basin, namely Leslie Dam (106 GL) and Chinchilla Weir (10 GL) on the Condamine River, and Beardmore Dam (82 GL) and Jack Taylor Weir (21.2 GL) on the Balonne River (Figure 3). The Maranoa River is largely unregulated. In addition to these major reservoirs, the Condamine-Balonne river basin has a range of water infrastructure including Cooby Dam and many weirs, most of which are committed to urban, agricultural and irrigation supply schemes (DERM, 2012a). The total volume of major dams, town water supply dams and weirs in the basin is 279.2 GL. There are, however, numerous private offstream water storages (e.g. ring tanks used for floodplain harvesting, runoff dams for stock and domestice use, small dams for irrigation and industrial uses) in the lower parts of the river basin with an estimated combined storage volume of 1916 GL (Webb, McKeown and Associates Pty Ltd, 2007).

1.5.1.1.2 Water accounts in the Moonie river basin

The tributaries of the Moonie river basin (Figure 5) are the Thomby, Bidgel, Farawell, Wongle Wongle, Stephens, Parrie Moolan, Toombilla and Teelba creeks. Teelba Creek is the largest tributary of the Moonie River. The Moonie River produces MAF of between 142 GL at Nindigully (417201B) and 170 GL at Fenton (417204A).

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 has been estimated to be 125 GL. These private off-river on-farm water storages are all in hillside dams with their own catchment (Webb, McKeown and Associates Pty Ltd, 2007). The Moonie river basin uses only 0.2% of the total surface water for irrigation. The baseline 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). The environmental water requirement for the region is estimated to be between 49 GL/year and 52 GL/year (Bureau of Meteorology, 2013).

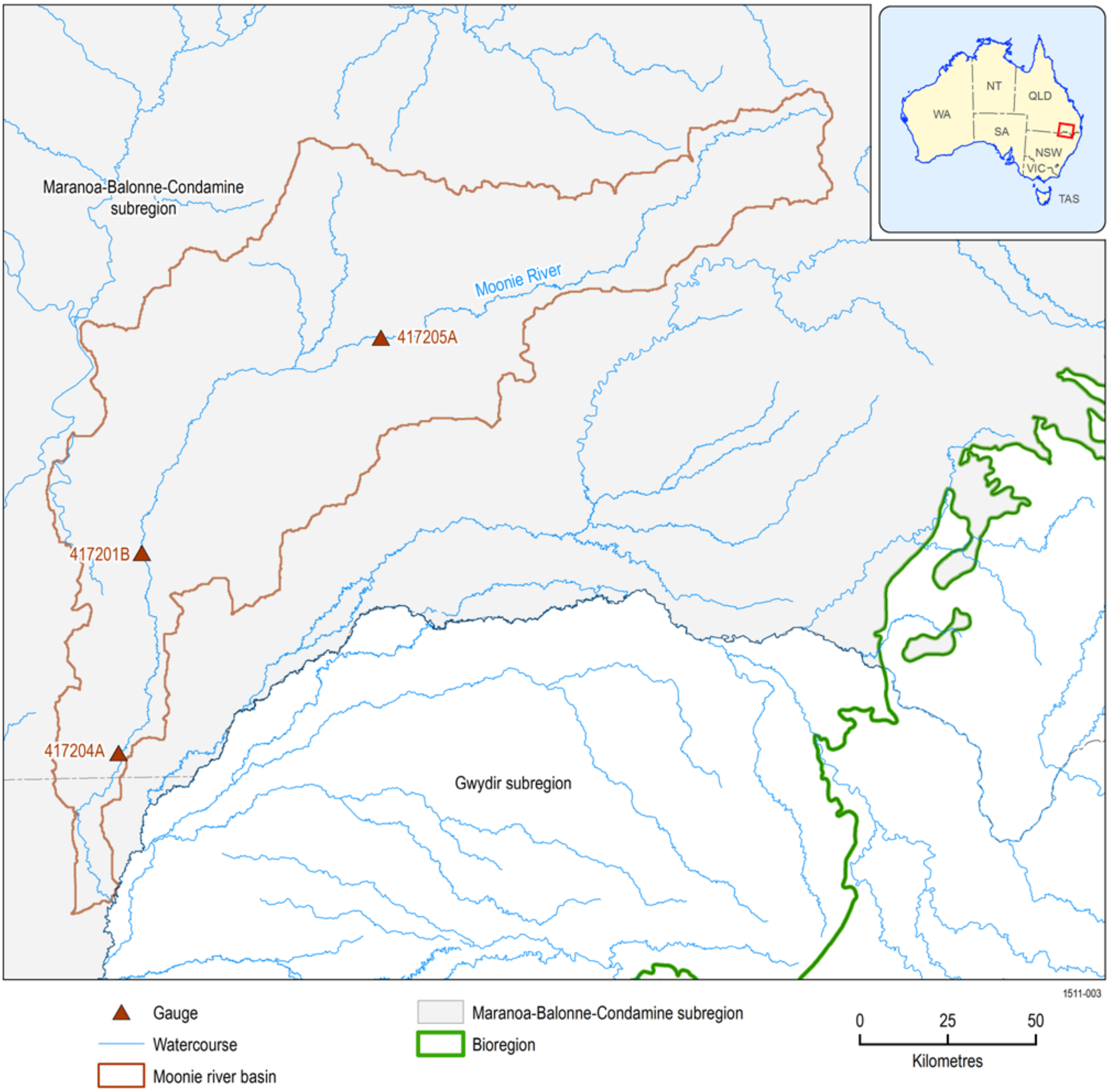

Figure 5 Tributaries of the Moonie river basin and streamflow stations

Data: Bureau of Meteorology (Dataset 2, Dataset 4)

1.5.1.1.3 Water accounts in the Border Rivers river basin

The Maranoa-Balonne-Condamine subregion contains the north-western part of the Border Rivers river basin as shown in Figure 6. The major surface water resources of the basin 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 is also 242 GL/year (CSIRO, 2007). One of the major tributaries of the Border Rivers river basin is the Macintyre River, which produces the maximum MAF of 961 GL at Goondiwindi (461201A) for the entire Border Rivers river basin. The Weir River is another major tributary of the Border Rivers river basin and produces MAF of between 72 GL at Gunn Bridge (416204A) and 252 GL at Mascot (416207A) (Welsh et al., 2014).

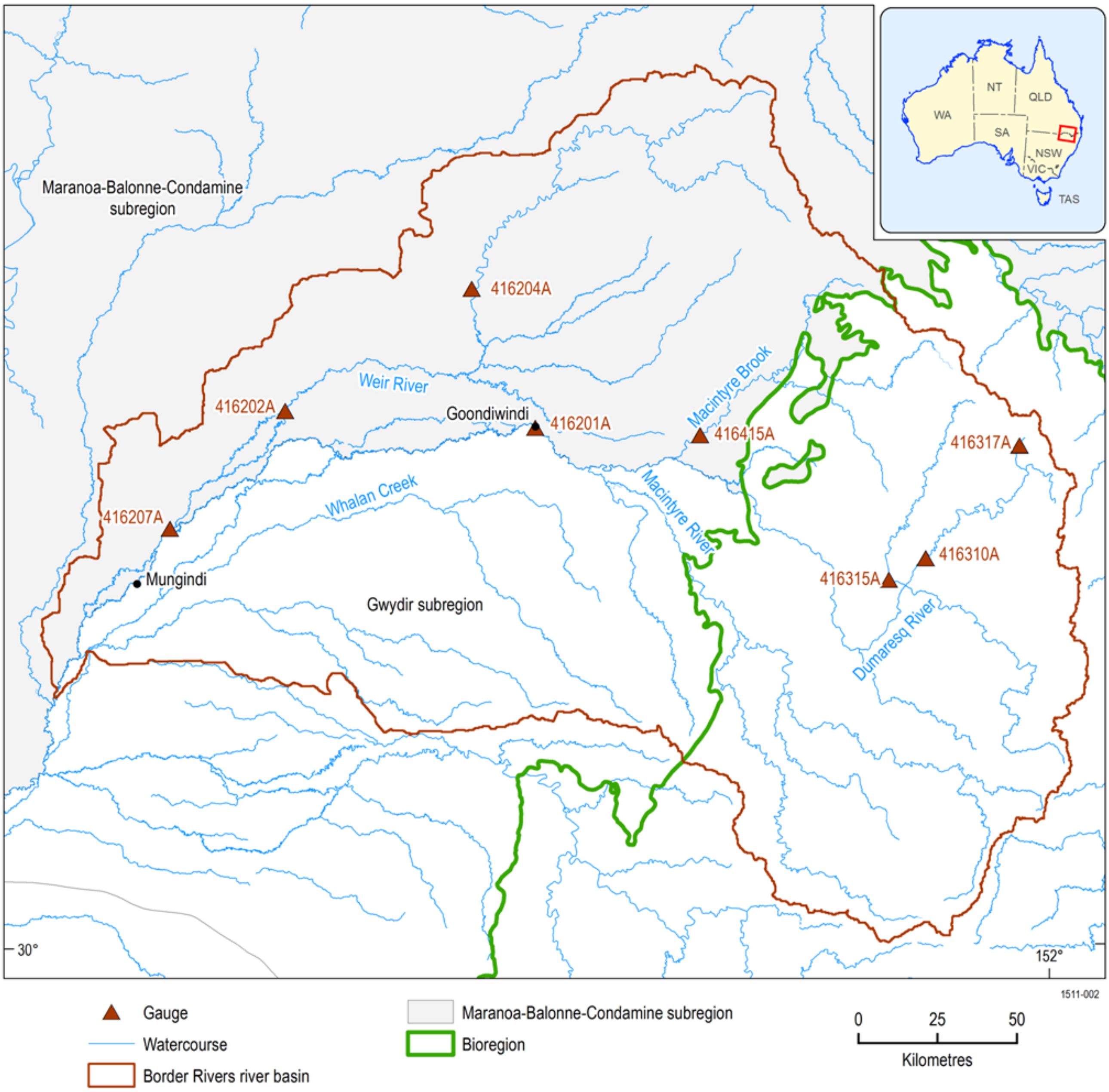

Figure 6 Tributaries of the Border Rivers river basin and streamflow stations

Data: Bureau of Meteorology (Dataset 2, Dataset 4)

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 (Welsh et al., 2014), comprising 78 GL/year (Welsh et al., 2014) in interceptions by runoff dams and 242 GL/year (Welsh et al., 2014) in watercourse diversions (MDBA, 2013b).

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). Coolmunda Dam on the Macintyre Brook is one of the major public water storage reservoirs in the river basin, with a storage capacity of 69 GL (Figure 3). 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).

1.5.1.1.4 Gaps

Currently, there is little information on how much surface water is actually used by the nominal entitlements in the Maranoa-Balonne-Condamine subregion.

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1.5.1.2 Groundwater

The groundwater accounts reported here pertain to the Surat cumulative management area (Surat CMA, Figure 7) as identified by the Office of Groundwater Impact Assessment (OGIA) of the Queensland Government. Surat CMA covers approximately 66% of the total area of the Maranoa-Balonne-Condamine subregion. Whilst the OGIA regional groundwater model covers a larger area of the Maranoa-Balonne-Condamine subregion, the water accounts provided in this section are consistent with the Surat Underground Water Impact Report (QWC, 2012). Groundwater modelling for the bioregional assessment of Maranoa-Balonne-Condamine subregion will be performed using the groundwater model built by OGIA targeting the Surat CMA. Hence, information on groundwater allocations and estimated use of groundwater as at the final quarter of 2012 is reported for the area demarcated by the Surat CMA rather than for the entire Maranoa-Balonne-Condamine subregion. This is determined from water accounts data supplied by OGIA (Dataset 1, Dataset 3) and Queensland Government (Dataset 4). Groundwater quality reported in Section 1.5.2.2 is for the entire Maranoa-Balonne-Condamine subregion, because water quality will not be modelled in this round of bioregional assessments.

1.5.1.2.1 Current water accounts

Requirements for water licences are triggered by the rules defined under water resource plans for groundwater management areas and sub-artesian areas in Queensland. A water licence is required if the:

- bore is artesian, regardless of purpose
- bore is sub-artesian and is located within a declared sub-artesian area or a groundwater management area
- sub-artesian bore is regulated by the Great Artesian Basin Water Resource Plan (GAB WRP).

The circumstances in which a water license becomes essential is explained in the subsequent sections.

For the bioregional assessment of the Maranoa-Balonne-Condamine subregion, stock, domestic and other commercial uses of water are accounted for as per the entitlements in the relevant water resource plans (WRPs) for the relevant management areas. Water use by the coal seam gas (CSG) industry is accounted for based on data supplied by CSG companies to OGIA. Groundwater accounts for the Surat CMA are broadly classified as water use for non-petroleum and non-CSG activities and water use for petroleum and CSG activities.

Groundwater account for non-petroleum and non-coal seam gas activities

Groundwater extracted for and used for purposes other than petroleum production (including CSG production) in the Surat CMA includes stock and domestic, agriculture, industrial and urban water use. Agricultural uses include irrigation, aquaculture, dairying, and intensive stock watering. Industrial uses include commercial and mining and water use by other industries. Urban water use is primarily for town water supplies. Groundwater licensing for non-petroleum and non-CSG uses is stipulated by Queensland's *Water Act 2000* and depends on the aquifer system and risk to resource. Water use from Great Artesian Basin (GAB) aquifers requires a water licence for all non-petroleum and non-CSG activities including stock and domestic use in most circumstances. For uses other than stock and domestic, licensed allocation stipulates an annual volumetric limit. Similarly, water use from the Condamine Alluvium aquifer is subject to water licensing with a volumetric limit for all non-stock and domestic uses. A statutory authorisation exists for stock and domestic use, meaning that a water licence is not required. While many bores with a volumetric limit are metered, most stock and domestic bores are not metered in the Surat CMA.

Licensing provisions required for water use are administered by the Queensland Department of Natural Resources and Mines (DNRM). DNRM holds the database containing information about water licences, authorised volumetric limits, details of bores and recorded water use.

Estimated water use for bores with a volumetric entitlement is the maximum authorised volume as per the water licence. However, actual water use may be less than this. OGIA estimated the water use for the stock and domestic bores by following the methodology used in the GAB water resource planning process and the Murray–Darling Basin planning process (QWC, 2012). A number of criteria were considered by this methodology in estimating the water use. These include considerations of the aquifer in which the bore is screened, property size, whether the property is rural or urban, and whether groundwater is the primary water source. Estimated annual non-petroleum and non-CSG groundwater usage per bore for the Surat CMA (Bioregional Assessment Programme, Dataset 2) is shown in Figure 7.

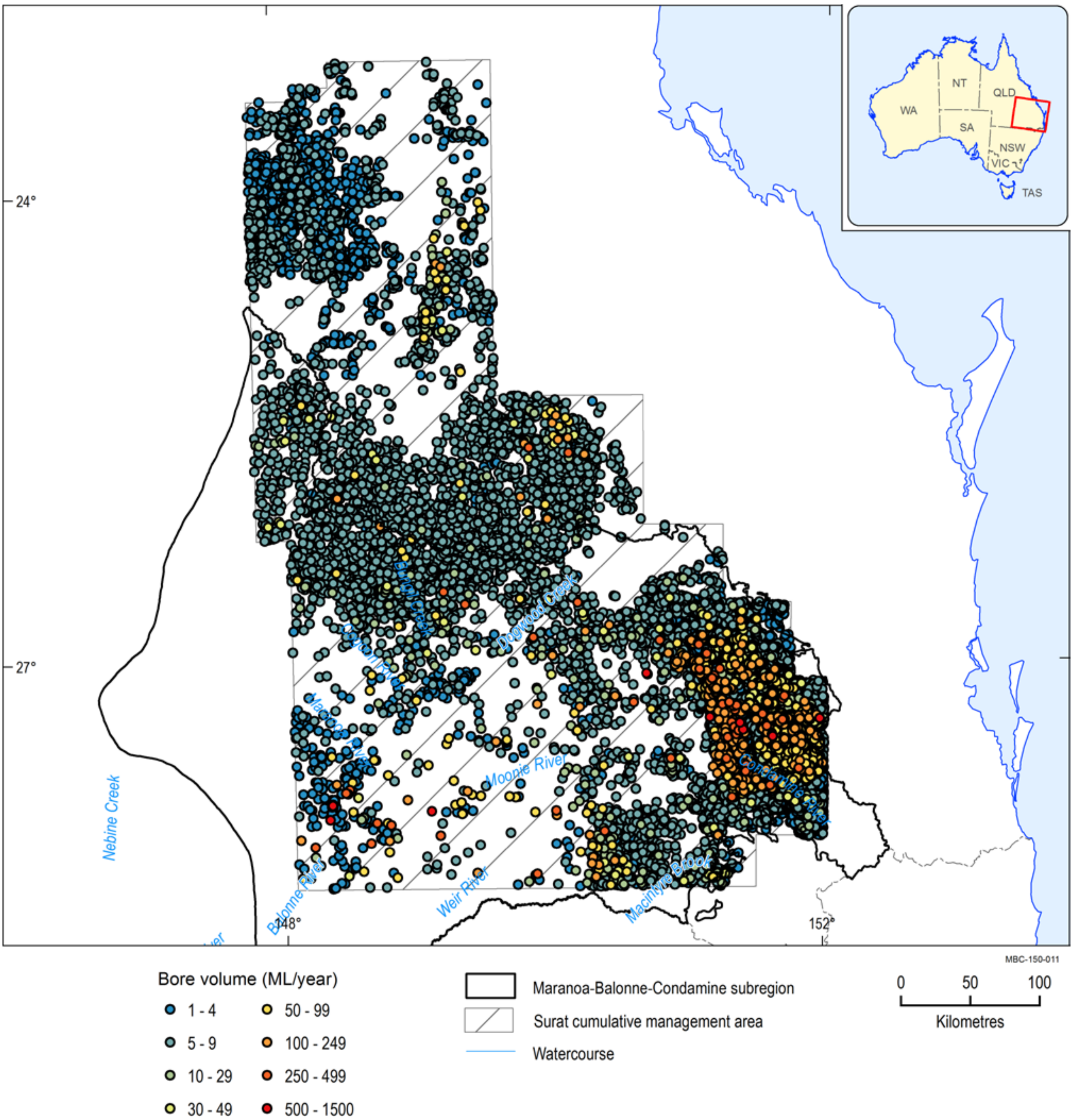

Figure 7 Estimated annual non-petroleum and non-coal seam gas groundwater usage per bore for the Surat cumulative management area

Data: Bioregional Assessment Programme (Dataset 2), Department of Environment and Heritage Protection (Dataset 5)
The estimated water use was based on the entitlement for majority of the bores. Where entitlement is not available (e.g. Volcanics), water use was estimated based on other criteria including aquifer type, property type etc. as mentioned earlier.

Based on this approach, OGIA estimated the total non-petroleum and non-CSG water extraction in the Surat CMA as 215 GL/year from about 21,200 water bores (QWC, 2012; Office of Groundwater Impact Assessment, Dataset 3). This is comprised of 85 GL/year from GAB aquifers and 130 GL/year from other aquifers. Table 3 gives estimates of the number of bores and Table 4 of their extraction rates in GAB and non-GAB aquifers.

Figure 8 shows the distribution of groundwater bores indicating the aquifer from which water is extracted.

Table 3 Number of bores for uses other than petroleum and gas production in Surat cumulative management area[a]

Aquifer	Non-stock and domestic	Stock and domestic	Total
Aquifers overlying Great Artesian Basin			
Condamine Alluvium aquifer	896	3,052	3,948
Other alluvial aquifers	42	715	757
Main Range Volcanics and Tertiary Volcanics aquifer	1,324	6,314	7,638
Rolling Downs Group	1	209	210
Subtotal	2,263	10,290	12,553
Great Artesian Basin			
Bungil Formation and Mooga Sandstone	31	1,068	1,099
Orallo Formation	3	57	60
Gubberamunda Sandstone aquifer	83	825	908
Westbourne Formation	na	3	3
Springbok Sandstone aquifer	10	213	223
Walloon Coal Measures	251	1,803	2,054
Eurombah Formation	na	18	18
Hutton and Marburg sandstone aquifer	358	2,470	2,828
Evergreen Formation	4	298	302
Precipice and Helidon sandstone aquifer	32	260	292
Moolayember Formation	na	86	86
Clematis Sandstone aquifer	na	195	195
Subtotal	772	7,296	8,068
Aquifers underlying Great Artesian Basin			
Rewan Group	na	37	37
Bandanna Formation	na	43	43
Undifferentiated Permian aquifers of the Bowen Basin	na	366	366
Fractured rock aquifers in the basement	2	123	125
Subtotal	2	569	571
Total	3,037	18,155	21,192

[a]This table is modified from QWC (2012).
na – not applicable

Table 4 Estimated groundwater extraction (ML/year) for uses other than petroleum production in Surat cumulative management area[a]

Aquifer	Agriculture	Industrial	Urban	Stock and domestic	Total (ML/year)
Aquifers overlying Great Artesian Basin					
Condamine Alluvium aquifer	41,450	550	4,400	8,600	55,000[b]
Other alluvial aquifers	5,928	51	na	2,294	8,273
Main Range Volcanics and Tertiary Volcanics aquifers	36,815	2,712	5,924	17,268	62,719
Rolling Downs Group	100	na	na	1,050	1,150
Subtotal	84,293	3,313	10,324	29,212	127,142
Great Artesian Basin					
Bungil Formation and Mooga Sandstone	417	1	239	8,418	9,075
Orallo Formation	30	na	na	300	330
Gubberamunda Sandstone aquifer	2,853	800	1,122	9,047	13,822
Westbourne Formation	na	na	na	15	15
Springbok Sandstone aquifer	220	na	351	1,143	1,714
Walloon Coal Measures	7,150	594	143	9,040	16,927
Eurombah Formation	na	na	na	381	381
Hutton and Marburg sandstone aquifer	8,804	3,698	3,049	12,710	28,261
Evergreen Formation	108	na	na	1,721	1,829
Precipice and Helidon sandstone aquifer	2,668	3,607	1,523	2,730	10,528
Moolayember Formation	na	na	na	433	433
Clematis Sandstone aquifer	na	na	na	2,123	2,123
Subtotal	22,250	8,700	6,427	48,061	85,438
Aquifers underlying Great Artesian Basin					
Rewan Group	na	na	na	185	185
Bandanna Formation	na	na	na	215	215
Undifferentiated Permian aquifers of the Bowen Basin	na	na	na	1,830	1,830
Fractured rock aquifers in the basement	16	20	na	529	565
Subtotal	16	20	0	2,759	2,795
Total	106,559	12,033	16,751	80,032	215,375

[a]This table is modified from QWC (2012).
[b]This is estimated annual use based on entitlements administered by DNRM. The total underlying entitlement is approximately 99 GL/year.
na – not applicable

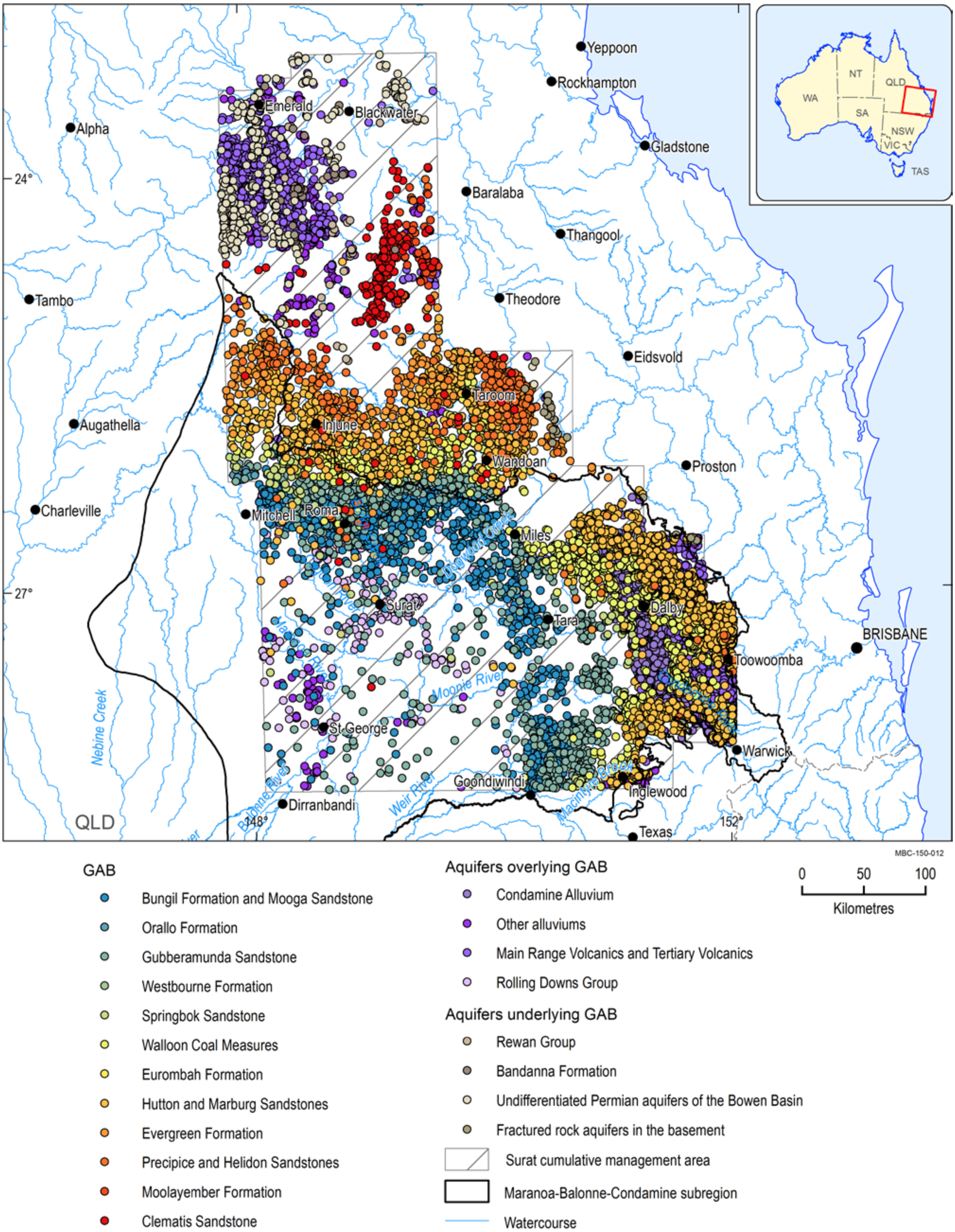

Figure 8 Groundwater bores identified by aquifer source in the Surat cumulative management area

Data: Bioregional Assessment Programme (Dataset 2), Department of Environment and Heritage Protection (Dataset 5)

Around 66% of the groundwater extraction from the aquifers overlying GAB is used for agriculture. The second major use of groundwater in the alluvial aquifers and Main Range Volcanics aquifers is for stock and domestic use accounting for about 28% of the total use. Stock and domestic use accounts for the major groundwater use of the GAB aquifers at around 56%, while the use for agriculture is around 26%. The distribution of the groundwater bores by purpose is shown in Figure 9.

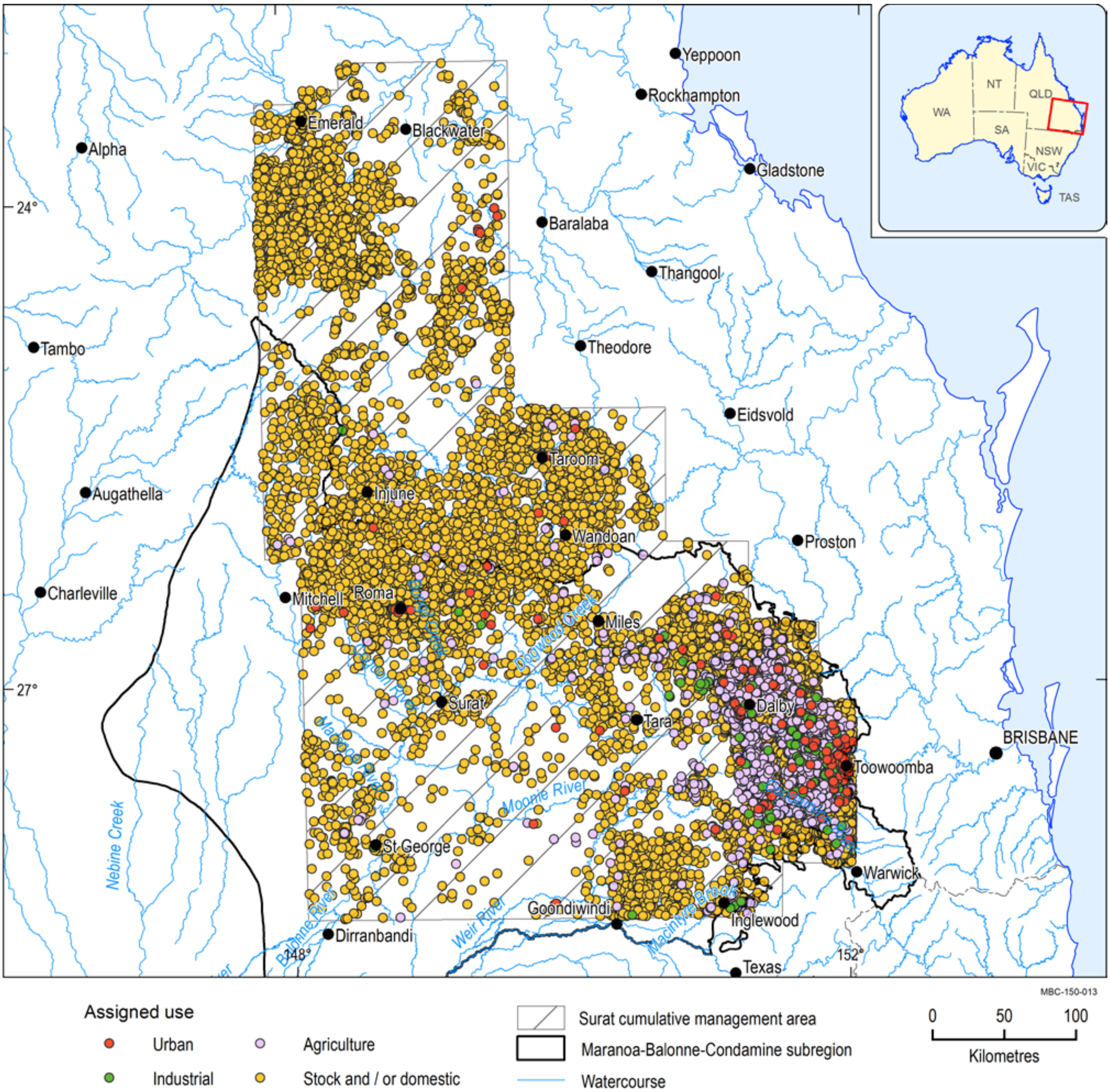

Figure 9 Distribution of bores indicating assigned purposes in the Maranoa-Balonne-Condamine subregion

Data: Bioregional Assessment Programme (Dataset 2), Department of Environment and Heritage Protection (Dataset 5)

Groundwater account for petroleum and coal seam gas activities

There are two kinds of petroleum and gas activities in the Surat CMA. These are (i) conventional hydrocarbon production and (ii) CSG production from coal formations. Both conventional petroleum and CSG operations produce water as a by-product of their operations to extract the hydrocarbons, but the amount of water produced in the case of CSG extraction is comparatively large. As of 2012, there were 154 conventional oil and gas wells extracting water from GAB formations (QWC, 2012). The amount of water extracted as part of conventional oil and gas production was estimated at 1.8 GL/year (QWC, 2012). The amount of water produced from individual production wells is generally very small, averaging less than 2.5 ML/year for most fields.

Large amounts of water are extracted from CSG production wells to depressurise coal seams. Groundwater extraction for CSG production in the Surat CMA commenced in 1995. The earliest operations focused on CSG development in the Bowen Basin at the Fairview Field operated by Santos. Groundwater extraction for CSG development commenced in the Surat Basin in 2002.

The volumes of water extracted by petroleum and gas tenure holders including CSG explorers are reported to DNRM. Based on this information, as of December 2013 there were 1534 CSG wells in the Surat CMA (Queensland Government, Dataset 4). Table 5 gives the account of CSG water production from the Surat CMA over the period 2005 to 2013. Clearly, there is an increasing trend in the number of wells over the years, however the half-yearly volume of water produced over the past 5 years was relatively consistent.

Table 5 Half-yearly account of coal seam gas water production from Surat cumulative management area from 2005 to 2013

Year	No. of wells	Volume of water (ML)
2005-I	279	2,008
2005-II	342	2,694
2006-I	319	3,707
2006-II	469	4,089
2007-I	534	5,402
2007-II	522	7,125
2008-I	725	6,330
2008-II	792	6,268
2009-I	984	7,929
2009-II	1,050	8,517
2010-I	1,048	8,482
2010-II	997	8,395
2011-I	1,008	7,032
2011-II	1,123	9,361
2012-I	1,127	8,595
2012-II	1,196	8,835
2013-I	1,230	7,892
2013-II	1,534	8,627
Total	na	121,288

Data: Queensland Government (Dataset 4)
na = not applicable

1.5.1.2.2 Water management

In Queensland, water sharing plans are called water resource plans (WRP). These are subordinate legislation under Queensland's *Water Act 2000*. Surface water catchments define the areal extent of the WRPs except for the Great Artesian Basin (GAB) WRP. The GAB WRP manages the GAB water resources by formation. A number of WRPs partially or fully overlap the Maranoa-Balonne-Condamine subregion: the Border Rivers, Burnett Basin, Condamine-Balonne, Moonie, Moreton and Warrego-Paroo-Bulloo-Nebine catchments and the GAB plan areas.

Groundwater extraction from the alluvial aquifers in the NSW part of the Maranoa-Balonne-Condamine subregion is governed by the NSW Border Rivers Unregulated and Alluvial, NSW Murray-Darling Basin Fractured Rock Groundwater, NSW Great Artesian Basin Groundwater and NSW Great Artesian Basin Shallow Groundwater water sharing plans. The NSW Great Artesian Basin Groundwater and NSW Great Artesian Basin Shallow Groundwater water sharing plan areas are identical, but relate to shallow (<60 m deep) and deep (>60 m deep) GAB groundwater sources. Relevant water resource plans (Queensland Government, Dataset 6) and water sharing plans (NSW Office of Water, Dataset 7) for the Maranoa-Balonne-Condamine subregion are listed in Table 6 and shown in Figure 10.

Table 6 Water resource and water sharing plans relevant for the Maranoa-Balonne-Condamine subregion

Groundwater system	Plan	Date commenced
Alluvial aquifers, fractured rock aquifers, undifferentiated sedimentary aquifers overlying the Great Artesian Basin	Border Rivers WRP	1 Jul 2004
Alluvial aquifers, coastal dune sand aquifers, basalt aquifers	Burnett Basin WRP	22 Aug 2014
Alluvial aquifers, fractured rock aquifers	Condamine and Balonne WRP	1 Feb 2005
Great Artesian Basin aquifers	Great Artesian Basin WRP	1 Mar 2006
Alluvial aquifers, undifferentiated sedimentary aquifers overlying the Great Artesian Basin	Moonie WRP	1 Jul 2004
Alluvial aquifers, hard rock aquifers	Moreton WRP	Mar 2007
Alluvial aquifers	NSW Border Rivers WSP	1 Jun 2012
Great Artesian Basin aquifers at a depth of more than 60 m below ground level within the Surat Groundwater Source	NSW Great Artesian Basin Groundwater	1 Jul 2008
Alluvial aquifers, shallow Great Artesian Basin aquifers to a depth of 60 m below the surface of the ground	NSW Great Artesian Basin Shallow Groundwater	14 Nov 2011
Alluvial aquifers, fractured rock aquifers	NSW Murray-Darling Basin Fractured Rock Groundwater – Lachlan Fold Belt MDB WSP	16 Jan 2012
Alluvial aquifers, undifferentiated sedimentary aquifers overlying the Great Artesian Basin	Warrego, Paroo, Bulloo and Nebine WRP	1 Jul 2004

WRP = water resource plans, WSP = water sharing plans

Further information on the WRPs and WSPs is available in Section 1.1.4.4 in the companion product 1.1 for the Maranoa-Balonne-Condamine subregion (Welsh et al., 2014).

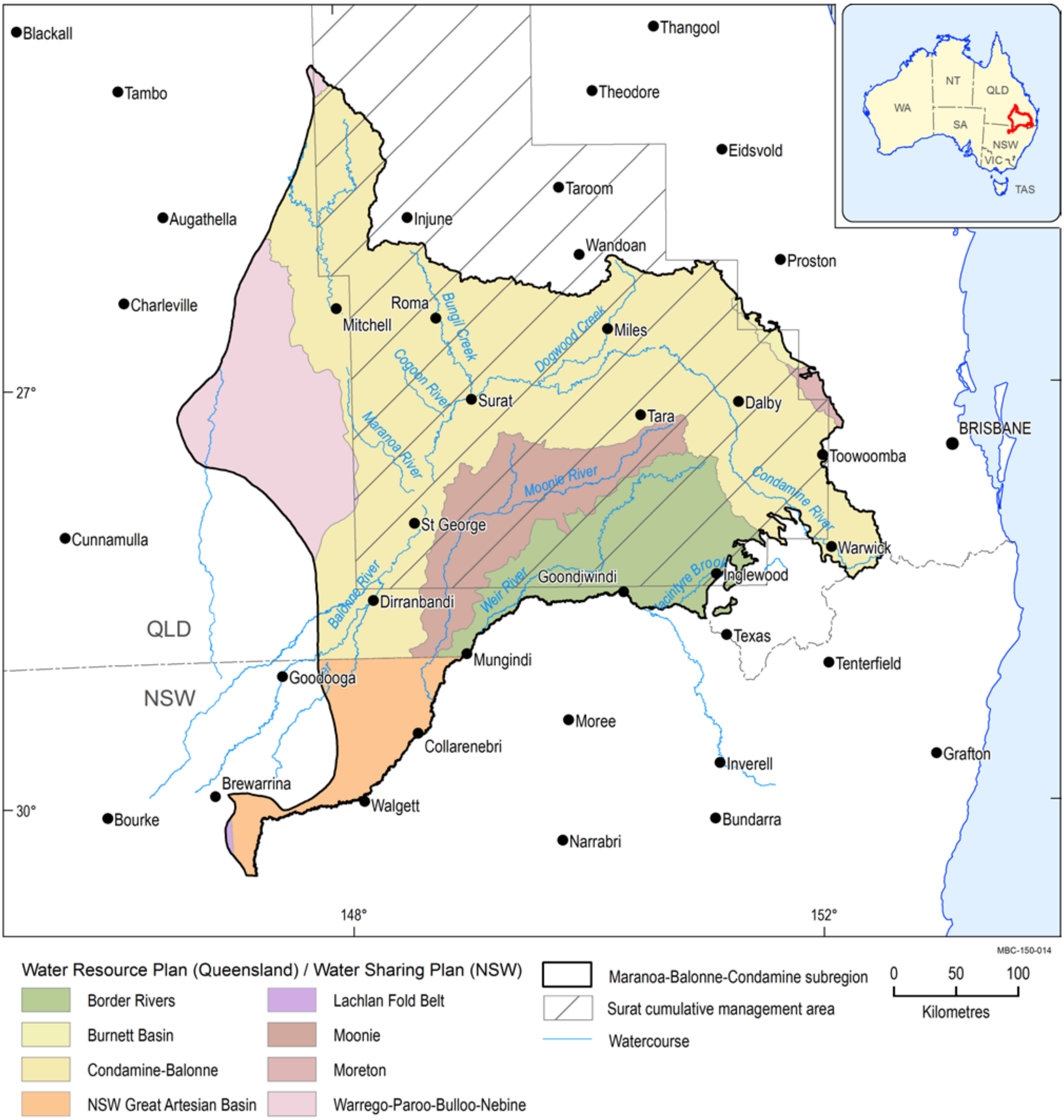

Figure 10 Distribution of water resource and water sharing plan areas across the Maranoa-Balonne-Condamine subregion. The Great Artesian Basin water resource plan area includes all of the Maranoa-Balonne-Condamine subregion in Queensland

Data: Department of Environment and Heritage Protection (Dataset 5), Queensland Government (Dataset 6), NSW Office of Water (Dataset 7)

In addition, the groundwater systems within the subregion are represented in the Basin Plan for the Murray–Darling Basin as sustainable diversion limits (SDLs). This includes all or part of the Condamine-Balonne, Moonie, New South Wales Border Rivers alluvium, Queensland Border Rivers, and Warrego-Paroo-Nebine groundwater water resource plan areas. The Basin Plan prescribes current limits on extraction based on existing planning regimes as baseline diversion limits (BDL) and the future extraction limits as SDLs. BDLs and SDLs of the groundwater systems are described in Section 1.1.4.4 of the companion product 1.1 for the Maranoa-Balonne-Condamine subregion (Welsh et al., 2014).

1.5.1.2.3 Gaps

Information on stratigraphy and screened intervals were only partially available for estimating groundwater use per aquifer. This information is very important for estimating the impacts as the stresses in different aquifers can have different impacts and hence knowing the aquifers that are actually stressed by the groundwater extraction is important to accurately predict the impacts.

Where actual groundwater use was not recorded, licensed volume was used in estimating groundwater use. Better estimates could be obtained if actual usage data become available.

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1.5.2 Water quality

Summary

Surface water quality was assessed in three river basins in the Maranoa-Balonne-Condamine subregion: the Condamine-Balonne, the Moonie and the portion of the Border Rivers river basin. In the upper Condamine river basin, stream nutrients are generally within water quality guidelines (Welsh et al., 2014), whereas the electrical conductivity (EC) ranges from 100 to 800 µS/cm, which is greater than levels found in some other Queensland rivers. In the Moonie river basin, two water quality sampling sites show high total nitrogen, but no trends for EC or turbidity are detected. In the Border Rivers river basin, there are insufficient data to assess the water quality for nutrients, turbidity and EC in most areas.

Groundwater quality in nine aquifers of the Maranoa-Balonne-Condamine subregion was compared to national guidelines for drinking water, stock use and irrigation, provided by the National Health and Medical Research Council (2011), and the Australian and New Zealand Environmental and Conservation Council (2000). Summary statistics and spatial distribution maps for Total Dissolved Solids (TDS), pH and alkalinity, are described for the following aquifers: Condamine Alluvium aquifer, Main Range Volcanics aquifer, Rolling Downs Group aquifer, Hooray Sandstone and equivalents aquifer, Adori / Springbok aquifer, Walloon aquifer, Hutton Sandstone aquifer, Evergreen (Boxvale) aquifer and Precipice aquifer.

Mean TDS ranges from 539 mg/L, for the Evergreen (Boxvale) aquifer, to 2777 mg/L for the Rolling Downs Group aquifers. The lowest median pH was 7.8 (Evergreen (Boxvale) aquifer) and the highest was 8.3 (Hooray Sandstone and equivalents and Precipice Sandstone aquifer). Mean alkalinity was lowest in the Evergreen (Boxvale) aquifer (234 mg/L) and highest in the Walloon aquifer (538 mg/L). Hydrochemical data availability was variable between hydrogeological units and not all analyses contain a full suite of hydrochemical parameters.

1.5.2.1 Surface water

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, 2012). 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, 2012). The water quality in the three river basins are described in the following sections.

1.5.2.1.1 Water quality in the Condamine-Balonne river basin

Water quality data were collected in the Condamine-Balonne river basin (Figure 4) 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 generally within the guidelines at the nutrient monitoring sites as described in DERM (2011). In addition, an ambient surface water quality summary report by the Department of Environment and Resource Management only reports the direction of water quality trends (mostly improving trends) due to data limitations in most Queensland river basins. They note that reporting on magnitude would not be sufficiently reliable or meaningful (DERM, 2011).

The 20 stations with EC data in the Condamine-Balonne river basin are shown in Table 7. Two examples of EC data in the Condamine-Balonne river basin are shown in Figure 11 and Figure 12 for the period from 1995 to 2015. The data gap shows when data were not collected. This was primarily due to no flow conditions and sometimes due to monitoring equipment failure. EC measured at the Condamine River at Chinchilla (422308C) station ranged from 77 to 1094 µS/cm with a mean of 447 µS/cm. The highest EC values occurred during low flows, which is more saline than in many other rivers in Queensland. EC measured near the outlet of the Condamine-Balonne river basin at the Culgoa River at Whyenbah (422204A) varies between 53 and 584 µS/cm with a mean of 187 µS/cm.

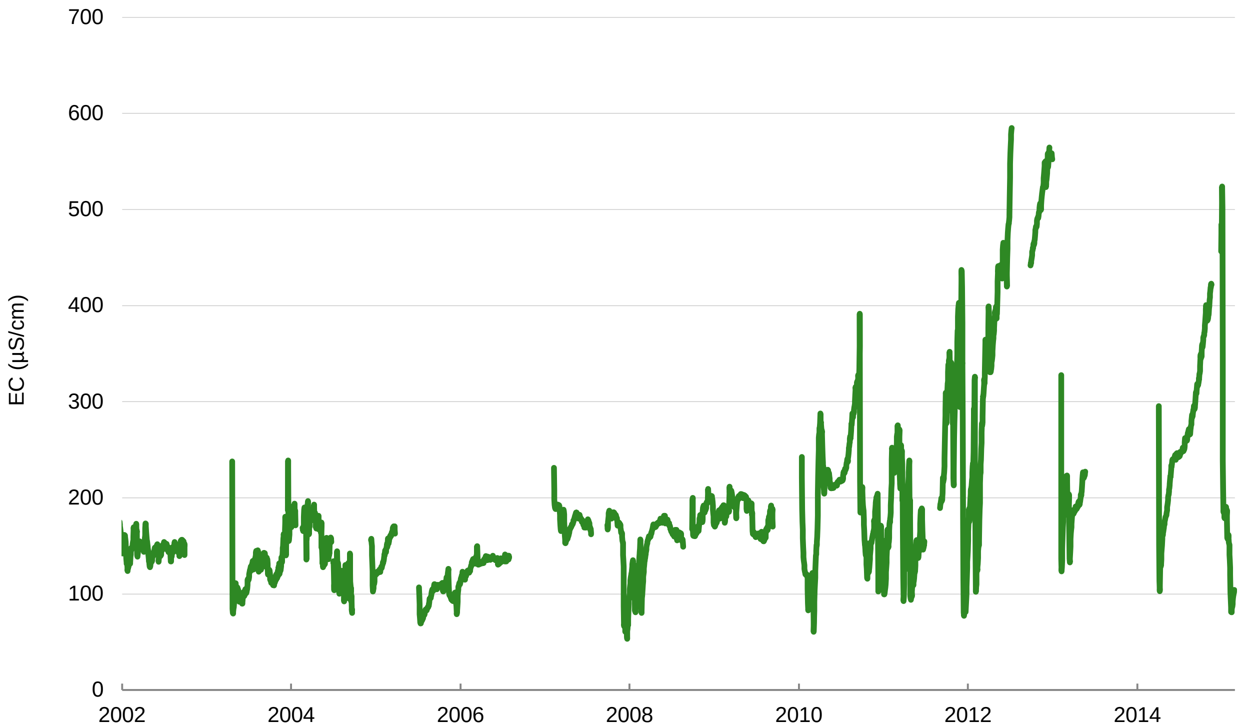

Figure 11 Observed electrical conductivity at gauging station 422204A, Culgoa River at Whyenbah

Data: Queensland Department of Natural Resources and Mines (Dataset 1)

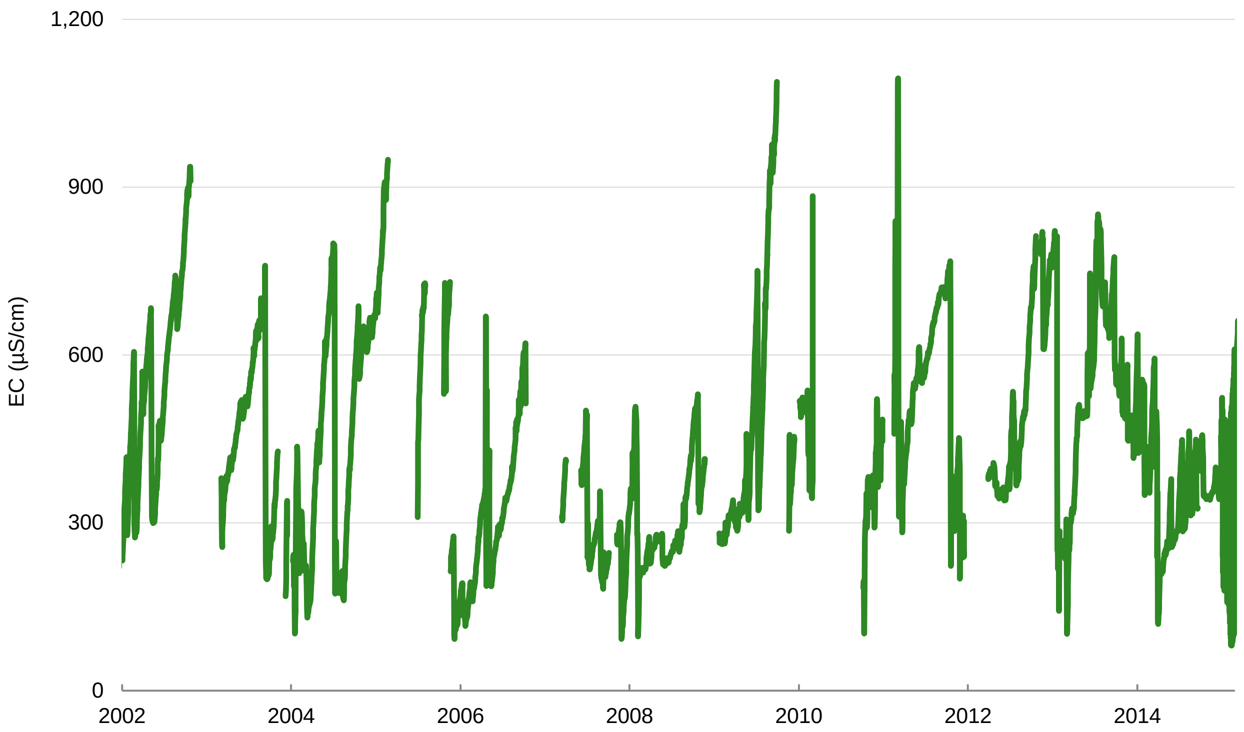

Figure 12 Observed electrical conductivity at gauging station 422308C, Condamine River at Chinchilla Weir

Data: Queensland Department of Natural Resources and Mines (Dataset 1)

Table 7 Gauging stations and monitoring period for electrical conductivity in the Condamine-Balonne river basin

Station number	Station name and location	Catchment area (km^2)	Start date	End date
422204A	Culgoa River at Whyenbah	79,330	02 Mar 1995	24 Feb 2015
422207A	Ballandool River at Hebel Bollon Road	80,185	15 May 2002	04 Mar 2015
422209A	Bokhara River at Hebel	80,030	16 May 2002	13 May 2015
422211A	Briarie Creek at Woolerbilla-Hebel Road	410	15 May 2002	24 Feb 2015
422306A	Swan Creek at Swanfels	83	10 Feb 1993	13 May 2015
422308C	Condamine River at Chinchilla Weir	19,190	25 Jul 1995	13 May 2015
422310C	Condamine River at Warwick	1,360	12 Feb 1993	21 Jan 2015
422313B	Emu Creek at Emu Vale	148	10 Feb 1993	13 May 2015
422316A	Condamine River at Cecil Weir	7,795	17 Feb 1993	29 Sep 2014
422319B	Dalrymple Creek at Allora	246	09 Feb 1993	20 Jan 2015
422323A	Condamine River at Tummaville	6,475	25 Feb 1993	30 Sep 2014
422326A	Gowrie Creek at Cranley	47	03 Mar 1993	31 Jul 2014
422332B	Gowrie Creek at Oakey	142	06 Jan 1994	26 Feb 2015
422333A	Condamine River at Loudouns Bridge	12,380	11 Feb 1993	25 Sep 2014
422334A	Kings Creek at Aides Bridge	516	17 Feb 1993	01 Oct 2014
422338A	Canal Creek at Leyburn	395	17 Feb 1993	14 Nov 2014
422345A	North Condamine River at Lone Pine	710	27 Apr 1993	29 Sep 2014
422350A	Oakey Creek at Fairview	1,970	11 Feb 1993	25 Feb 2015
422352A	Hodgson Creek at Balgownie	560	09 Feb 1993	01 Oct 2014
422394A	Condamine River at Elbow Valley	325	10 Feb 1993	09 Feb 2015

Data: Queensland Government (2015)

1.5.2.1.2 Water quality in the Moonie river basin

The two stations in the Moonie River at Nindigully (417201B) and at Fenton (417204A) as shown in Figure 5 have high concentrations of total nitrogen, which requires management action (DERM, 2011). EC data was only available from the station at the Moonie River at Fenton (417204A) for the period from 2003 to 2015, as shown in Table 8 and Figure 13. The data gap shows when data were not collected. This was primarily due to no flow conditions and sometimes due to monitoring equipment failure. EC measured at the Moonie River at Fenton (417204A) station ranged from 6 to 395 µS/cm with a mean of 143 µS/cm.

Table 8 Gauging stations and monitoring period for electrical conductivity in the Moonie river basin

Station number	Station name and location	Catchment area (km^2)	Start date	End date
417201B	Moonie River at Nindigully	12,030	NA	NA
417204A	Moonie River at Fenton	14,050	13 Jan 2003	23 Feb 2015

Data: Queensland Government (2015)
NA means data not available

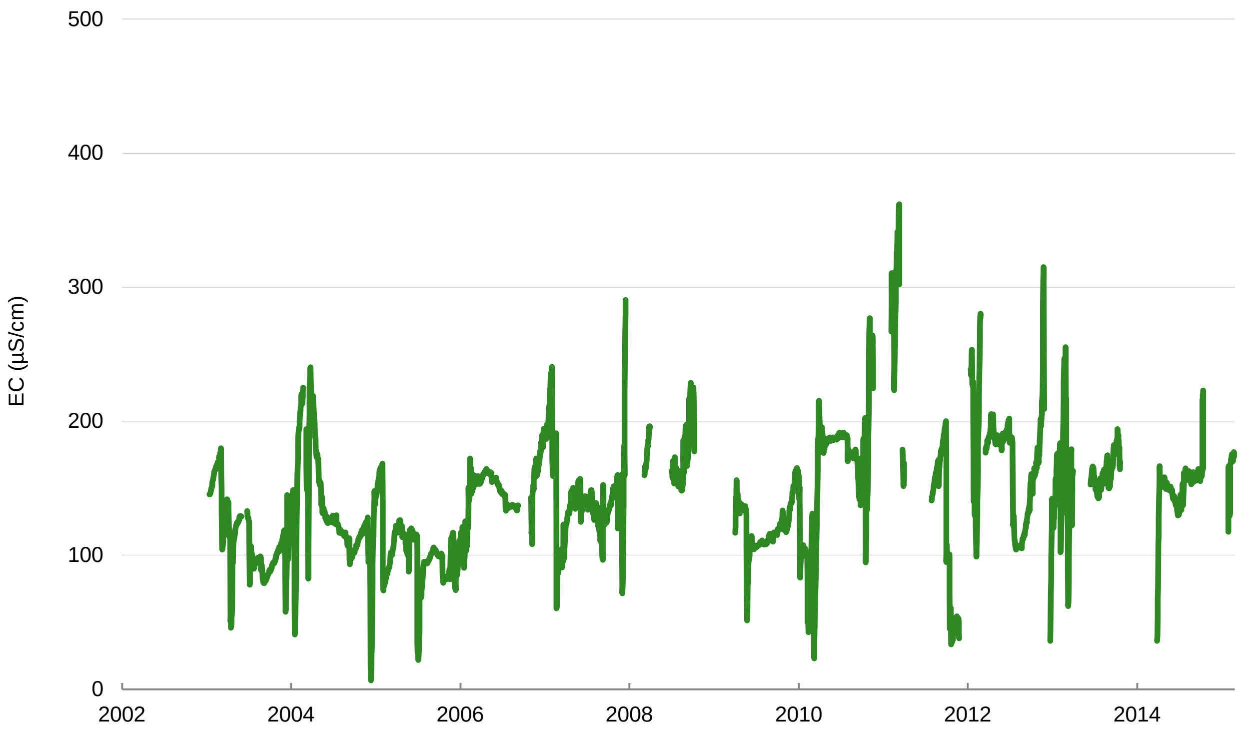

Figure 13 Observed electrical conductivity at gauging station 417204A, Moonie River at Fenton

Data: Queensland Department of Natural Resources and Mines (Dataset 1)

1.5.2.1.3 Water quality in the Border Rivers river basin

Sites in the Border Rivers river basin (Figure 6) in Queensland are monitored on a monthly basis by the NSW Office of Water on behalf of the Dumaresq Barwon Border Rivers Commission for EC, nutrients, turbidity, total suspended solids and water temperature. Summary statistics are reported for EC, total phosphorus, total nitrogen and turbidity (DBBRC, 2012a). Median salinity in the Border Rivers river basin is below the low salinity guidelines (300 µS/cm) for irrigation water (DBBRC, 2012b). However, Macintyre Brook had salinity levels above the guidelines (350 µS/cm) 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 (DBBRC, 2012b).

Four stations in the Border Rivers river basin had EC data (Table 9). Figure 14 shows an example of auto-sensor EC data in the Border Rivers river basin (station 416202A, Weir River at Talwood) for the period from 2002 to 2015. The data gap shows when data were not collected, especially between 2006 and 2008. This was primarily due to no flow conditions and sometimes due to monitoring equipment failure. EC measured at the Weir River at Talwood (416202A) station ranged from 29 to 471 µS/cm with a mean of 171 µS/cm. 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, whereas data for nitrogen, phosphorus and turbidity are insufficient for meaningful assessment (DERM, 2011).

Table 9 Gauging stations and monitoring period for electrical conductivity in the Border Rivers river basin

Station number	Station name and location	Catchment area (km^2)	Start date	End date
416202A	Weir River at Talwood	12,070	29 Aug 2002	26 Feb 2015
416310A	Dumaresq River at Farnbro	1,310	12 Mar 2002	03 Mar 2015
416317A	Broadwater Creek at Barkers	108	21 Mar 1994	18 Feb 2015
416415A	Macintyre Brook at Booba Sands	4,092	30 May 2002	13 Nov 2014

Data: Queensland Government (2015)

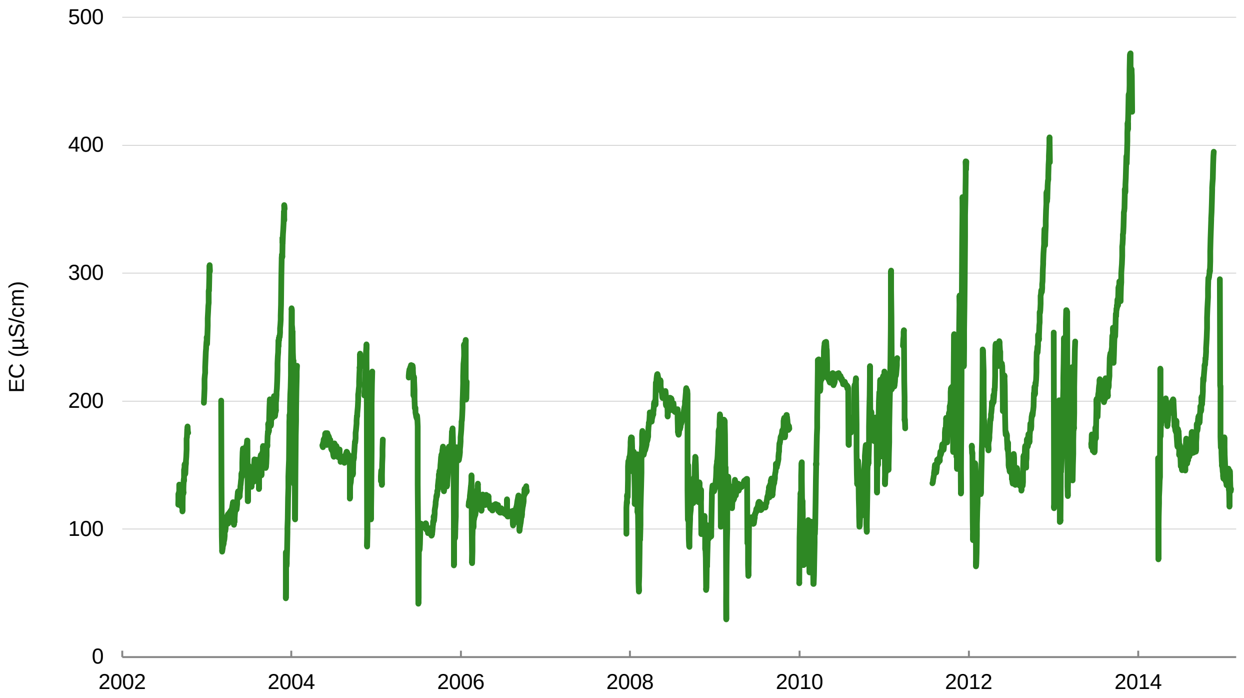

Figure 14 Observed electrical conductivity at the gauging station 416202A, Weir River at Talwood

Data: Queensland Department of Natural Resources and Mines (Dataset 1)

1.5.2.1.4 Gaps

There is a lack of long-term consistent water quality data measurements including EC at 25 °C, water temperature, turbidity, and nutrients within the Maranoa-Balonne-Condamine subregion, especially for the Moonie River and Border Rivers. As a result, the capacity to fully understand the baseline water quality for this area is limited.

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Queensland Government (2015) Water monitoring data portal. Queensland Government. Viewed 13 May 2015, http://watermonitoring.dnrm.qld.gov.au/host.htm.

Welsh W, Herron N, Rohead-O'Brien H, Ransley T, Aryal S, Mitchell P, Buckerfield S and Marshall S (2014) Context statement for the Maranoa-Balonne-Condamine subregion. Product 1.1 for the Maranoa-Balonne-Condamine from the Northern Inland Catchments Bioregional Assessment. Department of the Environment, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia. Viewed 1 March 2015, http://data.bioregionalassessments.gov.au/product/NIC/MBC/1.1.

Datasets

Dataset 1 Queensland Department of Natural Resources and Mines (2015) Maranoa-Balonne-Condamine surfacewater EC sites. Bioregional Assessment Source Dataset. Viewed 20 July 2015, http://data.bioregionalassessments.gov.au/dataset/4e7f862a-573c-440d-9974-7b83afc50db9.

1.5.2.2 Groundwater

This section provides a baseline assessment of groundwater quality within the major aquifers of the Maranoa-Balonne-Condamine subregion (Table 10). The groundwater quality for the whole subregion is presented here as water quality is not being modelled as part of the Bioregional Assessment Programme. Hydrochemistry summary statistics and spatial variation maps are provided for the major aquifers. To assess potential hazards associated with using groundwater in the subregion, a comparison of relevant parameters against guidelines for human consumption is provided. In addition, stock watering and water for long-term irrigation (defined as up to 100 years) was also considered.

Trigger values (Table 11) were taken from the Australian Drinking Water Guidelines (ADWG) (National Health and Medical Research Council, 2011) and the National Water Quality Management Strategy (NWQMS) (ANZECC, 2000).

1.5.2.2.1 Data sources and analysis

Hydrochemistry data (Geoscience Australia, Dataset 1) were sourced from the Geoscience Australia (2014) GA NCF Hydrochemistry - Surat Region. This dataset includes data for the Condamine Alluvium and Main Range Volcanics derived from the Office of Groundwater Impact Assessment (OGIA, 2013). The dataset identifies the particular geological unit from which the water sample was obtained. This information has been used as a basis for grouping the data into the hydrostratigraphic units that represent the major water-bearing units in the subregion (Table 10). It should be noted individual units that are hydrogeologically equivalent to each other have been grouped and assigned an aquifer name based on the primary contributing geological unit. Aquifers containing multiple units are referred to in Table 10 as the Rolling Downs Group aquifers, the Hooray Sandstone and equivalents aquifer and the Hutton Sandstone aquifer. Only those formations for which water quality data was available have been included in this analysis.

The Hooray Sandstone and equivalents aquifer group comprises the Bungil Formation aquifer, Mooga Sandstone aquifer, the Gubberamunda Sandstone aquifer, Kumbarilla Beds aquifer, Pilliga Sandstone aquifer and the Hooray Sandstone aquifer. This composite sequence of aquifers forms part of the major artesian aquifer of the GAB referred to as the Cadna-owie – Hooray aquifer and equivalents (Radke et al., 2000).

Table 10 Aquifer grouping for water quality reporting

Aquifer	Included units
Condamine Alluvium aquifer	Condamine Alluvium
Main Range Volcanics aquifers	Main Range Volcanics
Rolling Downs Group aquifers	Coreena Member, Doncaster Member, Griman Creek Formation, Surat Siltstone, Wallumbilla Formation, Mackunda Formation
Hooray Sandstone and equivalents aquifer	Hooray Sandstone, Wyandra Sandstone, Cadna-owie Formation, Gubberamunda Sandstone, Kumabrilla Beds, Bungil Formation, Mooga Sandstone, Pilliga Sandstone
Adori / Springbok aquifer	Adori Sandstone, Springbok Sandstone
Walloon aquifers	Walloon Coal Measures

Aquifer	Included units
Hutton Sandstone aquifer	Hutton Sandstone, Marburg Sandstone
Evergreen (Boxvale) aquifer	Evergreen Formation[a], Boxvale Sandstone
Precipice Sandstone aquifer	Precipice Sandstone

[a]The Evergreen Formation is recognised as a regional aquitard. Some analyses have the Evergreen Formation assigned as the contributing water-bearing formation. It is likely that the Boxvale Sandstone Member, which is an aquifer within the Evergreen Formation, is the contributing formation (Ransley and Smerdon, 2012).

Table 11 Water quality standards for trace elements

Parameter	ADWG[a] trigger (mg/L)	Irrigation trigger[b] (mg/L)	Stock trigger[c] (mg/L)
Electrical conductivity (EC)[d]	1,500	8,000	20,000
Silver (Ag)	0.00002	NA	NA
Aluminium (Al)	0.2[e]	5.00	5.00
Arsenic (As)	0.001	0.10	0.00
Boron (B)	4.00	0.50	5.00
Cadmium (Cd)	0.002	0.01	0.01
Cobalt (Co)	NA	0.05	1.00
Chromium (Cr)	0.05	1.00	1.00
Copper (Cu)	2.00	1.00	1.00
Fluorine (F)	1.50	1.00	2.00
Iron (Fe)	0.3[e]	0.20	NA
Mercury (Hg)	0.001	0.00	0.00
Manganese (Mn)	0.1[e]	0.20	NA
Molybdenum (Mo)	0.05	0.01	NA
Nickel (Ni)	0.02	0.20	1.00
Nitrate (NO_3)	50	NA	NA
Lead (Pb)	0.01	2.00	0.10
Selenium (Se)	0.01	0.02	0.02
Uranium (U)[f]	0.02	0.01	20.00
Vanadium (V)	NA	0.50	NA
Zinc (Zn)	3.00[e]	2.00	2.00

[a]Table 10.5 in Australian Drinking Water Guidelines NHMRC (2011)
[b]Table 4.2.10 in National Water Quality Management Strategy ANZECC (2000)
[c]Table 4.3.2 in National Water Quality Management Strategy ANZECC (2000)
[d]Electrical Conductivity is measured in µS/cm
[e]Aesthetic water quality trigger (not health related)
[f]Uranium is measured in parts per billion
NA means ‘not applicable’ because there is no relevant standard
Data: Geoscience Australia (Dataset 1)

1.5.2.2.2 Total dissolved solids, pH and alkalinity

A total of 4317 groundwater analyses were used to calculate aquifer mean and median values for total dissolved solids (TDS) (Table 12), 4939 analyses for mean and median alkalinity (Table 12) and 4842 analyses for median values for laboratory pH (Table 13). The maximum and minimum pH values are also provided to show the range of these values for each aquifer. The values can be compared to the water quality guidelines for human consumption, irrigation and stock watering in Table 14.

Table 12 Mean and median total dissolved solids and alkalinity for aquifers of the Maranoa-Balonne-Condamine subregion

Aquifer	Mean total dissolved solids (mg/L)	Median total dissolved solids (mg/L)	Number of samples	Mean alkalinity (mg/L)	Median alkalinity (mg/L)	Number of samples
Condamine Alluvium aquifer	1391	830	1137	408	390	1137
Main Range Volcanics aquifers	762	651	980	357	345	980
Rolling Downs Group aquifers	2777	1141	56	415	416	70
Hooray Sandstone and equivalents aquifer	1248	962	1635	529	524	2010
Adori / Springbok aquifer	1336	803	41	365	365	55
Walloon aquifers	2580	2078	191	538	538	374
Hutton Sandstone aquifer	1402	978	140	400	515	169
Evergreen (Boxvale) Formation aquifer	539	221	79	234	132	85
Precipice Sandstone aquifer	1281	1940	58	904	878	59

Data: Geoscience Australia (Dataset 1)

Table 13 Median, minimum and maximum laboratory pH[a] for the aquifers in the Maranoa-Balonne-Condamine subregion

Aquifer	Median pH	Minimum pH	Maximum pH	Number of samples
Condamine Alluvium aquifer	8.1	5.6	9.6	1137
Main Range Volcanics aquifers	8.0	5.4	10.0	980
Rolling Downs Group aquifers	8.1	6.2	9.0	63
Hooray Sandstone and equivalents	8.3	3.2	12.6[b]	1940
Adori / Springbok aquifer	8.1	6.4	8.9	54
Walloon aquifers	8.1	3.8	11.4[b]	363
Hutton Sandstone aquifer	8.2	6.4	9.7	164
Evergreen (Boxvale) aquifer	7.8	5.9	8.7	82
Precipice Sandstone aquifer	8.3	6.4	9.1	59

[a]These values are for laboratory pH. There are a limited number of samples with field pH recorded at the time when other field measurements were recorded (e.g. electrical conductivity, dissolved oxygen, redox) and when samples were prepared for laboratory analysis (e.g. cations and anions, stable isotopes). Groundwater pH may change during transport to the laboratory due to exchange with the atmosphere, which means that laboratory pH may not be representative of actual pH at the time of sampling. Therefore, laboratory pH is not an appropriate approximation in the absence of field pH when undertaking more in-depth hydrochemical analysis.
[b]These maximum pH values are abnormally high but have been left in to show the range of values in the data. It is rare for groundwater to have such high pH values.
Data: Geoscience Australia (Dataset 1)

Table 14 Water quality standards for total dissolved solids, alkalinity and pH

Parameter	ADWG[a] guidelines for human consumption (mg/L)	Irrigation guidelines[b] (mg/L)	Stock guidelines[c] (mg/L)
Total dissolved solids	<600[d]	NA	<4000
Alkalinity	NA	NA	NA
pH	6.5-8.5[d]	4-9	4-9

[a]Table 10.5 in Australian Drinking Water Guidelines NHMRC (2011)
[b]Section 4.2 in National Water Quality Management Strategy ANZECC (2000)
[c]Section 4.3 in National Water Quality Management Strategy ANZECC (2000)
[d]Aesthetic water quality trigger (not health related)
NA means ‘not applicable’ because there is no relevant standard

1.5.2.2.3 Total dissolved solids, pH and alkalinity distribution

Spatial interpolation

TDS, alkalinity and laboratory pH data from bores were used to generate trend maps for the aquifer groups using the ‘topo to raster’ interpolation method in ArcGIS. This is an iterative finite difference interpolation technique, which allows for surface continuity in sparse datasets. The available hydrochemistry data does not represent a single snapshot of water quality at a specific time; rather they provide a general indication of variations in hydrochemistry across the subregion. Furthermore, there is likely to be variations in quality of the sample analyses used to create the maps due to the archival nature of the data. Factors affecting archival data can include: use of different analysis methods; improvements in analyses technology over time; analysis accuracy and precision; variations in sample collection methodologies, and different bore construction techniques and quality. The archival nature of the data used means that temporal variation in water chemistry may contribute to the range of values seen in the hydrochemistry surfaces. However, the total spatial variation in hydrochemical composition of groundwater for each hydrostratigraphic unit is at least one (and up to three) orders of magnitude. Thus, any temporal variations are expected to be relatively minor in comparison to spatial variability in groundwater composition.

Distribution of bores is often limited to within the vicinity of outcrop areas. Results may also be skewed in part through clustering of bores in areas where there is high production due to the presence of relatively high quality water, or alternatively areas with undesirable water quality are likely to have fewer bores to constrain interpolation. Interpretation of the hydrochemistry surfaces should be considered with these uncertainties in mind, and these maps should be treated as an image of regional trends in hydrochemistry for the hydrostratigraphic units in the subregion rather than a predictive tool for determining water quality where there is little bore coverage.

A map of the spatial distribution of TDS, alkalinity and pH and the data locations for each aquifer unit is provided in Figure 15 to Figure 18.

It should be noted that in order to have enough data for spatial pH plots it was necessary to use laboratory pH rather than the more accurate field pH. Field pH is recorded at the time when other field measurements were recorded (e.g. electrical conductivity, dissolved oxygen, redox) and when samples were prepared for laboratory analysis (e.g. cations and anions, stable isotopes). Groundwater pH may change during transport to the laboratory due to exchange with the atmosphere, which means that laboratory pH may not be representative of actual pH at the time of sampling. Therefore, laboratory pH is not an appropriate approximation in the absence of field pH when undertaking more in-depth hydrochemical analysis.

Condamine Alluvium aquifer

Groundwater within the Condamine Alluvium aquifer is generally fresh and has median TDS and alkalinity concentrations of 830 mg/L and 390 mg/L respectively (Figure 15a and Figure 15e). The median groundwater pH is 8.1 and ranges from slightly acidic (pH 5.6) to highly alkaline (pH 9.6) (Figure 15c).

TDS concentrations are lowest (less than 500 mg/L) adjacent to the Condamine River and its upper tributaries, in the south of the area. TDS concentrations increase downstream, with maximum TDS slightly less than 5000 mg/L in the north-west extent of the mapped alluvium. Alkalinity concentrations show a similar distribution to that of TDS in the south-east with low values (less than 400 mg/L) evident adjacent to the Condamine River. However, in contrast to downstream increasing TDS values, alkalinity remains low, with concentrations less than 300 mg/L at the north-western extent of the mapped alluvium.

Main Range Volcanics aquifers

Groundwater within the Main Range Volcanics aquifer is generally fresh with median TDS and alkalinity concentrations of 651 mg/L and 345 mg/L respectively (Figure 16a and Figure 16e). The median groundwater pH is 8.0 and ranges from slightly acidic (pH 5.4) to highly alkaline (pH 10) (Figure 16c).

TDS concentrations of less than 1000 mg/L exist over much of the southern and northern extents of the aquifer. An area of elevated TDS (greater than 1000 mg/L) is present in the central eastern portion of the aquifer. Alkalinity concentrations are very low, less than 100 mg/L, along the north-eastern boundary of the aquifer, increasing westward.

Rolling Downs Group aquifers

The TDS, pH and alkalinity distribution of the Rolling Downs Group (RDG) are shown in Figure 17a, Figure 17b and Figure 17c respectively. There are no groundwater analyses for the RDG in the south-west of the subregion (Figure 17b, Figure 17d and Figure 17f). Alkalinity concentrations in the RDG have a median of 416 mg/L. Alkalinity concentrations are generally low (less than 200 mg/L) along the northern boundary of the unit. The eastern boundary of the unit is characterised by elevated alkalinity (greater than 500 mg/L) which extends toward the centre of the subregion.

TDS concentrations are highest in the centre of the subregion, where a limited number of samples exceed 10,000 mg/L. The median TDS for the RDG is 1141 mg/L. The pH values in the RDG range from slightly acidic (6.2) to alkaline (9.0) and have a median value of 8.1. Across the subregion, pH in the RDG is generally slightly alkaline to alkaline with areas of near neutral concentrations in the centre and northern portions of the unit.

Hooray Sandstone and equivalents aquifer

The median TDS in the Hooray and equivalents aquifer is 962 mg/L. The TDS concentration distribution is fairly uniform across the unit with areas of very low TDS (less than 500 mg/L) generally occurring close to the aquifer margins where recharge occurs (Figure 18). Note that only one TDS analysis was available in the southern NSW portion of the subregion (Figure 18b). Laboratory pH ranges from 3.2 to 12.6 (such a high value is likely to be incorrect, as it is rare for groundwater to have such a high pH) with a median of 8.3 (Figure 18e). The median alkalinity concentration is 524 mg/L. Alkalinity concentrations are relatively high (1000 mg/L) toward the centre and south of the subregion, with the lowest concentrations (less than 400 mg/L) occurring toward the margins of the units adjacent to the aquifer recharge areas (Figure 18e).

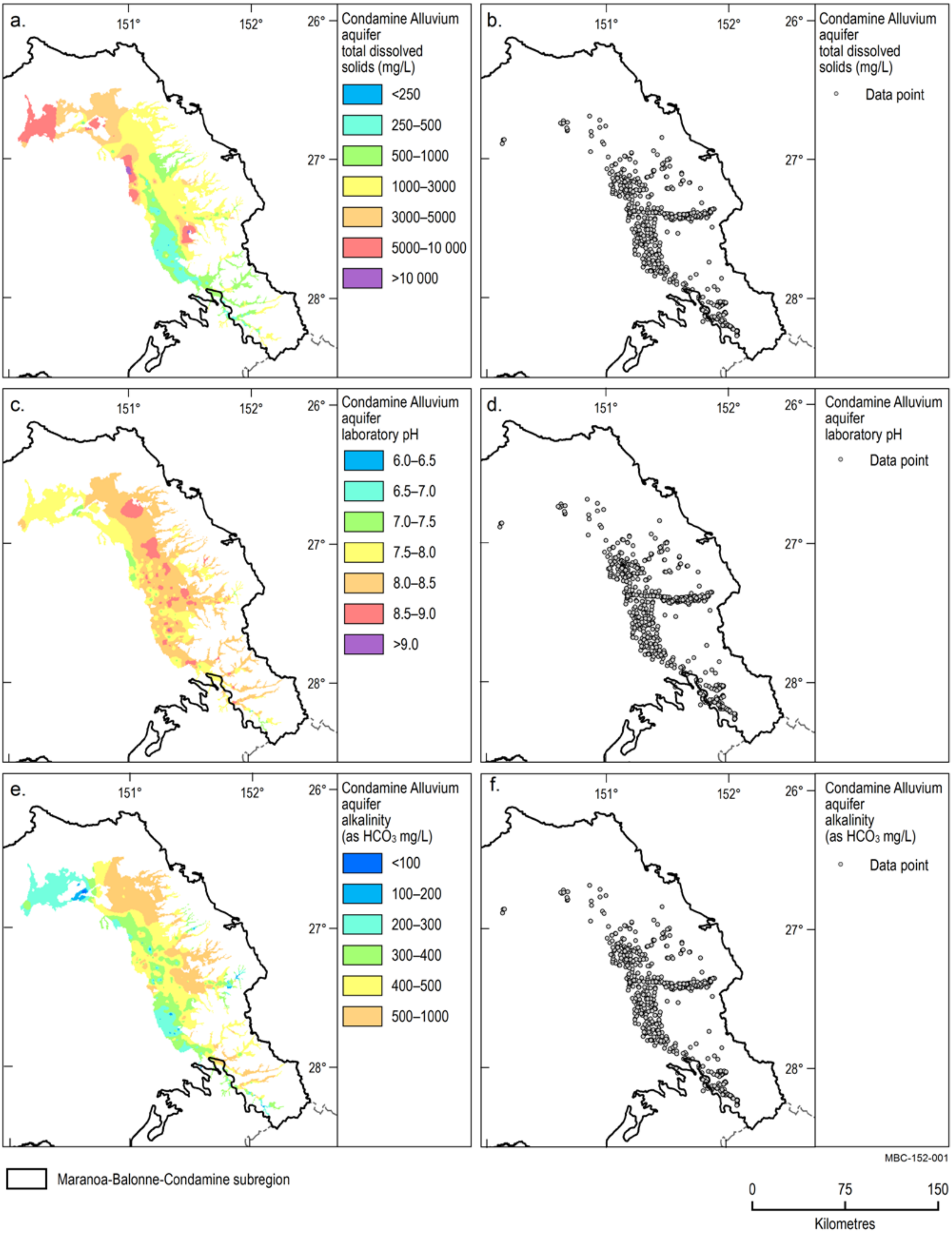

Figure 15 (a) Condamine Alluvium aquifer TDS distribution, (b) Condamine Alluvium aquifer TDS data point locations, (c) Condamine Alluvium aquifer laboratory pH distribution, (d) Condamine Alluvium aquifer laboratory pH data point locations, (e) Condamine Alluvium aquifer alkalinity distribution, (f) Condamine Alluvium aquifer alkalinity data point locations

Data: Geoscience (Dataset 1)

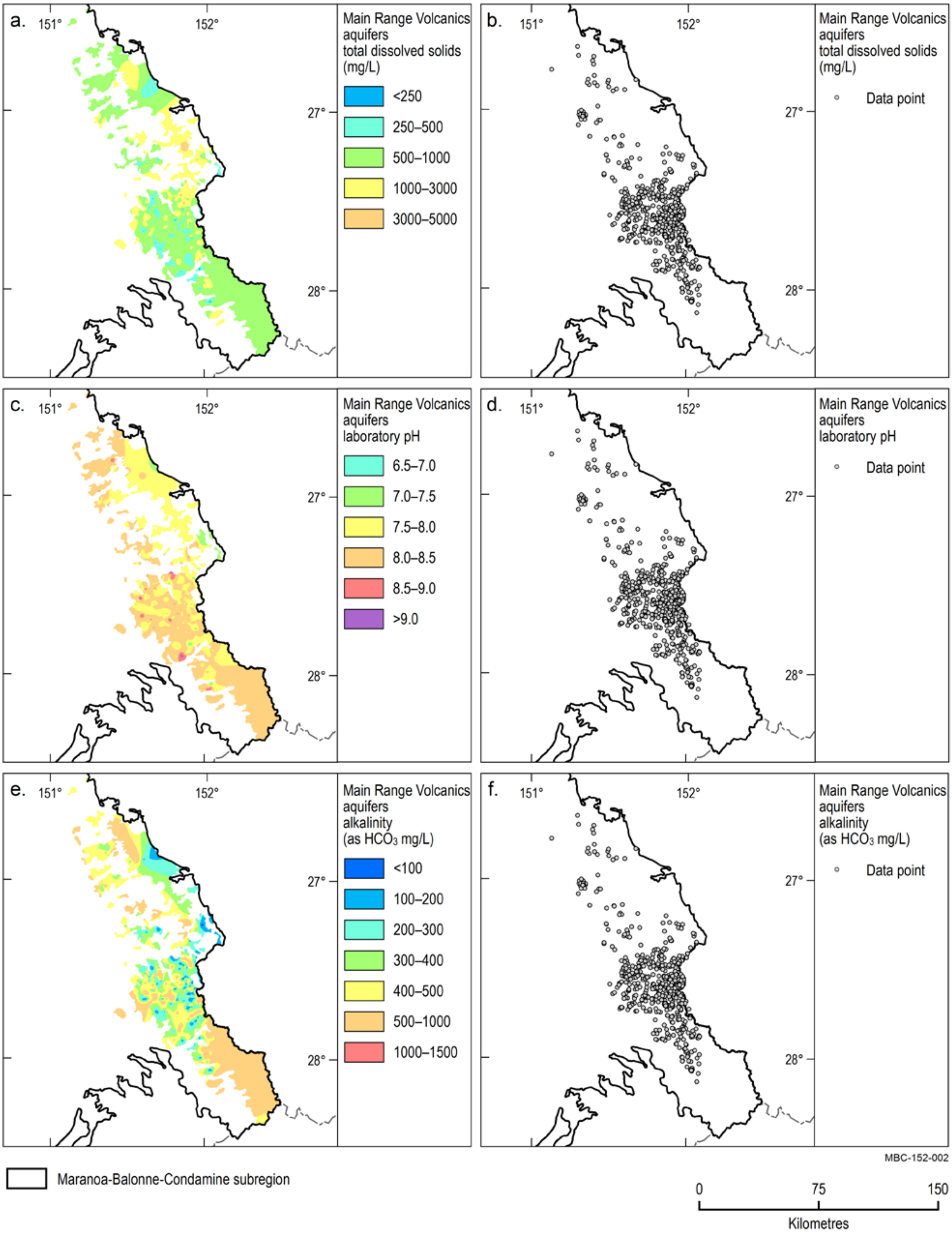

Figure 16 (a) Main Range Volcanics aquifers TDS distribution, (b) Main Range Volcanics aquifers TDS data point locations, (c) Main Range Volcanics aquifers lab pH distribution, (d) Main Range Volcanics aquifers lab pH data point locations, (e) Main Range Volcanics aquifers alkalinity distribution, (f) Main Range Volcanics aquifers alkalinity data point locations

Data: Geoscience Australia (Dataset 1)

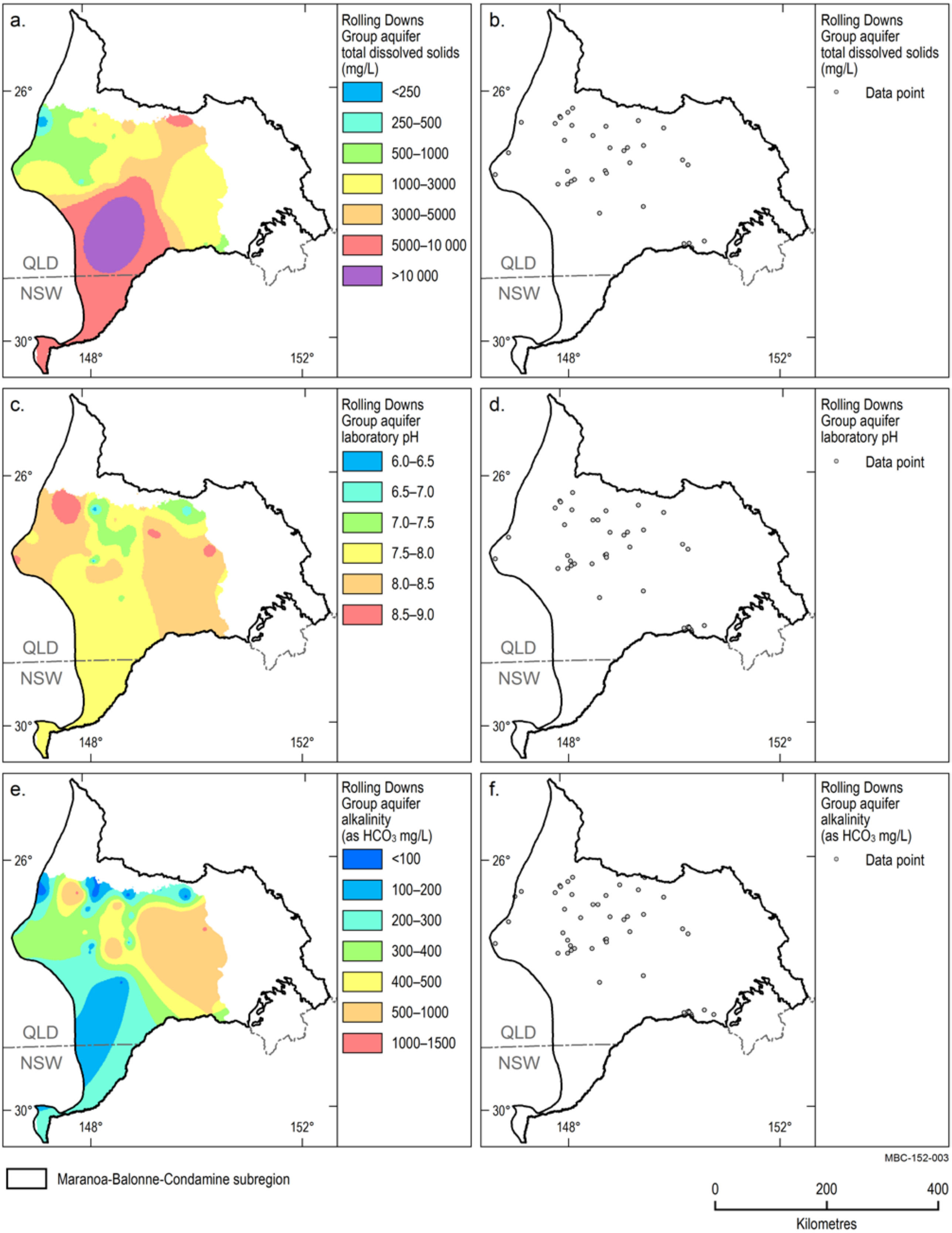

Figure 17 (a) Rolling Downs Group aquifers TDS distribution, (b) Rolling Downs Group aquifers TDS data point locations, (c) Rolling Downs Group aquifers laboratory pH distribution, (d) Rolling Downs Group aquifers laboratory pH data point locations, (e) Rolling Downs Group aquifers alkalinity distribution, (f) Rolling Downs Group aquifers alkalinity data point locations

Data: Geoscience Australia (Dataset 1)

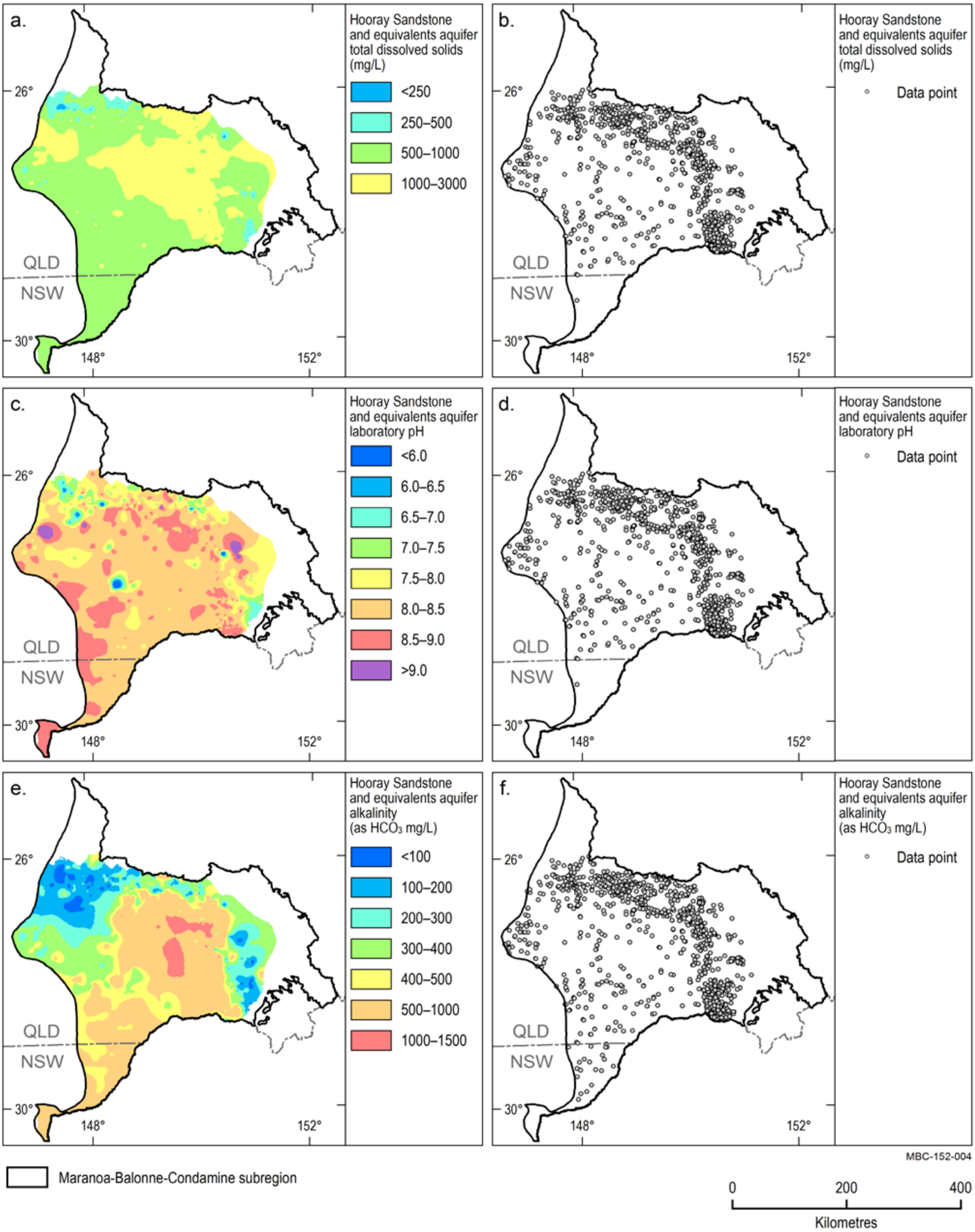

Figure 18 (a) Hooray Sandstone and equivalents aquifer TDS distribution, (b) Hooray Sandstone aquifer and equivalents aquifer TDS data point locations, (c) Hooray Sandstone aquifer and equivalents laboratory pH distribution, (d) Hooray Sandstone and equivalents aquifer laboratory pH data point locations, (e) Hooray Sandstone and equivalents aquifer alkalinity distribution, (f) Hooray Sandstone and equivalents alkalinity aquifer data point locations

Data: Geoscience Australia (Dataset 1)

Adori / Springbok aquifer

A limited number of analyses were available for the Adori / Springbok aquifer (Figure 19b, Figure 19d and Figure 19f). The median TDS concentration for this aquifer is 803 mg/L. The highest TDS concentrations (greater than 1000 mg/L) occur in the north-western area of the subregion (Figure 19a). pH for the Adori / Springbok aquifer ranges from acidic (4.2) to alkaline (9.9) and has median values of 8.1. Near neutral pH occurs in groundwater along the north-eastern margin of the unit, becoming increasingly alkaline to the south-west of the region (Figure 19c). The median alkalinity concentration for the Adori / Springbok aquifer is 295 mg/L. The highest alkalinity concentrations (greater than 500 mg/L) occur in the centre of the subregion and decrease toward the north-west and eastern boundary of the subregion (Figure 19e).

Walloon aquifers

The distribution of data points within the Walloon aquifers is clustered in the east and, to a lesser extent, the northern boundary of the unit. There were limited or no data available in the centre and south-west of the subregion to inform this analysis (Figure 20b, Figure 20d, Figure 20f). Groundwater within the Walloon aquifers is generally brackish with a median TDS concentration of 2079 mg/L – the second highest value for the subregion (Figure 20d). pH values range from highly acidic (3.8) to highly alkaline (11.4) (it is likely that this value is incorrect as it is rare for groundwater to have such a high pH) with a median value of 8.1. The large area of alkaline water (pH greater than 8.5) mapped on Figure 20c is an artefact of the uneven data distribution and unlikely to represent actual conditions. The median alkalinity concentration for this unit is 448 mg/L with lower alkalinity areas in the west and south-east of the subregion (Figure 20e).

Hutton Sandstone aquifer

The TDS, pH and alkalinity distribution of the Hutton Sandstone aquifer are shown in Figure 21. Median TDS is 978 mg/L and TDS is slightly lower in the north-west of the subregion. TDS concentrations over much of the eastern half of the region are relatively higher (greater than 1000 mg/L) and become brackish (greater than 1500 mg/L) in some isolated areas. TDS in the western half of the subregion is relatively lower (less than 1000 mg/L). The low concentrations that occur at the northernmost boundary of the subregion are coincident with the aquifer recharge area where the aquifer outcrops at the surface. Groundwater pH values range from slightly acidic (6.4) to alkaline (9.7) with a median value of 8.2. Much of the subregion is characterised by slightly alkaline groundwater (pH greater than 8) with small areas of near neutral groundwater limited to the isolated areas along the northern and eastern boundary of the subregion (Figure 21c). Alkalinity in the Hutton Sandstone aquifer generally increases from north to south, with concentrations exceeding 1500 mg/L in isolated areas (Figure 21e). The median alkalinity for the Hutton Sandstone aquifer is 515 mg/L.

Evergreen (Boxvale) aquifer

Limited data are available within the Evergreen (Boxvale) aquifer and the most data points are concentrated in the northernmost portion of the subregion (north of 26° latitude) (Figure 22). It should be noted that the interpolated values are unreliable south of 26° latitude as there are no data points to constrain them.

The median TDS concentration is 221 mg/L, which is the lowest of all hydrogeological units in the subregion (Figure 22a). The median alkalinity concentration is 132 mg/L (Figure 22e). Groundwater pH ranges from acid (pH 5.9) to alkaline (pH 8.7), with a median value of 7.8 (Figure 22c).

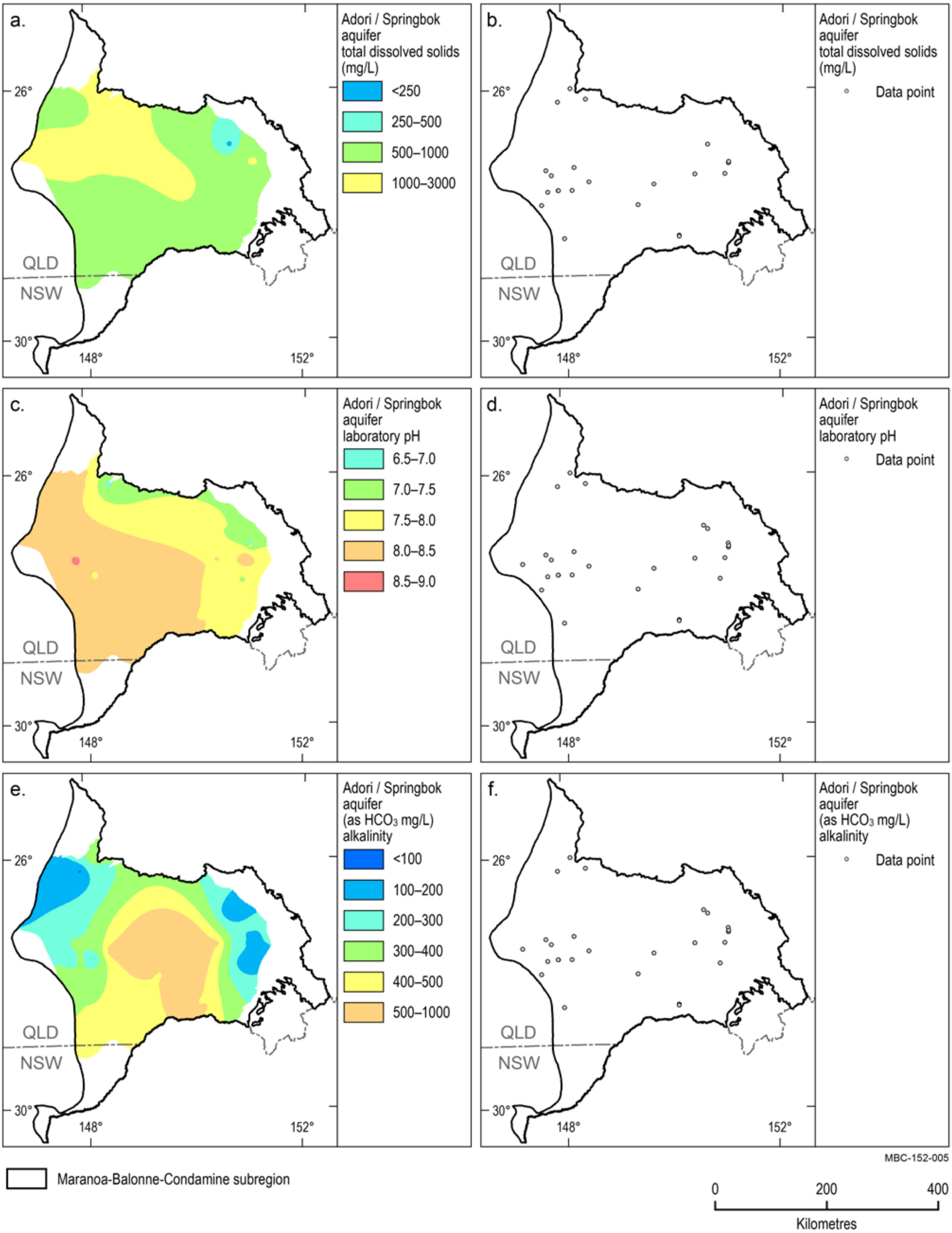

Figure 19 (a) Adori / Springbok aquifer TDS distribution, (b) Adori / Springbok aquifer TDS data point locations, (c) Adori / Springbok aquifer laboratory pH distribution, (d) Adori / Springbok aquifer laboratory pH data point locations, (e) Adori / Springbok aquifer alkalinity distribution, (f) Adori / Springbok aquifer alkalinity data point locations

Data: Geoscience Australia (Dataset 1)

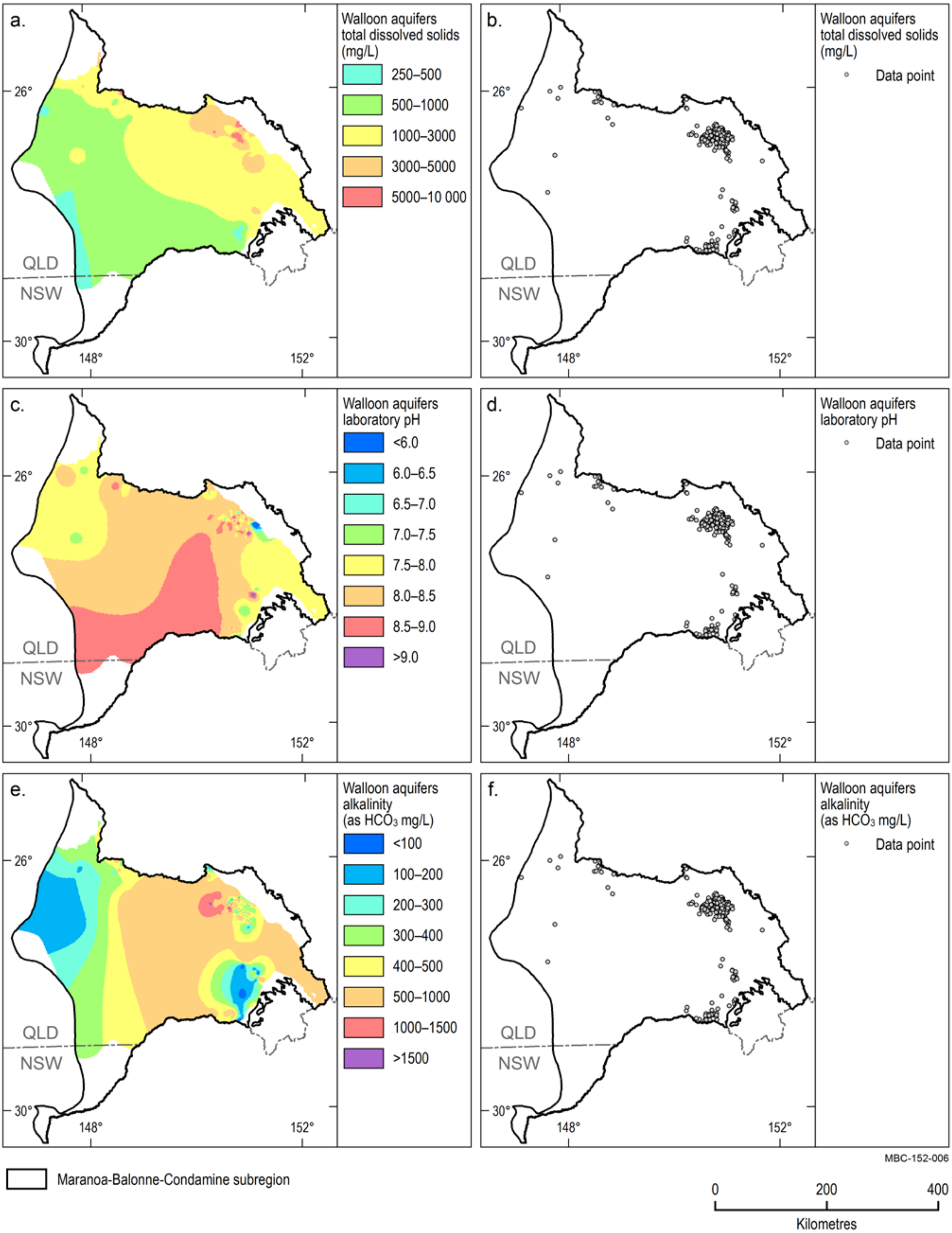

Figure 20 (a) Walloon aquifers TDS distribution, (b) Walloon aquifers TDS data point locations, (c) Walloon aquifers laboratory pH distribution, (d) Walloon aquifers laboratory pH data point locations, (e) Walloon aquifers alkalinity distribution, (f) Walloon aquifers alkalinity data point locations

Data: Geoscience Australia (Dataset 1)

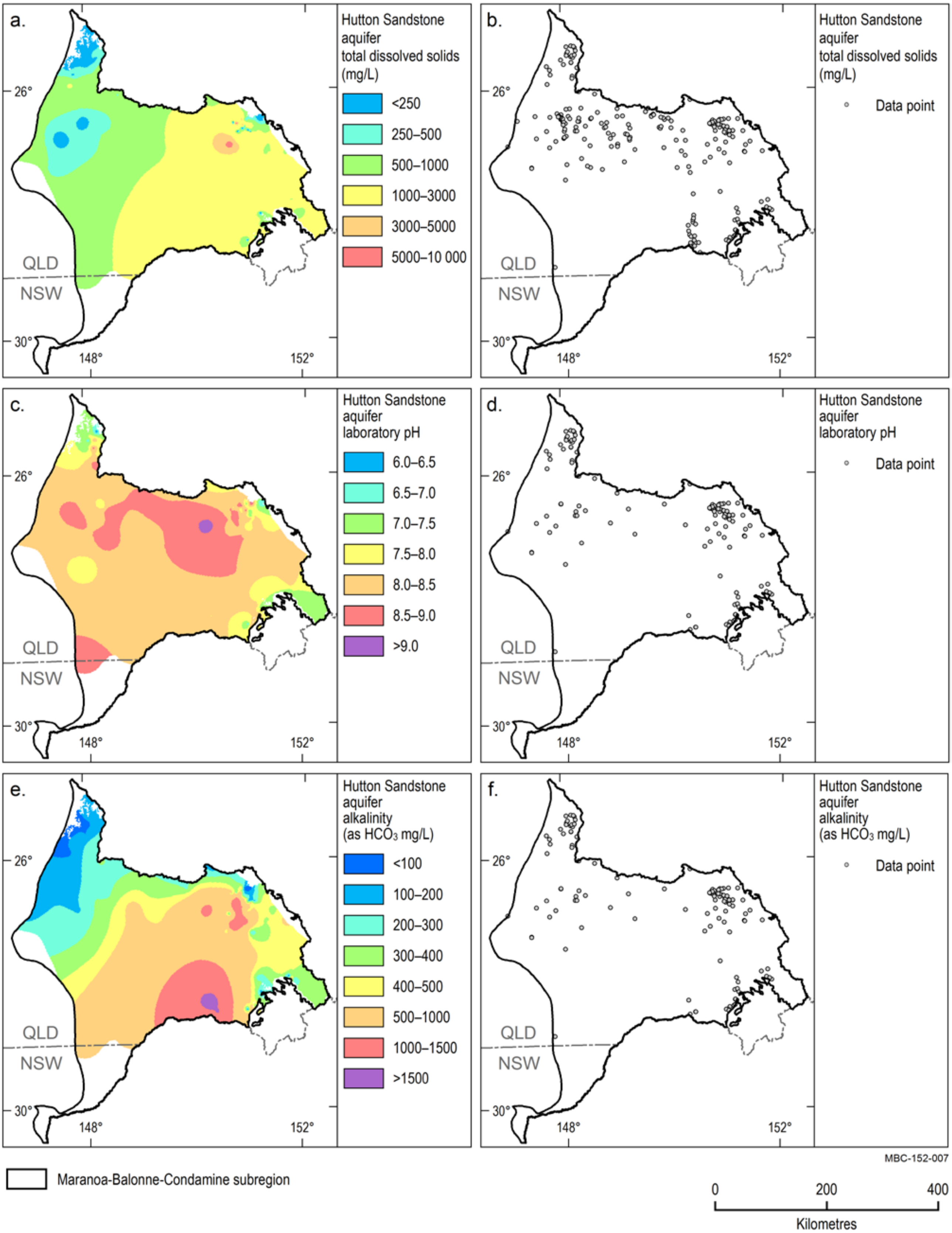

Figure 21 (a) Hutton Sandstone aquifer TDS distribution, (b) Hutton Sandstone aquifer TDS data point locations, (c) Hutton Sandstone aquifer laboratory pH distribution, (d) Hutton Sandstone aquifer laboratory pH data point locations, (e) Hutton Sandstone aquifer alkalinity distribution, (f) Hutton Sandstone aquifer alkalinity data point locations

Data: Geoscience Australia (Dataset 1)

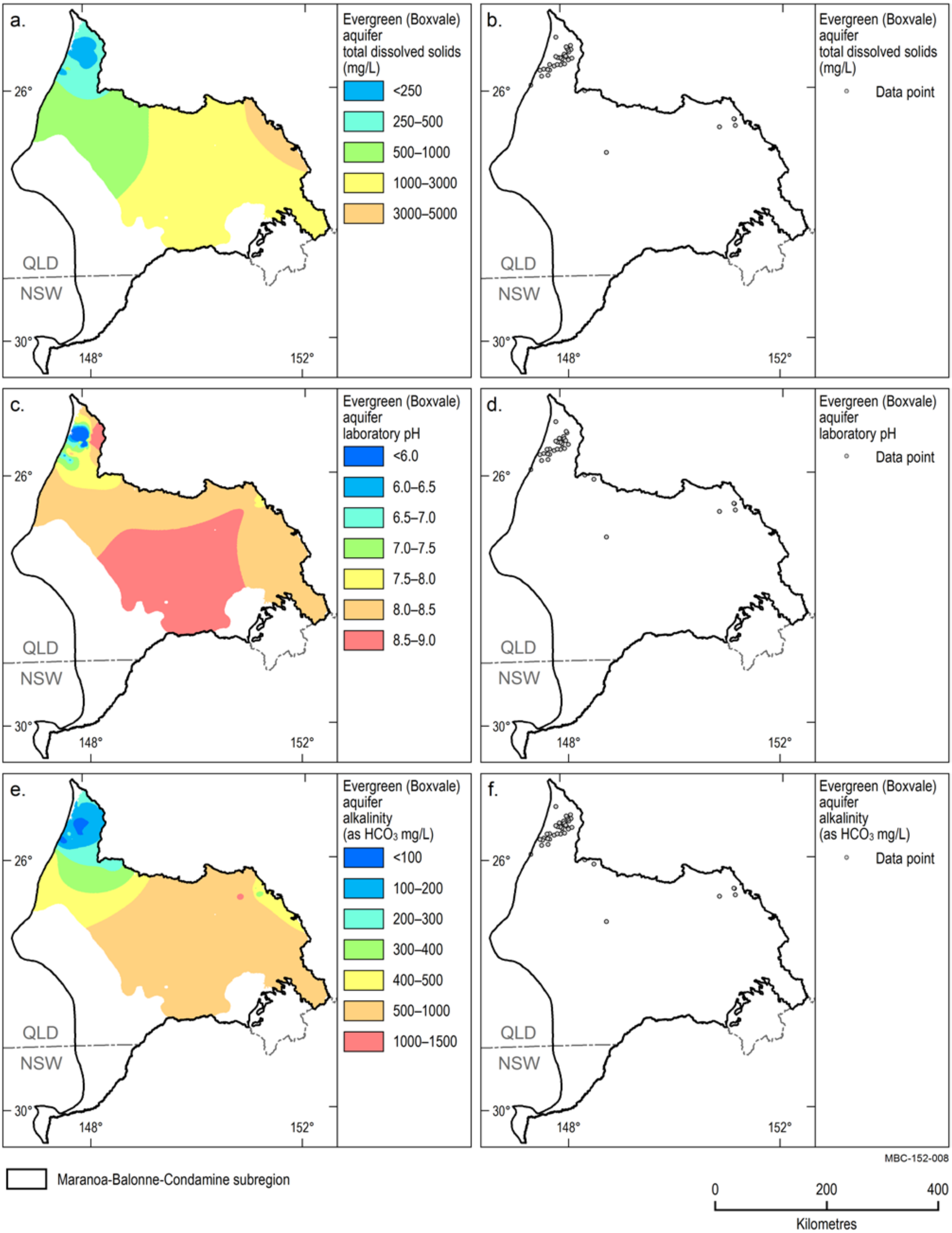

Figure 22 (a) Evergreen (Boxvale) aquifer TDS distribution, (b) Evergreen (Boxvale) aquifer TDS data point locations, (c) Evergreen (Boxvale) aquifer laboratory pH distribution, (d) Evergreen (Boxvale) aquifer laboratory pH data point locations, (e) Evergreen (Boxvale) aquifer alkalinity distribution, (f) Evergreen (Boxvale) aquifer data point locations

Data: Geoscience Australia (Dataset 1)

Precipice Sandstone aquifer

The distribution of data within the Precipice Sandstone aquifer is limited and is insufficient to produce spatial distribution maps for the subregion. The median TDS concentration within the Precipice Sandstone aquifer is 1940 mg/L. Groundwater pH ranges from slightly acidic (6.4) to alkaline (9.1) and has a median pH value of 8.3. The median alkalinity concentration is 878 mg/L and alkalinity ranges between 30 and 1776 mg/L.

1.5.2.2.4 Trace elements

Exceedances for the trace elements available in the dataset were determined using the Australian Drinking Water Guidelines (ADWG) for human consumption (NHMRC, 2011). Exceedances for irrigation and stock water were determined using trigger values in the National Water Quality Management Strategy (NWQMS) (ANZECC, 2000). The trigger values are shown in Table 11. Trace element ranges and the number of exceedances in the dataset are shown in Table 15 to Table 23.

Table 15 Condamine Alluvium aquifer water quality compared to standards

Parameter	Number of analyses	Minimum value (mg/L)	Maximum value (mg/L)	Fraction in exceedance of ADWG trigger[a] (%)	Fraction in exceedance of Irrigation trigger[b] (%)	Fraction in exceedance of Stock trigger[c] (%)
Electrical conductivity (EC)[d]	1,137	295	25,000	48.2%	4.3%	0.5%
Fluorine (F)	1,137	0.01	1.90	0.3%	0.5%	0%

[a]Table 10.5 in Australian Drinking Water Guidelines NHMRC (2011)
[b]Table 4.2.10 in National Water Quality Management Strategy ANZECC (2000)
[c]Table 4.3.2 in National Water Quality Management Strategy ANZECC (2000)
[d]Electrical Conductivity is measured in µS/cm
Data: Geoscience Australia (Dataset 1)

Table 16 Main Range Volcanics aquifers water quality compared to standards

Parameter	Number of analyses	Minimum value (mg/L)	Maximum value (mg/L)	Fraction in exceedance of ADWG trigger[a] (%)	Fraction in exceedance of Irrigation trigger[b] (%)	Fraction in exceedance of Stock trigger[c] (%)
Electrical conductivity (EC)[d]	980	135	9600	31.3%	0.2%	0%
Fluorine (F)	980	0.01	3.50	0.5%	0.8%	0.4%

[a]Table 10.5 in Australian Drinking Water Guidelines NHMRC (2011)
[b]Table 4.2.10 in National Water Quality Management Strategy ANZECC (2000)
[c]Table 4.3.2 in National Water Quality Management Strategy ANZECC (2000)
[d]Electrical Conductivity is measured in µS/cm
Data: Geoscience Australia (Dataset 1)

Table 17 Rolling Downs Group aquifers water quality compared to standards

Parameter	Number of analyses	Minimum value (mg/L)	Maximum value (mg/L)	Fraction in exceedance of ADWG trigger[a] (%)	Fraction in exceedance of Irrigation trigger[b] (%)	Fraction in exceedance of Stock trigger[c] (%)	Number of samples below detection limit	Fraction of samples below detection limit (%)
Electrical conductivity (EC)[d]	57	373	34,000	68.4%	12.3%	5.3%	0	0%
Boron (B)	6	0.08	3.60	0%	50.0%	0%	0	0%
Copper (Cu)	3	0.02	0.05	0%	0%	0%	0	0%
Fluorine (F)	66	0.05	4.50	13.6%	24.2%	9.1%	1	1.5%
Iron (Fe)	22	0.01	6.20	13.6%[e]	18.2%	NA	0	0%
Manganese (Mn)	17	0.01	6.00	47.1%[e]	35.3%	NA	0	0%
Zinc (Zn)	4	0.01	0.27	0%[e]	0%	0%	1	25.0%

[a]Table 10.5 in Australian Drinking Water Guidelines NHMRC (2011)
[b]Table 4.2.10 in National Water Quality Management Strategy ANZECC (2000)
[c]Table 4.3.2 in National Water Quality Management Strategy ANZECC (2000)
[d]Electrical Conductivity is measured in µS/cm
[e]Aesthetic water quality trigger (not health related)
NA means 'not applicable' because there is no relevant standard
Data: Geoscience Australia (Dataset 1)

Table 18 Hooray Sandstone and equivalents aquifer water quality compared to standards

Parameter	Number of analyses	Minimum value (mg/L)	Maximum value (mg/L)	Fraction in exceedance of ADWG trigger[a] (%)	Fraction in exceedance of Irrigation trigger[b] (%)	Fraction in exceedance of Stock trigger[c] (%)	Number of samples below detection limit	Fraction of samples below detection limit (%)
Electrical conductivity (EC)[d]	1893	121	64074	54.3%	2.41%	0.4%	0	0%
Silver (Ag)	42	0.001	0.005	100%	NA	NA	0	0%
Aluminium (Al)	75	0.009	0.1	0%	0%	0%	18	24%
Arsenic (As)	42	0.001	0.001	0%	0%	0%	0	0%
Boron (B)	489	0.02	8.5	1.8%	42.5%	1.8%	0	0%
Cadmium (Cd)	43	0.0001	0.002	0%	0%	0%	0	0%
Chromium (Cr)	42	0.001	0.005	0%	0%	0%	0	0%
Copper (Cu)	257	0.001	0.339	0%	0%	0%	16	6.2%

Parameter	Number of analyses	Minimum value (mg/L)	Maximum value (mg/L)	Fraction in exceedance of ADWG trigger[a] (%)	Fraction in exceedance of Irrigation trigger[b] (%)	Fraction in exceedance of Stock trigger[c] (%)	Number of samples below detection limit	Fraction of samples below detection limit (%)
Fluorine (F)	1101	0.01	7.2	18.6%	29.5%	11.4%	12	1.1%
Iron (Fe)	768	0.008	431.860	18%[e]	23.7%	100%	0	0%
Mercury (Hg)	43	0.0001	0.001	0%	0%	0%	0	0%
Manganese (Mn)	607	0.001	431.86	9.2%[e]	5.8%	100%	0	0%
Molybdenum (Mo)	43	0.001	0.05	0%	0%	100%	0	0%
Nickel (Ni)	42	0.001	0.05	0%	0%	0%	0	0%
Nitrate (NO_3)	1	0.07	0.07	0%	100%	100%	0	0%
Lead (Pb)	201	0.001	0.1	0%	0%	0%	0	0%
Selenium (Se)	42	0.001	0.01	0%	0%	0%	0	0%
Uranium (U)[f]	218	0.00006	0.05	0%	0%	0%	0	0%
Vanadium (V)	217	0.005	0.5	100%	0%	100%	0	0%
Zinc (Zn)	259	0.002	6	0.4%[e]	0.4%	0.4%	12	4.6%

[a]Table 10.5 in Australian Drinking Water Guidelines NHMRC (2011)
[b]Table 4.2.10 in National Water Quality Management Strategy ANZECC (2000)
[c]Table 4.3.2 in National Water Quality Management Strategy ANZECC (2000)
[d]Electrical Conductivity is measured in µS/cm
[e]Aesthetic water quality trigger (not health related)
[f]Uranium is measured in parts per billion
NA means 'not applicable' because there is no relevant standard
Data: Geoscience Australia (Dataset 1)

Table 19 Adori / Springbok aquifer water quality compared to standards

Parameter	Number of analyses	Minimum value (mg/L)	Maximum value (mg/L)	Fraction in exceedance of ADWG trigger[a] (%)	Fraction in exceedance of Irrigation trigger[b] (%)	Fraction in exceedance of Stock trigger[c] (%)
Electrical conductivity (EC)[d]	54	250	24,100	51.85%	18.52%	3.7%
Aluminium (Al)	1	0.05	0.05	0%[e]	0%	0%
Boron (B)	6	0.10	4.00	0%	50.0%	0%
Copper (Cu)	1	0.03	0.03	0%	0%	0%
Fluorine (F)	53	0.04	4.80	30.2%	34.0%	18.9%
Iron (Fe)	13	0.01	1.20	7.7%[e]	23.1%	NA

Parameter	Number of analyses	Minimum value (mg/L)	Maximum value (mg/L)	Fraction in exceedance of ADWG trigger[a] (%)	Fraction in exceedance of Irrigation trigger[b] (%)	Fraction in exceedance of Stock trigger[c] (%)
Manganese (Mn)	12	0.01	3.80	8.3%[e]	8.3%	NA
Zinc (Zn)	1	0.01	0.01	0%[e]	0%	0%

[a]Table 10.5 in Australian Drinking Water Guidelines NHMRC (2011)
[b]Table 4.2.10 in National Water Quality Management Strategy ANZECC (2000)
[c]Table 4.3.2 in National Water Quality Management Strategy ANZECC (2000)
[d]Electrical Conductivity is measured in µS/cm
[e]Aesthetic water quality trigger (not health related)
NA means 'not applicable' because there is no relevant standard
Data: Geoscience Australia (Dataset 1)

Table 20 Walloon aquifers water quality compared to standards

Parameter	Number of analyses	Minimum value (mg/L)	Maximum value (mg/L)	Fraction in exceedance of ADWG trigger[a] (%)	Fraction in exceedance of Irrigation trigger[b] (%)	Fraction in exceedance of Stock trigger[c] (%)	Number of samples below detection limit	Fraction of samples below detection limit (%)
Electrical conductivity (EC)[d]	354	160	500,000	81.4%	19.2%	0.3%	0	0%
Aluminium (Al)	11	0.01	8.03	9.1%[e]	9.1%	9.1%	2	18.2%
Boron (B)	13	0.09	0.60	0%	7.7%	0%	0	0%
Copper (Cu)	11	0.01	0.04	0%	0%	0%	1	9.1%
Fluorine (F)	358	0.01	4.50	21.2%	28.8%	15.9%	1	0.3%
Iron (Fe)	67	0.01	5.40	16.4%[e]	17.9%	NA	0	0%
Manganese (Mn)	53	0.01	0.70	7.6%[e]	5.7%	NA	0	0%
Zinc (Zn)	12	0.01	3.93	8.3%[e]	8.3%	8.3%	0	0%

[a]Table 10.5 in Australian Drinking Water Guidelines NHMRC (2011)
[b]Table 4.2.10 in National Water Quality Management Strategy ANZECC (2000)
[c]Table 4.3.2 in National Water Quality Management Strategy ANZECC (2000)
[d]Electrical Conductivity is measured in µS/cm
[e]Aesthetic water quality trigger (not health related)
NA means 'not applicable' because there is no relevant standard
Data: Geoscience Australia (Dataset 1)

Table 21 Hutton Sandstone aquifer water quality compared to standards

Parameter	Number of analyses	Minimum value (mg/L)	Maximum value (mg/L)	Fraction in exceedance of ADWG trigger[a] (%)	Fraction in exceedance of Irrigation trigger[b] (%)	Fraction in exceedance of Stock trigger[c] (%)	Number of samples below detection limit	Fraction of samples below detection limit (%)
Electrical conductivity (EC)[d]	165	133	22,500	55.2%	7.3%	0.6%	0	0%
Silver (Ag)	26	0.001	0.005	100%	NA	NA	0	0%
Aluminium (Al)	37	0.01	0.10	0%[e]	0%	0%	8	21.6%
Arsenic (As)	26	0.001	0.001	0%	0%	0%	0	0%
Boron (B)	52	0.02	1.02	0%	11.5%	0%	0	0%
Cadmium (Cd)	27	0.0001	0.002	0%	0%	0%	0	0%
Chromium (Cr)	26	0.001	0.01	0%	0%	0%	0	0%
Copper (Cu)	38	0.01	0.06	0%	0%	0%	5	13.5%
Fluorine (F)	159	0.02	5.79	18.9%	26.4%	13.2%	2	1.3%
Iron (Fe)	69	0.01	9.12	33.3%[e]	34.8%	NA	0	0%
Mercury (Hg)	27	0.0001	0.001	0%	0%	0%	0	0%
Manganese (Mn)	66	0.003	25	22.7%[e]	13.6%	NA	0	0%
Molybdenum (Mo)	27	0.001	0.05	0%	0%	NA	0	0%
Nickel (Ni)	26	0.001	0.01	0%	0%	0%	0	0%
Lead (Pb)	27	0.001	0.01	0%	0%	0%	0	0%
Selenium (Se)	26	0.001	0.01	0%	0%	0%	0	0%
Uranium (U) [f]	26	0.001	0.01	0%	0%	0%	0	0%
Vanadium (V)	26	0.01	0.01	NA	0%	NA	0	0%
Zinc (Zn)	40	0.001	3.30	2.5%[e]	2.5%	2.5%	0	0%

[a]Table 10.5 in Australian Drinking Water Guidelines NHMRC (2011)
[b]Table 4.2.10 in National Water Quality Management Strategy ANZECC (2000)
[c]Table 4.3.2 in National Water Quality Management Strategy ANZECC (2000)
[d]Electrical Conductivity is measured in µS/cm
[e]Aesthetic water quality trigger (not health related)
[f]Uranium is measured in parts per billion
NA means ‘not applicable’ because there is no relevant standard
Data: Geoscience Australia (Dataset 1)

Table 22 Evergreen (Boxvale) aquifer water quality compared to standards

Parameter	Number of analyses	Minimum value (mg/L)	Maximum value (mg/L)	Fraction in exceedance of ADWG trigger[a] (%)	Fraction in exceedance of Irrigation trigger[b] (%)	Fraction in exceedance of Stock trigger[c] (%)
Electrical conductivity (EC)[d]	80	140	10,000	8.8%	2.5%	0%
Silver (Ag)	2	0.001	0.001	100%	NA	NA
Aluminium (Al)	5	0.01	0.04	0%[e]	0%	0%
Arsenic (As)	2	0.001	0.001	0%	0%	0%
Boron (B)	11	0.05	0.40	0%	0%	0%
Cadmium (Cd)	2	0.0010	0.0001	0%	0%	0%
Chromium (Cr)	2	0.001	0.001	0%	0%	0%
Copper (Cu)	4	0.001	0.01	0%	0%	0%
Fluorine (F)	72	0.03	5.20	9.7%	13.9%	9.7%
Iron (Fe)	30	0.01	2.94	13.3%[e]	20.0%	NA
Mercury (Hg)	2	0.0001	0.0001	0%	0%	0%
Manganese (Mn)	30	0.01	0.21	13.3%[e]	3.3%	NA
Molybdenum (Mo)	2	0.001	0.001	0%	0%	NA
Nickel (Ni)	2	0.002	0.002	0%	0%	0%
Lead (Pb)	2	0.001	0.001	0%	0%	0%
Selenium (Se)	2	0.01	0.01	0%	0%	0%
Uranium (U)[f]	2	0.001	0.001	0%	0%	0%
Vanadium (V)	2	0.01	0.01	NA	0%	NA
Zinc (Zn)	5	0.01	0.09	0%[e]	0%	0%

[a]Table 10.5 in Australian Drinking Water Guidelines NHMRC (2011)
[b]Table 4.2.10 in National Water Quality Management Strategy ANZECC (2000)
[c]Table 4.3.2 in National Water Quality Management Strategy ANZECC (2000)
[d]Electrical Conductivity is measured in µS/cm
[e]Aesthetic water quality trigger (not health related)
[f]Uranium is measured in parts per billion
NA means 'not applicable' because there is no relevant standard
Data: Geoscience Australia (Dataset 1)

Table 23 Precipice Sandstone aquifer water quality compared to standards

Parameter	Number of analyses	Minimum value (mg/L)	Maximum value (mg/L)	Fraction in exceedance of ADWG trigger[a] (%)	Fraction in exceedance of Irrigation trigger[b] (%)	Fraction in exceedance of Stock trigger[c] (%)
Electrical conductivity (EC)[d]	59	231	5110	54.2%	0%	0%
Silver (Ag)	8	0.001	0.001	100%	NA	NA
Aluminium (Al)	9	0.01	0.01	0%[e]	0%	0%
Arsenic (As)	8	0.001	0.001	0%	0%	0%
Boron (B)	9	0.05	0.43	0%	0%	0%
Cadmium (Cd)	8	0.0001	0.0001	0%	0%	0%
Chromium (Cr)	8	0.001	0.005	0%	0%	0%
Copper (Cu)	13	0.00	0.02	0%	0%	0%
Fluorine (F)	58	0.03	10.89	56.9%	58.6%	51.7%
Iron (Fe)	36	0.01	4.92	19.4%[e]	19.4%	NA
Mercury (Hg)	8	0.0001	0.0003	0%	0%	0%
Manganese (Mn)	24	0.003	0.09	0%[e]	0%	NA
Molybdenum (Mo)	8	0.001	0.001	0%	0%	NA
Nickel (Ni)	8	0.001	0.001	0%	0%	0%
Lead (Pb)	9	0.001	0.001	0%	0%	0%
Selenium (Se)	8	0.01	0.01	0%	0%	0%
Uranium (U)[f]	9	0.001	0.003	0%	0%	0%
Vanadium (V)	9	0.02	0.01	NA	0%	NA
Zinc (Zn)	10	0.001	0.05	0%[e]	0%	0%

[a]Table 10.5 in Australian Drinking Water Guidelines NHMRC (2011)
[b]Table 4.2.10 in National Water Quality Management Strategy ANZECC (2000)
[c]Table 4.3.2 in National Water Quality Management Strategy ANZECC (2000)
[d]Electrical Conductivity is measured in µS/cm
[e]Aesthetic water quality trigger (not health related)
[f]Uranium is measured in parts per billion
NA means 'not applicable' because there is no relevant standard
Data: Geoscience Australia (Dataset 1)

1.5.2.2.5 Gaps

The available groundwater chemistry data is unevenly distributed for many of the hydrogeologic units, specifically the Evergreen (Boxvale) aquifer, Walloon aquifer and Adori / Springbok aquifer. Large areas of these units have little or no data to constrain the interpolated hydrochemistry spatial distribution mapping, thus reducing its reliability in some areas. Data for the Precipice Sandstone was so sparse it was not possible to produce hydrochemical spatial distribution maps.

A limited amount of field pH data is available to provide an accurate picture of the in situ pH conditions of groundwater in the subregion.

The quality of the hydrochemistry data available for this assessment is difficult to determine, as analytical uncertainties are not reported in the dataset. The dataset includes chemical analyses of differing ages, sometimes decades apart, which will have differing levels of accuracy and precision.

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www.bioregionalassessments.gov.au

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