Australian Government

BIOREGIONAL ASSESSMENTS

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

Impact and risk analysis for the Maranoa-Balonne-Condamine subregion

Product 3-4 for the Maranoa-Balonne-Condamine subregion from the Northern Inland Catchments Bioregional Assessment

6 July 2017

A scientific collaboration between the Department of the Environment and Energy, 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 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 and Energy. The Department of the Environment and Energy, 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 and Energy

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

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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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Executive summary

This product describes the analysis of potential impacts of coal seam gas (CSG) and coal mining developments on water resources and water-dependent assets in the Maranoa-Balonne-Condamine subregion. This impact and risk analysis identified where water resources and water-dependent assets are *very unlikely* to be impacted (with a less than 5% chance), or are potentially impacted. Governments, industry and the community can then focus on the areas that are potentially impacted and apply local-scale modelling when making regulatory, water management and planning decisions.

The Maranoa-Balonne-Condamine subregion covers 144,890 km^2 and is mainly within the Queensland part of the Murray–Darling Basin, with a small area in NSW. It includes the headwaters of the Condamine River and the Maranoa River as well as the floodplains of the Upper Darling Plains. The main cities and towns are Toowoomba, Warwick, Dalby, Chinchilla, Roma, St George and Goondiwindi.

The geographic area where impacts were assessed, known as the assessment extent, covers 129,956 km^2.

The impact and risk analysis considered two potential coal resource development futures:

- *baseline coal resource development (baseline)*: a future that includes all coal mines and coal seam gas (CSG) fields that were commercially producing as at December 2012 and five CSG fields reported in the *Annual report 2014 for the Surat underground water impact report*
    - In the Maranoa-Balonne-Condamine subregion, there are five baseline coal mines (Cameby Downs Mine, Commodore Mine, Kogan Creek Mine, New Acland Coal Mine Stage 2 and Wilkie Creek Mine) and five baseline CSG fields (Australia Pacific Liquefied Natural Gas (LNG) Project, Santos Gladstone LNG Project, Queensland Curtis LNG Project, Surat Gas Project and Ironbark Project).
- *coal resource development pathway (CRDP)*: a future that includes all coal mines and CSG fields that are in the baseline as well as the additional coal resource development (those that were expected to begin commercial production after December 2012, including expansions of baseline operations)
    - In the Maranoa-Balonne-Condamine subregion, there are two additional open-cut coal mines (New Acland Coal Mine Stage 3, an extension to the existing New Acland Coal Mine, and The Range, a proposed open-cut mine).

The difference in results between CRDP and baseline is the change that is primarily reported in a bioregional assessment (BA). This change is due to additional coal resource development.

Potential hydrological changes

Impacts to water-dependent landscapes and assets are mostly caused by changes to groundwater in the regional watertable. The regional watertable represents the upper groundwater level within the near-surface aquifer, and may exist in different geological layers. Near the two additional coal resource developments it occurs in the alluvium, as well as the Main Range Volcanics and the Walloon Coal Measures. Springs and groundwater bores may be affected by hydrological changes in deeper geological layers, which may have ecological repercussions for surface ecosystems surrounding springs.

Predicted groundwater drawdown was used to define a zone to 'rule out' potential impacts. The *zone of potential hydrological change* is the area with at least a 5% chance of greater than 0.2 m drawdown due to additional coal resource development. This threshold is consistent with the most conservative minimal impact thresholds in NSW and Queensland state regulations, and is close to the practical resolution limits of modelled and measured drawdown. Because surface water modelling was not undertaken for this subregion, groundwater hydrological changes alone were used to define the zone.

Outside the zone of potential hydrological change, potential hydrological changes (and hence impacts) are *very unlikely*. Inside the zone, further work is required to determine whether the hydrological changes in the zone translate into impacts for water-dependent assets and landscapes.

Drawdown in the regional watertable under the baseline has at least a 5% chance of exceeding 0.2 m in an area of 17,132 km^2. Baseline drawdown in the regional watertable is typically less than 20 m and occurs in the east and north of the subregion, where deeper geological layers, including the Walloon Coal Measures, outcrop at the surface.

Drawdown in the regional watertable due to additional coal resource development is *very unlikely* to exceed 0.2 m, except within 15 km of New Acland Coal Mine Stage 3 and within 25 km of The Range coal mine. The area in the zone of potential hydrological change is 1544 km^2 (11 times less than under the baseline), and includes 1095 km of streams.

Near New Acland Coal Mine Stage 3, additional drawdown in the regional watertable in excess of 0.2 m is *very likely* (greater than 95% chance) over an area of 7 km^2 (containing 4 km of streams) and *very unlikely* to extend beyond an area of 134 km^2 (containing 55 km of streams). Median baseline drawdown is less than 3.6 m in all model layers. Median additional drawdown is up to 65 m in the regional watertable next to the modelled pits, and up to 25 m in the Walloon Coal Measures, the target of CSG production, which is up to 120 m thick in this area.

Near The Range coal mine, additional drawdown in the regional watertable in excess of 0.2 m is *very likely* over an area of 377 km^2 (containing 231 km of streams) and *very unlikely* to extend beyond an area of 1409 km^2 (containing 1040 km of streams). Median baseline drawdown, associated with CSG fields to the south-west, is up to 8.3 m in the regional watertable and up to 82 m in the Walloon Coal Measures, which is up to 170 m thick in this area. Median additional drawdown is up to 10.2 m in all model layers in the vicinity of The Range coal mine.

Impacts on and risks to landscape classes

The heterogeneous natural and human-modified ecosystems in the Maranoa-Balonne-Condamine subregion were classified into 34 landscape classes, which were aggregated into five landscape groups based on their likely response to hydrological changes. Overall, more than 35,000 km^2 of remnant vegetation, 59,000 km of streams, 1600 km^2 of wetlands, 177 springs and 93,000 km^2 of productive land within the assessment extent are *very unlikely* to be impacted, because they are outside the zone of potential hydrological change.

Within the zone of potential hydrological change, most of the area falls into two landscape groups with limited or no potential impact due to changes in the water regime arising from coal resource development:

- *'Dryland remnant vegetation'* (49% of the zone)
- natural environments and dryland agriculture in *'Human-modified'* (44% of the zone).

These areas are ruled out of potential impacts because they rely on incident rainfall and local surface water runoff and therefore are not considered water dependent for this assessment.

Outside the modelled mine pits, landscapes that are potentially impacted include:

- '*Floodplain or lowland riverine (including non-GAB GDEs)':* 20 km^2 of remnant vegetation and 299 km of streams, which are predominantly not groundwater dependent. Median drawdown due to additional coal resource development for floodplain or lowland riverine GDEs associated with alluvial or basalt aquifers is in addition to the range of natural watertable fluctuation (<2 m) and of a comparable magnitude
- '*GAB GDEs (riverine, springs, floodplain or non-floodplain)*': 76 km^2 of remnant vegetation and 319 km of temporary streams connected to GAB aquifers. None of the 153 GAB springs in the assessment extent are within 50 km of where there is at least a 5% chance of exceeding 0.2 m drawdown due to additional coal resource development in the source aquifer identified for each spring. Median additional drawdown is in addition to and of a comparable magnitude to the range of natural watertable fluctuation (<2 m)
- *'Non-floodplain or upland riverine (including non-GAB GDEs)'*: 12 km^2 of remnant vegetation and 477 km of temporary upland streams and wetlands that are not associated with floodplains or GAB GDEs. None of the 24 springs in the assessment extent that are connected to aquifers overlying the GAB (non-GAB springs) are potentially impacted. Local impact assessment and modelling is required to supplement regional groundwater model predictions of localised cumulative drawdown (<5 m) that may affect ecosystems dependent on permeable rock or basalt aquifers
- *'Human-modified'*: 2 km^2 of water-dependent human-modified land. Median additional drawdown in excess of 2 m may affect 0.2 km^2 classified as 'Intensive use' and 'Production from irrigated agriculture and plantations' that may rely on groundwater for extraction.

Impacts on and risks to water-dependent assets

Of the 2660 water-dependent assets nominated by the community for the subregion, most (2495) are *very unlikely* to be impacted because they experience less than 0.2 m drawdown due to additional coal resource development. This includes protected reserves, parks, bird habitats or key environmental assets, and surface water features classified as a spring, floodplain, lake, reservoir, estuary, marsh, sedgeland, bog, spring, soak, waterhole, pool, rock pool or billabong.

However, 130 water-dependent assets are subject to potential hydrological change due to additional coal resource development. This does not mean that these assets are definitely impacted – finer resolution models are required for that local-scale assessment of impact. On the basis of this assessment, however, there is not compelling evidence to rule out impacts for the following water-dependent assets:

- 115 of the 2215 *ecological assets*, including 41 ecosystems. This includes potential habitats of 4 threatened ecological communities and 18 species listed under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act); an additional 6 endangered regional ecosystems and potential habitats of 11 species listed under Queensland's *Nature Conservation Act 1992*; and 2 riparian vegetation assets.
- 14 of the 310 *economic assets*, including one licensed surface water access right and 13 groundwater economic assets comprising 163 bores (7 water access rights and 6 basic water rights (stock and domestic)). Of these 163 bores, 17 to 30 are predicted to experience additional drawdown in excess of 5 m.
- 1 of the 135 *sociocultural assets*, the Barakula State Forest, near Miles in Queensland, is located where drawdown in the regional watertable due to additional coal resource development exceeds 0.2 m with greater than 5% chance. It is *very likely* that 21 km^2 (0.7% of the 3092 km^2 forest) experiences more than 0.2 m of drawdown due to additional coal resource development.

Consultation with Traditional Owners in the Maranoa-Balonne-Condamine subregion identified an additional 56 Indigenous assets. Of these, 35 are cultural values associated with animals and plants that do not have geographic location information, which means they cannot be specifically assessed for impacts due to additional coal resource development.

Conclusion

Assessment results flag where future efforts of regulators and proponents can be directed, and where further attention is not necessary. Extending this Assessment should focus on incorporating surface water modelling and representing surface water – groundwater interactions.

Key knowledge gaps identified below detail where confidence in this Assessment can be improved through further work. For example, if new coal resource developments emerge in the future, the data, information, analytical results and models from this Assessment would provide a comprehensive basis for a subregion-scale re-assessment of potential impacts under an updated CRDP. The full suite of information is provided at www.bioregionalassessments.gov.au. Users can explore detailed results (including information for individual landscape classes and assets in the subregion) using a map-based interface in the BA Explorer, available at www.bioregionalassessments.gov.au/explorer/MBC.

Key knowledge gaps identified for this Assessment are:

- *hydrological modelling*: the greatest opportunities to improve model predictions in this Assessment involve the incorporation of surface water modelling and surface water – groundwater interactions to quantify changes in streams and the regional watertable that may occur as a result of coal resource development. Using the revised OGIA 2016 model, with improved representation of regional geology, hydrostratigraphy and faults, as well as model discretisation, parameterisation and calibration, would increase confidence in this Assessment, as would water quality models and data

- *assessing impacts in the landscape*: assessment of potential impacts to the landscape was limited to an overlay analysis. While this is valuable, receptor impact models would provide better indicators of potential changes in ecosystems. Improved knowledge about the nature of a species' or community's water dependency and identification of the geographic location of Indigenous cultural assets would also increase confidence in this Assessment
- *model resolution*: there is a high level of confidence in the ability of the OGIA model to reflect broad-scale hydrological changes related to the cumulative impacts of coal resource development. However, while the resolution of the OGIA model is considered fit for purpose, a finer resolution model would be more suitable for local-scale analysis
- *climate change and land use*: factors such as climate change or land use were held constant for the two coal resource development futures. Future assessments could include these and other stressors to more fully predict cumulative impacts of coal resource development.

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This technical product was reviewed by several groups:

- Technical Assurance Reference Group: Chaired by Peter Baker (Principal Science Advisor, Department of the Environment and Energy), this group comprises officials from the NSW, Queensland, South Australian and Victorian governments
- Independent reviewers: National Centre for Groundwater Research and Training.

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 (IESC, 2015).

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 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 is 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 and Energy, 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, has undertaken BAs for the following bioregions and subregions (see http://www.bioregionalassessments.gov.au/assessments for a map and further information):

- 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.

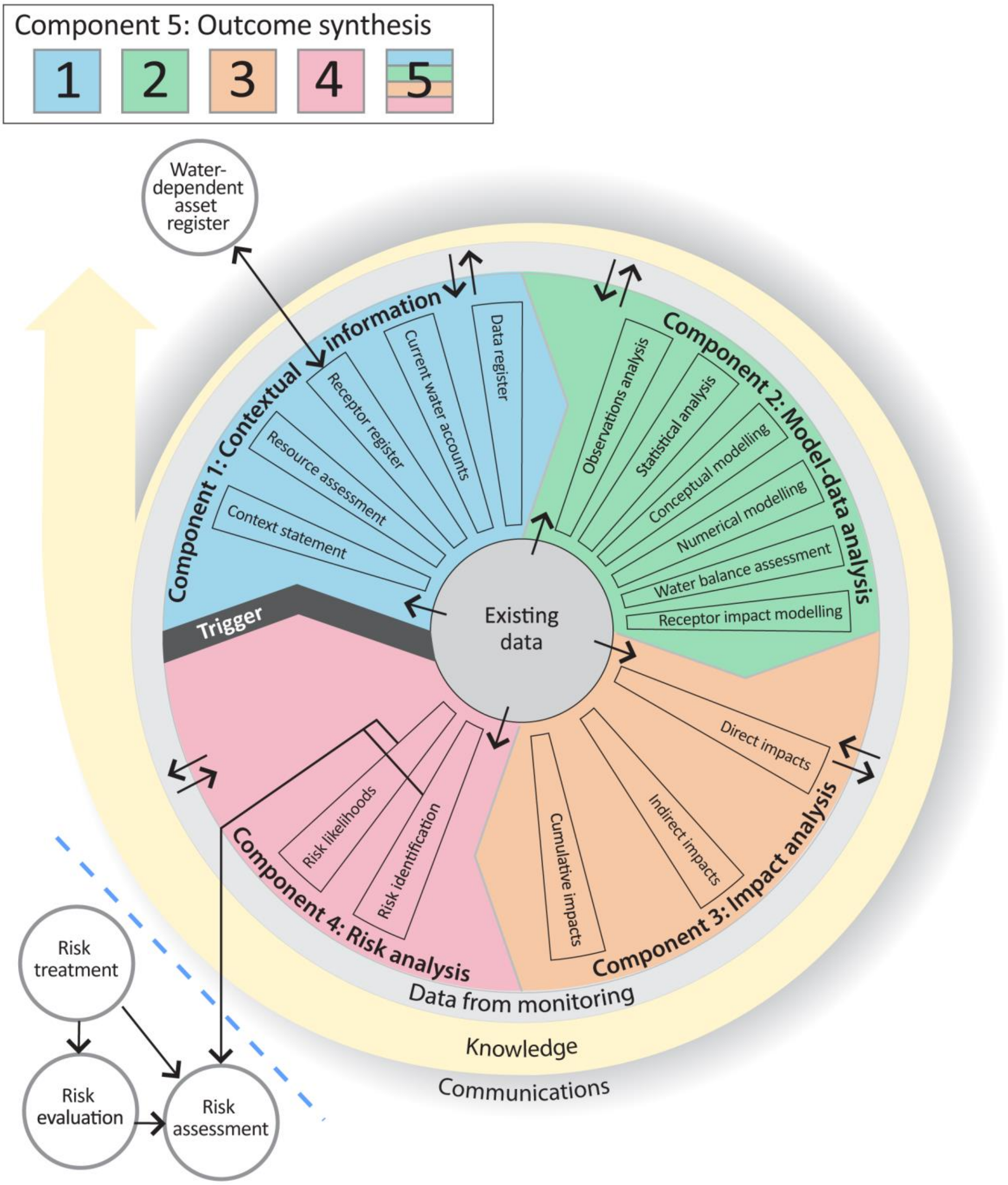

Figure 1 Schematic diagram of the bioregional assessment methodology

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

The overall scientific and intellectual basis of the BAs is provided in the BA methodology (Barrett et al., 2013). Additional guidance is required, however, about how to apply the BA methodology to a range of subregions and bioregions. To this end, the teams undertaking the BAs have developed and documented detailed scientific submethodologies (Table 1), in the first instance, to support the consistency of their work across the BAs and, secondly, to open the approach to scrutiny, criticism and improvement through review and publication. In some instances, methodologies applied in a particular BA may differ from what is documented in the submethodologies.

The relationship of the submethodologies to BA components and technical products is illustrated in Figure 2. While much scientific attention is given to assembling and transforming information, particularly through the development of the numerical, conceptual and receptor impact models, integration of the overall assessment is critical to achieving the aim of the BAs. To this end, each submethodology explains how it is related to other submethodologies and what inputs and outputs are required. They also define the technical products and provide guidance on the content to be included. When this full suite of submethodologies is implemented, a BA will result in a substantial body of collated and integrated information for a subregion or bioregion, including new information about the potential impacts of coal resource development on water and water-dependent assets.

Table 1 Methodologies

Each submethodology is available online at http://data.bioregionalassessments.gov.au/submethodology/XXX, where 'XXX' is replaced by the code in the first column. For example, the BA methodology is available at http://data.bioregionalassessments.gov.au/submethodology/bioregional-assessment-methodology and submethodology M02 is available at http://data.bioregionalassessments.gov.au/submethodology/M02. Submethodologies might be added in the future.

Code	Proposed title	Summary of content
bioregional-assessment-methodology	*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
M02	*Compiling water-dependent assets*	Describes the approach for determining water-dependent assets
M03	*Assigning receptors to water-dependent assets*	Describes the approach for determining receptors associated with water-dependent assets
M04	*Developing a coal resource development pathway*	Specifies the information that needs to be collected and reported about known coal and coal seam gas resources as well as current and potential resource developments
M05	*Developing the conceptual model of causal pathways*	Describes the development of the conceptual model of causal pathways, which summarises how the 'system' operates and articulates the potential links between coal resource development and changes to surface water or groundwater
M06	*Surface water modelling*	Describes the approach taken for surface water modelling
M07	*Groundwater modelling*	Describes the approach taken for groundwater modelling
M08	*Receptor impact modelling*	Describes how to develop receptor impact models for assessing potential impact to assets due to hydrological changes that might arise from coal resource development
M09	*Propagating uncertainty through models*	Describes the approach to sensitivity analysis and quantification of uncertainty in the modelled hydrological changes that might occur in response to coal resource development
M10	*Impacts and risks*	Describes the logical basis for analysing impact and risk
M11	*Systematic analysis of water-related hazards associated with coal resource development*	Describes the process to identify potential water-related hazards from coal resource development

Technical products

The outputs of the BAs include a suite of technical products presenting information about the ecology, hydrology, hydrogeology and geology of a bioregion and the potential 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 relationship of the technical products to BA components and submethodologies. 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 outlines in both Figure 2 and Table 2 indicate the information included in this technical product.

Technical products are delivered as reports (PDFs). Additional material is also provided, as specified by the BA methodology:

- unencumbered data syntheses and databases
- unencumbered tools, model code, procedures, routines and algorithms
- unencumbered forcing, boundary condition, parameter and initial condition datasets
- lineage of datasets (the origin of datasets and how they are changed as the BA progresses)
- gaps in data and modelling capability.

In this context, unencumbered material is material that can be published according to conditions in the licences or any applicable legislation. All reasonable efforts were made to provide all material under a Creative Commons Attribution 3.0 Australia Licence.

Technical products, and the additional material, are available online at http://www.bioregionalassessments.gov.au.

The Bureau of Meteorology archives a copy of all datasets used in the BAs. This archive includes datasets that are too large to be stored online and datasets that are encumbered. The community can request a copy of these archived data at http://www.bioregionalassessments.gov.au.

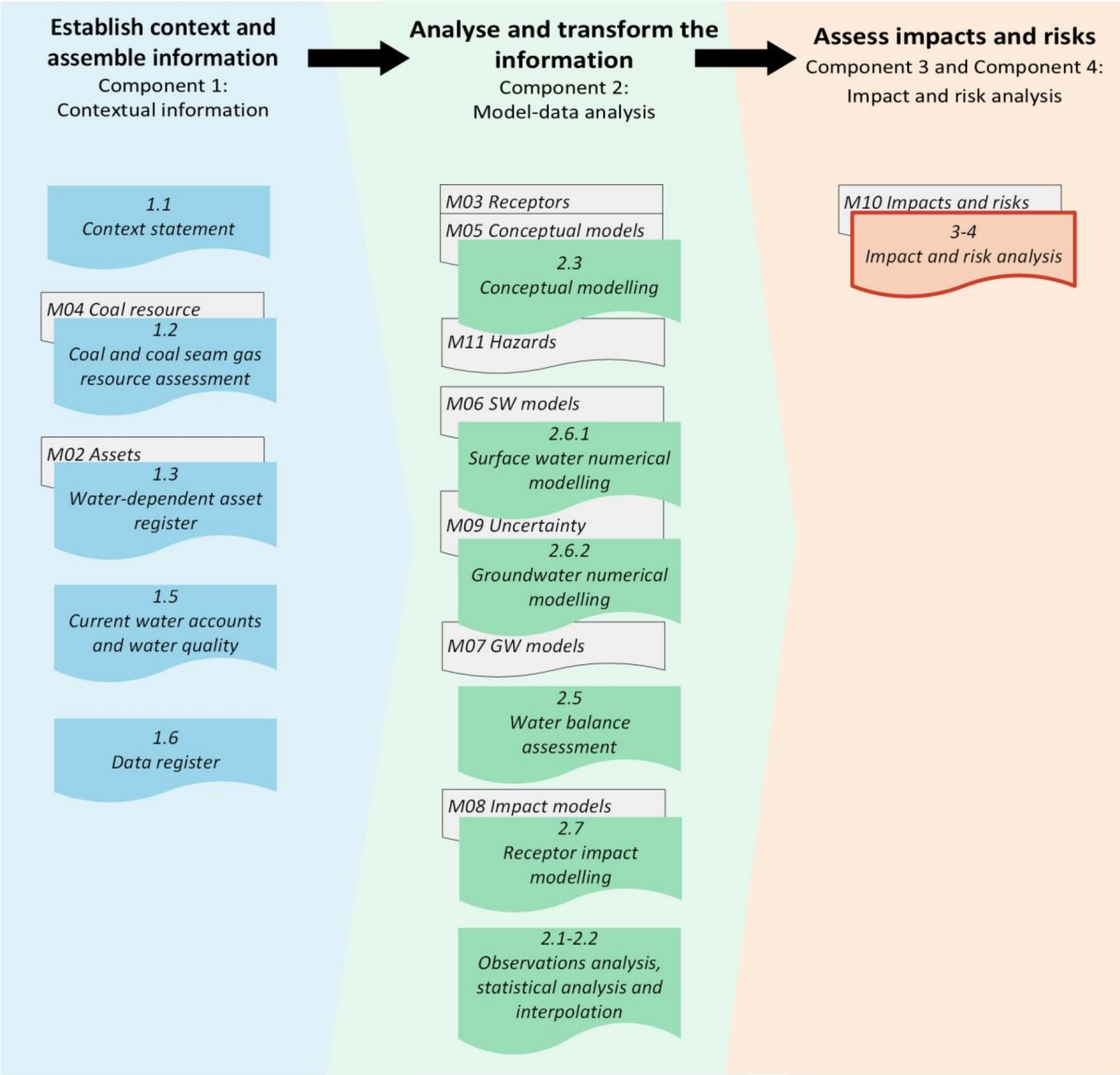

Figure 2 Technical products and submethodologies associated with each component of a bioregional assessment

In each component (Figure 1) of a bioregional assessment, a number of technical products (coloured boxes, see also Table 2) are potentially created, depending on the availability of data and models. The light grey boxes indicate submethodologies (Table 1) that specify the approach used for each technical product. The red outline indicates this technical product. The BA methodology (Barrett et al., 2013) specifies the overall approach.

Table 2 Technical products delivered for the Maranoa-Balonne-Condamine subregion

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. There is no product 1.4. Originally this product was going to describe the receptor register and application of landscape classes as per Section 3.5 of the BA methodology, but this information is now included in product 2.3 (conceptual modelling) and used in product 2.6.1 (surface water numerical modelling) and product 2.6.2 (groundwater numerical modelling). There is no product 2.4. Originally this product was going to include two- and three-dimensional representations as per Section 4.2 of the BA methodology, but these are instead included in products such as product 2.3 (conceptual modelling) and product 2.6.2 (groundwater numerical modelling).

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
	1.5	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	Not produced
	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 and Component 4: Impact and risk analysis for the Maranoa-Balonne-Condamine subregion	3-4	Impact and risk analysis	5.2.1, 2.5.4, 5.3	PDF, HTML
Component 5: Outcome synthesis for the Maranoa-Balonne-Condamine subregion	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 format 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.
- '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°.
- Visit http://bioregionalassessments.gov.au to access metadata (including copyright, attribution and licensing information) for datasets cited or used to make figures in this product.
- In addition, the datasets are published online if they are unencumbered (able to be published according to conditions in the licence or any applicable legislation). The Bureau of Meteorology archives a copy of all datasets used in the BAs. This archive includes datasets that are too large to be stored online and datasets that are encumbered. The community can request a copy of these archived data at http://www.bioregionalassessments.gov.au.
- 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.

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3. Impact analysis for the Maranoa-Balonne-Condamine subregion

The impact and risk analysis is the key output of a bioregional assessment (BA). This product presents potential impacts of coal resource development on water resources and water-dependent assets in the Maranoa-Balonne-Condamine subregion. Risks are analysed by assessing the magnitude and likelihood of these potential impacts.

The impact and risk analysis (Component 3 and Component 4) builds on the contextual information (Component 1) and knowledge from the model-data analysis (Component 2).

In this impact and risk analysis:

- A zone of potential hydrological change is determined using the groundwater numerical hydrological modelling results (from product 2.6.2 (groundwater numerical modelling)). Note that surface water numerical modelling was not undertaken for this subregion thus the zone was defined solely based on changes in groundwater.
- The zone of potential hydrological change is overlain with the extent of the landscape classes (product 2.3 (conceptual modelling)) and water-dependent assets (product 1.3 (description of water-dependent asset register)) to identify those ecosystems and assets that might be subject to hydrological change.
- Potential impacts to ecological assets are considered via only the overlay analysis. In contrast to other subregions, this BA did not develop qualitative mathematical models of the response of ecosystems to hydrological changes, nor undertake receptor impact modelling, which translates the changes in hydrology into changes in ecosystems.
- Potential impacts to economic and sociocultural assets are considered via changes to water availability and accessibility.

The product concludes with key findings, knowledge gaps and next steps.

3.1 Overview

Summary

The Maranoa-Balonne-Condamine subregion has an area of 144,890 km^2 and includes the headwaters of the Condamine River and the Maranoa River, as well as the floodplains of the Upper Darling Plains. The main cities and towns are Chinchilla, Dalby, Goondiwindi, Roma, St George, Toowoomba and Warwick. The subregion contains seasonal, semi-permanent and permanent wetlands and lagoons, including some nationally significant wetlands.

Bioregional assessments (BAs) are independent scientific assessments of the potential cumulative impacts of coal seam gas (CSG) and coal mining developments on water resources and water-dependent assets such as rivers, wetlands and groundwater systems. The assessments identify areas where water resources and water-dependent assets are *very unlikely* to be impacted (less than 5% chance), or are potentially impacted. This will allow governments, industry and the community to focus on areas that are potentially impacted when making regulatory, water management and planning decisions.

The impact and risk analysis considers hydrological changes under two potential futures: the baseline and the coal resource development pathway (CRDP). Baseline drawdown is the maximum difference in groundwater drawdown (*dmax*) in metres under the baseline relative to no coal resource development. Additional drawdown is the maximum difference in drawdown (*dmax*) between the CRDP and baseline, due to the two additional coal resource developments: New Acland Coal Mine Stage 3 and The Range coal mine. The groundwater model's limited capabilities with respect to simulating surface water – groundwater interactions mean that surface water modelling was not undertaken for this subregion.

3.1.1 Maranoa-Balonne-Condamine subregion

The Maranoa-Balonne-Condamine subregion has an area of 144,890 km^2 and is mainly within the Queensland part of the Murray–Darling Basin, with a small area in NSW. It includes the headwaters of the Condamine River and the Maranoa River, as well as the floodplains of the Upper Darling Plains. The main cities and towns are Chinchilla, Dalby, Goondiwindi, Roma, St George, Toowoomba and Warwick (Figure 3).

Most of the land is used for agriculture. Groundwater use varies across the subregion, but is commonly extracted for stock and domestic purposes, as well as for town water supply, agriculture and coal seam gas (CSG) production.

Wetlands in the subregion include seasonal, semi-permanent and permanent wetlands and lagoons. Some of these wetlands are nationally significant. The Culgoa River Floodplains and the Narran Lakes system are downstream of the subregion, with the northern part of the Narran Lakes system identified as an internationally recognised and protected wetland. The subregion is home to a number of water-dependent ecological communities, animals and plants which are listed as threatened under Queensland and Commonwealth legislation.

The Maranoa-Balonne-Condamine subregion is underlain by extensive sedimentary rock sequences associated with several geological basins, including large parts of the Surat Basin, the north-west part of the Clarence-Moreton Basin and the southern Bowen Basin. These sedimentary basins are endowed with nationally significant fossil fuel resources, such as coal and hydrocarbons, and include most of Australia's recognised CSG reserves. There has been a long history of coal mining and conventional petroleum extraction within the Maranoa-Balonne-Condamine subregion, with CSG production from the Surat Basin's Walloon Coal Measures becoming an important driver of coal resource development in the subregion since the late 1990s.

In the context of BAs, coal resource development in the Maranoa-Balonne-Condamine subregion can potentially affect surface water and groundwater systems, and the water-dependent ecosystems and assets that rely on these water resources. Of particular focus in this Assessment is understanding the potential for cumulative hydrological impacts arising from the interaction of open-cut coal mining operations and CSG production in the subregion. This analysis especially applies to those coal mines likely to begin commercial operations after 2012, termed additional coal resource development in the BAs (see Section 3.1.2 for further details about the baseline and CRDP).

This assessment used the Office of Groundwater Impact Assessment's (OGIA) 2012 model that was adapted to include open-cut coal mines in both the baseline and the CRDP, compared to previous versions that only included CSG developments. OGIA's most recent model was not available for this Assessment (OGIA, 2016). OGIA is an independent entity established to assess and manage cumulative groundwater impacts from resource activities in areas of concentrated CSG development, known as cumulative management areas (CMAs). The Surat Cumulative Management Area (CMA) includes almost the entire Maranoa-Balonne-Condamine assessment extent.

The representation of hydrological changes in surficial aquifers that affect surface water – groundwater interactions and groundwater-dependent ecosystems (GDEs) is identified by the formal qualitative uncertainty analysis as providing the greatest opportunity to reduce predictive uncertainty in the OGIA model. The representation of surface water – groundwater interactions in the model, where groundwater only flows from the aquifer into the watercourse, is a conservative approach to predicting groundwater drawdown as it means that recharge from surface water cannot affect predicted groundwater drawdown. These model assumptions do not affect predicted groundwater drawdown, but mean that modelled surface water – groundwater interactions that are necessary for coupled surface water – groundwater modelling are not feasible at this time (see Section 2.6.2.8 in companion product 2.6.2 for the Maranoa-Balonne-Condamine subregion (Janardhanan et al., 2016) for further details about the groundwater modelling qualitative uncertainty analysis).

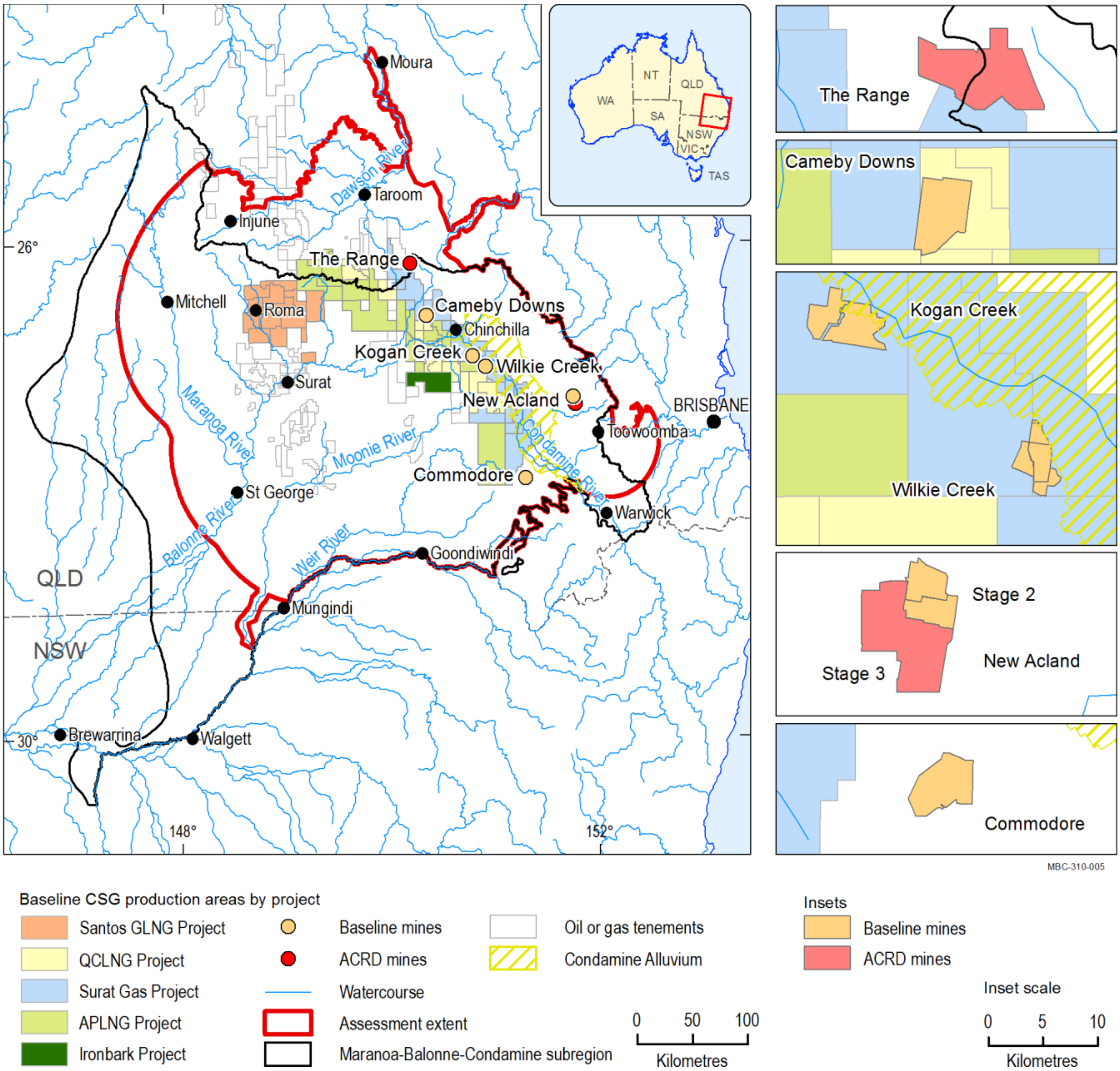

Figure 3 Baseline and additional coal resource developments included in the coal resource development pathway

Coal seam gas (CSG) production is shown by the extent of petroleum tenures, which are all in the baseline. Some of the petroleum tenures are located outside the subregion, but are included in the coal resource development pathway (CRDP) as they contain gas fields located partially within the subregion. The mines in the CRDP are the sum of those in the baseline and the additional coal resource development (ACRD). All petroleum tenures shown are part of the baseline.
APLNG Project = Australia Pacific LNG Project, LNG = Liquefied Natural Gas, QCLNG Project = Queensland Curtis LNG Project, Santos GLNG Project = Santos Gladstone LNG Project + GLNG Gas Field Development Project
Data: Bioregional Assessment Programme (Dataset 1); Department of Natural Resources and Mines (Dataset 2)

3.1.2 Scope and context

The objective of the Bioregional Assessment Programme is to understand and predict regional-scale cumulative impacts on water resources and water-dependent assets caused by coal resource developments in Australia's major coal-bearing sedimentary basins. The assessments identify areas where water resources and water-dependent assets are *very unlikely* to be impacted (less than 5% chance), or are potentially impacted. Governments, industry and the community can then focus on areas that are potentially impacted when making regulatory, water management and planning decisions.

The impact and risk analysis considered only biophysical consequences, such as changes in hydrology or ecology; fully evaluating consequences requires value judgments and non-scientific information that is beyond the scope of BAs. A full risk assessment (with risk evaluation and risk treatment) was not conducted as part of BAs.

The purpose of this section is to highlight the design choices that have steered the direction of this Assessment and culminated in the impact and risk analysis. The following six themes are covered:

- choice of modelled futures
- focus on water quantity and availability
- assessment of cumulative developments
- focus on predictive uncertainty
- a landscape classification
- ruling out potential impacts.

Further details about the design choices are provided in companion submethodology M10 (as listed in Table 1) for analysing impacts and risks (Henderson et al., 2017).

3.1.2.1 Choice of modelled futures

A BA is a regional analysis that compares two futures of coal resource development. In BAs, the term 'coal resource development' specifically includes coal mining (both open-cut and underground) as well as CSG extraction. Other forms of coal-related development activity, such as underground coal gasification and microbial enhancement of gas resources, are not within the scope of BAs.

The two futures considered in the BA for the Maranoa-Balonne-Condamine subregion are:

- *baseline coal resource development (baseline)*[1]: a future that includes all coal mines that are commercially producing as of December 2012 and five CSG fields reported in the *Annual report 2014 for the Surat underground water impact report* (OGIA, 2014)
- *coal resource development pathway (CRDP):* a future that includes all coal mines and CSG fields that are in the baseline as well as those that are expected to begin commercial production after December 2012.

The five baseline open-cut coal mines in the subregion are Cameby Downs Mine, Commodore Mine, Kogan Creek Mine, New Acland Coal Mine Stage 2 and Wilkie Creek Mine (which ceased operations in December 2013). For this Assessment, the five baseline CSG fields (Australia Pacific Liquefied Natural Gas (LNG) Project, Santos Gladstone LNG Project, Queensland Curtis LNG Project, Surat Gas Project and Ironbark Project) are deemed to be in the BA baseline to ensure consistency with the CSG development profile reported in the *Annual report 2014 for the Surat underground water impact report* (OGIA, 2014). The OGIA model was the best available representation of CSG development in the Surat CMA when the CRDP was finalised in July 2015

[1] Note this differs from the usual definition of baseline used across the Bioregional Assessment Technical Programme, which is defined as a future that includes all coal mines and CSG fields that are commercially producing as of December 2012.

(see companion product 2.3 for the Maranoa-Balonne-Condamine subregion (Holland et al., 2016)).

The difference in results between CRDP and baseline is the change that is primarily reported in a BA. This change is due to the *additional coal resource development* – all coal mines and CSG fields, including expansions of baseline operations, that are expected to begin commercial production after December 2012. In the Maranoa-Balonne-Condamine subregion these are the New Acland Coal Mine Stage 3 and The Range coal mine. Further details are provided in companion product 2.3 for the Maranoa-Balonne-Condamine subregion (Holland et al., 2016).

Although the difference in potential impacts between these two futures is of most concern, the potential impacts under the baseline are important for regional context. For instance, the potential implications to groundwater-dependent assets of an additional 2 m of drawdown may depend on whether the drawdown under the baseline is 0.05, 0.5 or even 50 m. Potentially important impacts due to coal resource development under the baseline may also occur in parts of the subregion that are not further affected by additional coal resource development, and so are given less attention in the assessment. Note that the year in which maximum drawdown occurs under each future is unlikely to coincide and that simply adding the drawdown results in a worst-case scenario that is unlikely to eventuate.

The CRDP is considered the most likely future, based on the analysis and expert judgment of the Assessment team in consultation with coal and gas industry representatives, state agencies and the Australian Government. The CRDP was finalised based on information available as of July 2015 (companion product 2.3 (Holland et al., 2016)). The reality is that the CRDP may ultimately be implemented in different ways (e.g. changes to timing) or circumstances of coal resource developments may even change (e.g. a proponent may withdraw for some reason). This reflects the dynamic nature of resource investment decision making, which may ultimately be impacted by diverse economic, political or social factors. Consequently, the CRDP needs to be viewed as an indicative future that highlights potential changes for water resources and water-dependent assets that may need to be considered further in local analyses or conditions. Equally as important, the CRDP plays a role in identifying where changes will not occur and thus flagging where potential impacts to water resources and water-dependent assets are *very unlikely* (less than 5% chance).

Factors such as climate change or land use (such as agriculture) are held constant between the two futures. Although the future climate and/or land use may differ from those assumed in BAs, the effect of this choice is likely to be small because the focus of BAs is on reporting the difference in results between the CRDP and baseline.

3.1.2.2 Focus on water quantity and availability

BAs focus solely on water-related impacts, and specifically those related to water quantity or availability. Potential water quality hazards were identified through the comprehensive hazard analysis undertaken as part of conceptual modelling for the Maranoa-Balonne-Condamine subregion (companion product 2.3 (Holland et al., 2016)). Potential water quality hazards were identified but the analysis, as determined by the BA scope, was limited to salinity, which was addressed qualitatively.

BAs focus on those surface water and groundwater effects that may accumulate, either over extended time frames or as a result of multiple coal resource developments. These typically correspond to changes in surface water and groundwater that are sustained over long periods of time, sometimes over decades, and that may create the potential for flow-on effects through the wider hydrological system.

Many activities related to coal resource development may cause local or on-site changes to surface water or groundwater. These are not considered in BAs because they are assumed to be adequately managed by site-based risk management and mitigation procedures, and are unlikely to create potential cumulative impacts. Impacts and risks associated with water quality attributes other than salinity that are potentially affected by coal resource development are identified, but not analysed further, in this Assessment.

3.1.2.3 Assessment of cumulative developments

BAs are designed to analyse the cumulative impacts of coal resource developments. The baseline and CRDP may each consider a suite of developments, the potential impacts of which may overlap to varying degrees in both time and space. This allows users of an assessment to predict and understand the cumulative hydrological changes and potential impacts of those developments on surface water, groundwater and water-dependent assets. In some cases, the spatial or temporal alignment of certain coal resource developments may allow for some attribution of potential effects to individual developments, but is due to this alignment rather than by design.

The hydrological modelling results are reported for each grid cell individually. The maximum hydrological change in each grid cell occurs at different times across the area assessed, and the year of maximum change under the baseline does not necessarily coincide with the year of maximum change due to additional coal resource development. Therefore, adding these two results in a hydrological change that is unlikely to eventuate.

3.1.2.4 Focus on predictive uncertainty

In BAs, parameter uncertainty was considered as fully as possible when predicting hydrological outcomes (i.e. changes to surface water or groundwater) and ecological outcomes (i.e. changes to ecologically relevant receptor impact variables). For example, groundwater models were run hundreds to thousands of times using a wide range of plausible input parameters for many of the critical hydraulic properties, such as the hydraulic conductivity and storage coefficients of all modelled hydrogeological layers. This differs from the traditional deterministic approach used more routinely for groundwater and surface water modelling and is driven by the risk analysis focus of BAs. The quantitative representation of the predictive uncertainty through probability distributions allows BAs to consider the likelihood of impacts with a specified magnitude and underpins the impact and risk analysis. Sources of uncertainty that could not be quantified through numerical modelling were considered qualitatively.

3.1.2.5 A landscape classification

Subregions are complex landscapes with a wide range of human and ecological systems. The systems can be discrete, overlapping or integrated. Because of this complexity, a direct analysis of each and every point, or water-dependent asset, in the landscape across the subregion is not possible. Abstraction and a system-level classification was used to manage the challenges of the dimensionality of the task.

A set of landscape classes were defined that are similar in their physical, biological and hydrological characteristics. This reduced the complexity for each subregion and is appropriate for a regional-scale assessment. The landscape classification characterises the landscape and focuses on the key processes, functions and interactions for the individual landscape classes. The landscape classification for the Maranoa-Balonne-Condamine subregion built on existing well-accepted classifications and is described in detail in companion product 2.3 for the Maranoa-Balonne-Condamine subregion (Holland et al., 2016). The landscape classification allowed effort to be focused on those landscape classes that are water dependent.

The assessment of impacts on and risks to water-dependent ecological assets relied heavily on the landscape classification. Potential impacts to individual assets were assessed via their constituent landscape classes. The zone of potential hydrological change was overlain with the extent of the landscape classes to identify those ecosystems and assets that might be subject to hydrological change.

3.1.2.6 Ruling out potential impacts

The 'rule-out' process is used to identify areas, and consequently water resources and water-dependent assets, that are *very unlikely* to experience hydrological change or impact due to additional coal resource development.

Firstly, the 'preliminary assessment extent' is defined for each subregion or bioregion. This is a conservative spatial boundary that includes the groundwater and surface water systems that may be affected by coal resource development in the subregion. The preliminary assessment extent (PAE) contains all water-dependent assets, landscape classes that summarise key surface ecosystems, and helps define the spatial extent of numerical surface water and/or groundwater models in the subregion. Hydrological modelling is used to finalise the 'assessment extent' used for the impact and risk analysis. The assessment extent used in this product is identical to the PAE identified in product 1.3 for the Maranoa-Balonne-Condamine subregion (Mitchell et al., 2015).

Hydrological modelling results are then used to define a zone to 'rule out' potential impacts. The zone of potential hydrological change is the area with at least a 5% chance of greater than 0.2 m drawdown due to additional coal resource development. This threshold matches state regulations to protect sensitive water-dependent landscapes and assets from adverse effects. Because surface water modelling was not undertaken for this subregion, groundwater hydrological changes alone were used to define the zone.

The zone is represented at the surface, or in the relevant geological layer from which water-dependent landscapes and assets source water. Water-dependent landscapes and assets outside of this zone are *very unlikely* to be impacted by hydrological changes due to additional coal resource development.

3.1.3 Structure of this product

This product presents information about the impact and risk analysis for the Maranoa-Balonne-Condamine subregion and is the key output of the BAs. The structure is as follows:

- Section 3.1 describes the scope of the BA conducted for the Maranoa-Balonne-Condamine subregion and summarises the critical philosophical and operational choices.
- Section 3.2 describes the methods for assessing impacts and risks in the Maranoa-Balonne-Condamine subregion. There is a strong focus on the conceptual model of causal pathways as this provides the logic and reasoning for the impact and risk analysis. It includes details of the databases, tools and geoprocessing that support the impact and risk analysis, and the approach to aggregating potential impacts to landscape classes and assets. The approach is consistent with that outlined in the companion submethodology M10 (as listed in Table 1) for analysing impacts and risks (Henderson et al., 2017).
- Section 3.3 provides a closer look at the spatial extent of hydrological changes within the zone of potential hydrological change. Outputs of the modelling are used to define a zone of potential hydrological change, which is used to focus the analysis, noting that surface water was not modelled in the Maranoa-Balonne-Condamine and this zone is therefore based on groundwater modelling only.
- Section 3.4 considers the impacts on and risks to landscape classes in the zone of potential hydrological change due to additional coal resource development. This section presents an aggregated, system-level analysis of potential impacts on landscape classes. Landscape classes (where they exist) and other information sources are described, including iconic species or communities within each landscape class. The zone of potential hydrological change is overlain with the extent of the landscape classes to identify those ecosystems and assets that might be subject to hydrological change (noting that quantitative receptor impact models were not developed for the Maranoa-Balonne-Condamine subregion).
- Section 3.5 considers the impacts on and risks to water-dependent assets (Mitchell et al., 2015) in the zone of potential hydrological change due to additional coal resource development. The analysis focuses predominantly on asset subgroups and classes, rather than each individual asset. It includes ecological, economic and sociocultural assets.
- Section 3.6 assesses the potential hydrological changes and impacts due to the additional coal resource development that were not modelled (noting that all mines and gas fields included in the CRDP for the Maranoa-Balonne-Condamine subregion are modelled).
- Section 3.7 concludes with key findings and knowledge gaps. Commentary is provided on how to validate and build on this Assessment in the future.

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Datasets

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3.2 Methods

Summary

The impact and risk analysis followed the overarching methodology described in companion submethodology M10 (as listed in Table 1) for analysing impacts and risks (Henderson et al., 2017). The impact analysis quantified the magnitude or extent of the potential hydrological or ecosystem changes due to coal resource development, including direct, indirect and cumulative. The risk analysis considered not only the magnitude or extent of the potential impact, but also the likelihood of the impact.

The first step in the impact and risk analysis was to use the conceptual model of causal pathways and probabilistic estimates of hydrological change to identify potential impacts to water-dependent landscapes and assets. Impacts to water-dependent landscapes and assets are mostly caused by changes to groundwater in the regional watertable.

For bioregional assessment (BA) purposes, the regional watertable represents the upper groundwater level within the near-surface aquifer (not perched), and may exist in different geological units or layers. Near the two additional coal resource developments it occurs in the alluvium, as well as the Main Range Volcanics and the Walloon Coal Measures. Springs and groundwater bores may be affected by hydrological changes in deeper geological layers, which may have repercussions for surface ecosystems surrounding springs.

The adapted Office of Groundwater Impact Assessment (OGIA) model was used to quantify hydrological changes to the groundwater system arising from coal resource development in the subregion. Estimates of groundwater drawdown for the two futures considered by BAs were used to define a zone of potential hydrological change for each potentially affected model layer or source aquifer.

Potential impacts to water-dependent landscapes and assets were assessed by overlaying their location on the zone of potential hydrological change for the relevant source aquifer. Outside this zone, landscapes and assets were ruled out from potential impacts and not analysed further. Inside the zone, potential hydrological changes were summarised for each landscape class or asset. The databases, tools and geoprocessing that support the impact and risk analysis were also summarised.

3.2.1 Impact and risk analysis

The *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) states:

> The central purpose of BAs is to analyse the impacts and risks associated with changes to water-dependent assets that arise in response to current and future pathways of CSG and coal mining development.

The impact and risk analysis for the Maranoa-Balonne-Condamine subregion (Component 3 and Component 4) followed the overarching logic described in companion submethodology M10 (as listed in Table 1) for analysing impacts and risks (Henderson et al., 2017), and is summarised diagrammatically in Figure 4. It builds on the contextual information (Component 1) and model-data analysis (Component 2) (as listed in Table 2). The impact and risk analysis represents the culmination of effort to improve the knowledge base around the coal resource development, and to understand how water resources and water-dependent assets may be affected by hydrological changes due to additional coal resource development in the Maranoa-Balonne-Condamine subregion.

The impact analysis quantified the magnitude or extent of the potential hydrological and ecosystem changes due to coal resource development. This included:

- *direct impacts*: a change in water resources and water-dependent assets resulting from coal seam gas (CSG) and coal mining developments without intervening agents or pathways
- *indirect impacts*: a change in water resources and water-dependent assets resulting from CSG and coal mining developments with one or more intervening agents or pathways
- *cumulative impacts*: the total change in water resources and water-dependent assets resulting from CSG and coal mining developments when all past, present and reasonably foreseeable actions that are likely to impact on water resources are considered.

The risk analysis is related, but considered not only the magnitude or extent of the potential impact but also the likelihood of that impact. This is often framed as 'consequence multiplied by the likelihood'. The quantification of the likelihood was underpinned by a dedicated uncertainty analysis that allowed probabilistic statements to be made about certain events or impacts occurring. Within BAs, the uncertainty analysis stochastically propagated uncertainties in underlying hydrological parameters through hydrological models to produce distributions of potential surface water and groundwater changes. These in turn were input to receptor impact models to produce distributions of receptor impact variables, which were chosen as indicators of potential ecosystem impacts.

BAs identify risks through a hazard analysis and analyse those risks by estimating the magnitude and likelihood of specific impacts. The risk assessment, risk evaluation and the risk treatment that occur as part of the broader risk management (see for instance ISO 31000:2009 *Risk Management Standards*) are considered beyond the scope of BAs. BAs do not consider a number of non-scientific matters and value judgements; these are roles of proponents and government regulators in the first instance, and often in response to specific community values.

Throughout this product there is a focus on describing the hydrological changes, and then the potential impacts of those changes to landscape classes and water-dependent assets, which contain ecological, economic and sociocultural values.

BAs present the likelihood of certain impacts occurring, for example, the percent chance of exceeding 5 m of drawdown in a particular aquifer and location. The underpinning data and information are available at www.bioregionalassessments.gov.au for others to use in their own targeted risk assessments. Users can choose thresholds of impact that may threaten the specific values they are trying to protect and calculate the corresponding likelihood of occurrence.

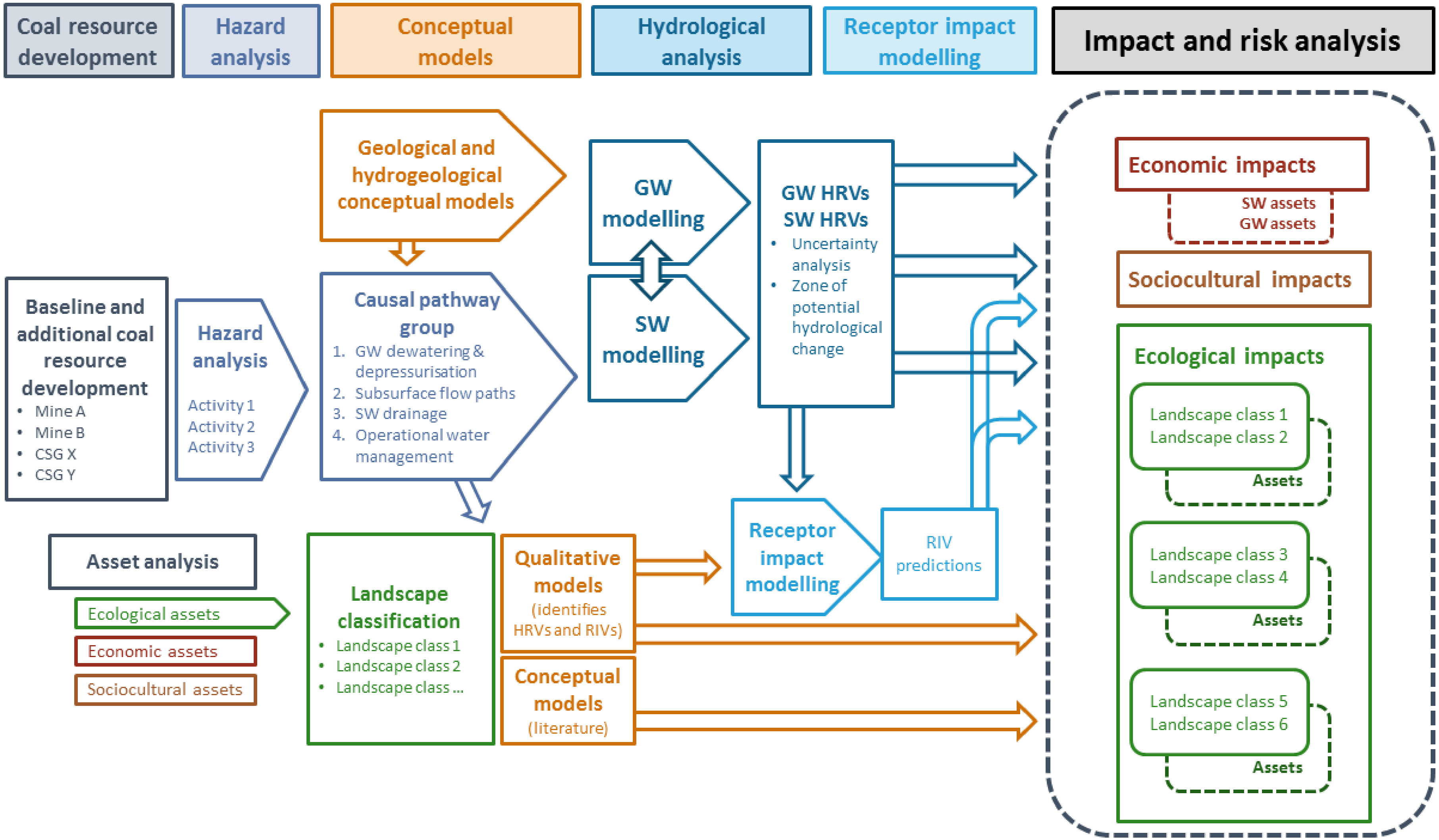

Figure 4 Overarching methodology for impact and risk analysis in bioregional assessments

CSG = coal seam gas, GW = groundwater, HRV = hydrological response variable, RIV = receptor impact variable, SW = surface water

3.2.2 Causal pathways

The conceptual model of causal pathways describe the logical chain of events – either planned or unplanned – that link coal resource development to potential impacts on water resources and water-dependent assets. These causal pathways provided the logical and transparent foundation for the impact and risk analysis and are described in companion product 2.3 for the Maranoa-Balonne-Condamine subregion (Holland et al., 2016).

A systematic hazard analysis, using the Impact Modes and Effects Analysis method (described in companion submethodology M11 (as listed in Table 1) for hazard analysis (Ford et al., 2016)), was undertaken for the Maranoa-Balonne-Condamine subregion. The hazard analysis identified activities that occur as part of coal resource development that might result in a change in the quality or quantity of surface water or groundwater. Hazards were prioritised according to the likelihood, severity and detectability of potential impacts (Bioregional Assessment Programme, Dataset 1). It is important to ensure that all hazards are addressed by the impact and risk analysis, but this does not mean that all causal pathways need to be assessed in the same way, only that they are all addressed in some way.

The many individual 'hazards' themselves were not represented directly in the hydrological models, but instead were grouped into four causal pathway groups, which reflect the main hydrological pathways by which the effects of a hazard can propagate from its origin. These simplified pathways are broadly represented in the BA hydrological models. These causal pathway groups are:

- 'Subsurface depressurisation and dewatering'
- 'Subsurface physical flow paths'
- 'Surface water drainage'
- 'Operational water management'.

Figure 5, Figure 6 and Table 3 describe the system components and associated hydrological effects of the causal pathways considered to be in scope for open-cut coal mines and CSG operations in the Maranoa-Balonne-Condamine subregion (refer Section 2.3.5 in companion product 2.3 (Holland et al., 2016)). Hydrological effects associated with coal resource development occur in four system components:

- 'watercourses within and downstream of tenements' system component
- 'alluvium and watercourses in aquifer outcrop areas within and downstream of tenements' system component
- 'aquifers within tenements' system component
- 'aquifers' system component.

The hydrological models represent causal pathways through their conceptualisations and parameterisations. The outputs from the hydrological models do not identify individual causal pathways but rather integrate the various possible causal pathways into the predicted hydrological response at particular points in space and time.

Not all hydrological effects can be modelled. Some cannot be modelled due to scale or complexity and were addressed qualitatively using the current conceptual understanding and knowledge base. Changes in water quality due to coal resource development activities were considered qualitatively through potential effects on stream salinity (Section 3.3.4). Some identified hazards were deemed to be local in scale and addressed by existing site-based management, whereas some were considered knowledge gaps (e.g. because the location and volume of reinjection of co-produced water to restore groundwater pressure in a depleted aquifer is unknown). Others were considered of such low likelihood and/or consequence for broader cumulative impacts at the regional scale that they were not included.

While the causal pathway groups are generic, the physical characteristics of a subregion, such as its geological, geophysical and topographic architecture, and related surface water and groundwater networks, will influence the hydrological connectivity across the subregion. The Assessment team's conceptual understanding of the dominant geological and topographic influences on surface water and groundwater connectivity in the Maranoa-Balonne-Condamine subregion is described in companion product 2.3 (Holland et al., 2016). The cumulative effects of aquifer depressurisation associated with coal resource development in the Maranoa-Balonne-Condamine subregion predicted by the groundwater numerical modelling is described in companion product 2.6.2 (Janardhanan et al., 2016). Hydrological effects that can and cannot, or have not been modelled are indicated in Figure 6.

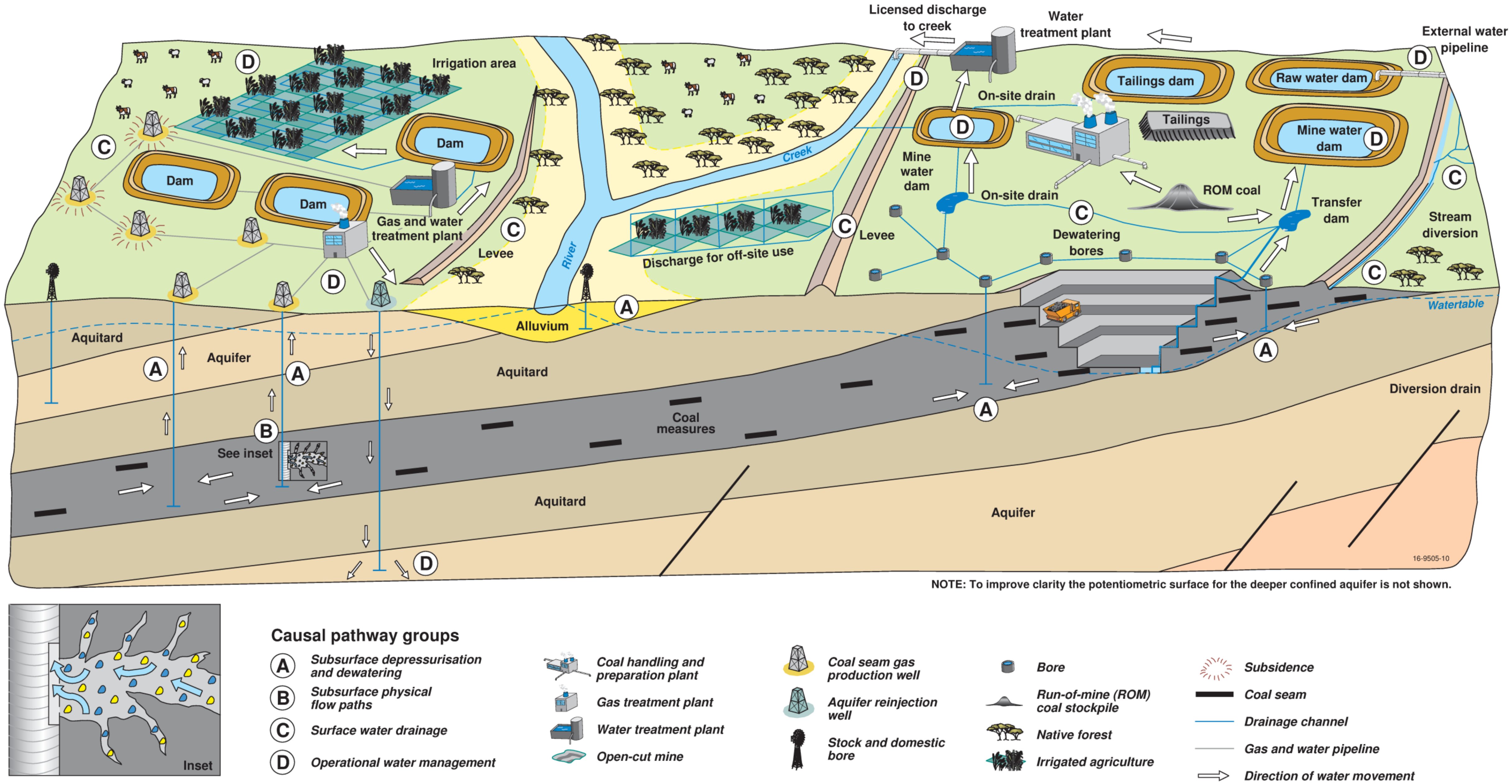

Figure 5 Conceptual diagram of the causal pathway groups associated with coal seam gas operations and open-cut coal mines for the Maranoa-Balonne-Condamine subregion

This conceptual diagram is not drawn to scale. The inset schematic shows hydraulic fracturing of a coal seam, where a mixture predominantly composed of water (blue) and sand (yellow), with minor amounts of chemical additives, is injected at high pressure into the well to produce small cracks in the coal (lighter grey zone). This process enhances the permeability of the coal seam, enabling larger volumes of gas and water to be subsequently pumped from the well.

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

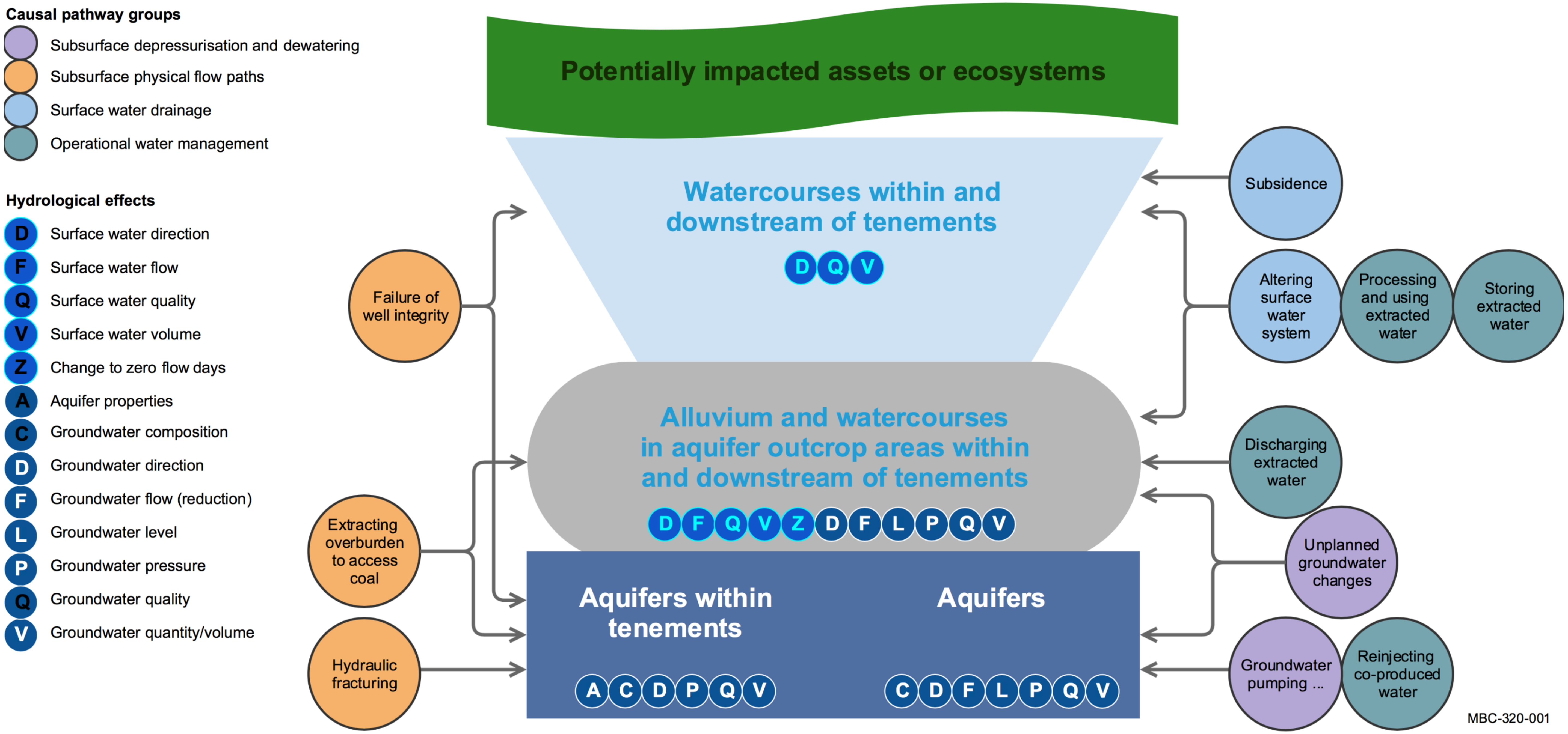

Figure 6 System components and associated hydrological effects of the causal pathways considered to be in scope in the Maranoa-Balonne-Condamine subregion, for both the baseline and coal resource development pathway

Hydrological effects denoted by symbols with black font are not predicted by numerical modelling in the Maranoa-Balonne-Condamine subregion, but are instead assessed qualitatively.

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

Table 3 Causal pathways in the Maranoa-Balonne-Condamine subregion and their associated hazards, hydrological effects, system components and temporal context

Each causal pathway is listed in a chain of logic from the hazard and associated hydrological effects to system components (as defined in Figure 5) that may contain potentially impacted assets or ecosystems.

Causal pathway group – Causal pathway	Hazards (impact mode)	Hydrological effects	System components	Temporal context[a]
Subsurface depressurisation and dewatering – Groundwater pumping enabling coal seam gas extraction, Groundwater pumping enabling open-cut coal mining, Groundwater pumping of target aquifer	Aquifer depressurisation, Aquifer depressurisation (coal seam), Groundwater extraction (groundwater supply bore), Localised watertable reduction, Reduction in pressure head (pump testing), Very localised watertable reduction	Groundwater flow (reduction), Groundwater level, Groundwater pressure	Target aquifer	Short term, Long term
Subsurface depressurisation and dewatering – Unplanned groundwater changes in non-target aquifers	Aquifer depressurisation (fault-mediated), Aquifer depressurisation (non-target, non-reservoir), Deliberate dewatering (pit wall stabilization), Miss perforation of target aquifer[b]	Surface water flow, Groundwater direction, Groundwater flow (reduction), Groundwater pressure, Groundwater quality, Groundwater quantity/volume	Non-target aquifer, Alluvium and watercourses in aquifer outcrop areas within and downstream of tenements	Medium to long term, Long term
Subsurface physical flow paths – Failure of well integrity	Bore leakage between aquifers, Bore leakage to surface, Fluid loss to aquifer, Incomplete seal, Incomplete/ compromised cementing/casing (gas leakage), Incomplete/ compromised cementing/ casing (linking aquifers), Intersection of artesian aquifer, Miss perforation of target aquifer[b] (connecting aquifers), Mud pressure imbalance, Seal integrity loss	Surface water quality, Groundwater quality, Groundwater composition, Groundwater pressure	Aquifers within tenements, Watercourses within and downstream of tenements	Short term, Long term
Subsurface physical flow paths – Hydraulic fracturing	Accidental intersection of fault, Changing non-target aquifer properties (physical or chemical), Changing target aquifer properties (physical or chemical), Connecting aquifers (too much pressure), Contaminate non-target aquifer (chemical), Contaminate target aquifer (chemical), Intersection of aquifer	Aquifer properties, Groundwater composition, Groundwater pressure, Groundwater quality	Target aquifers within tenements, Non-target aquifers within tenements	Long term

Causal pathway group – Causal pathway	Hazards (impact mode)	Hydrological effects	System components	Temporal context[a]
Subsurface physical flow paths – Extracting overburden to access coal	Artificial point of recharge, Enhanced aquifer interconnectivity, Groundwater sink, Linking aquifers, preferential drainage	Surface water flow, Change to zero-flow days, Groundwater direction, Groundwater pressure, Groundwater quality, Groundwater quantity/volume	Alluvium and watercourses in aquifer outcrop areas within and downstream of tenements, Aquifers within tenements	Medium to long term, Long term
Surface water drainage – Altering surface water system	Change to natural surface drainage, Disruption of natural surface drainage	Surface water direction, Surface water quality, Surface water volume, Groundwater quantity/volume	Alluvium and watercourses in aquifer outcrop areas within and downstream of tenements	Medium to long term
Surface water drainage – Subsidence of land surface	Subsidence	Surface water direction	Watercourses within and downstream of tenements	Long term
Operational water management – Discharging extracted water into surface water system	Discharge to river, Discharge to river following heavy rainfall, Discharge to river: rising watertable, Discharge to river (via first or third party)	Surface water flow, Surface water quality, Groundwater level, Groundwater quality	Alluvium and watercourses in aquifer outcrop areas within and downstream of tenements	Short term
Operational water management – Processing and using extracted water	Increase discharge to rivers following irrigation, Raise watertable following irrigation, Soil salt mobilization following irrigation	Surface water flow, Surface water quality, Groundwater level, Groundwater quality	Alluvium and watercourses in aquifer outcrop areas within and downstream of tenements, Watercourses within and downstream of tenements	Short term
Operational water management – Reinjecting co-produced water into aquifer	Injection of water into aquifer	Groundwater composition, Groundwater pressure	Aquifers targeted for reinjection	Long term

Causal pathway group – Causal pathway	Hazards (impact mode)	Hydrological effects	System components	Temporal context[a]
Operational water management – Storing extracted water	Change to natural surface drainage, Disruption of natural surface drainage (freshwater storage), Disruption of natural surface drainage (mine water storage), Disruption of natural surface drainage (tailings water storage), Excessive runoff during closure (water management structures)	Surface water direction, Surface water flow, Surface water quality, Surface water volume, Groundwater quality, Groundwater quantity/volume	Alluvium and watercourses in aquifer outcrop areas within and downstream of tenements, Watercourses within and downstream of tenements	Medium to long term

Full descriptions of the causal pathways and causal pathway groups are available in companion submethodology M05 (as listed in Table 1) for developing a conceptual model of causal pathways (Henderson et al., 2016).
[a]short term = less than 5 years, medium term = 5 to 10 years, long term = 10 to 100 year
[b]Misspelled in the hazard workshop. Correct terminology is 'mis-perforation of coal seam'.
Typology and punctuation are consistent with the hazard analysis (Bioregional Assessment Programme, Dataset 1).
Data: Bioregional Assessment Programme (Dataset 1)

3.2.3 Hydrological analysis

BAs focus on potential hydrological changes due to additional coal resource development, which for this subregion are The Range in the north of the subregion and New Acland Coal Mine Stage 3 in the east. The impact and risk analysis used potential hydrological changes due to additional coal resource development to assess possible impacts on ecosystems and water-dependent assets. (Note that surface water numerical modelling was not undertaken in the Maranoa-Balonne-Condamine subregion).

3.2.3.1 Groundwater

3.2.3.1.1 Regional watertable

This section describes the creation of a hypothetical regional watertable to represent hydrological changes in the uppermost geological layers using spatially explicit, probabilistic estimates of hydrological change predicted by the Queensland Office of Groundwater Impact Assessment (OGIA) regional groundwater model. Potential hydrological changes in the regional watertable were used to assess possible impacts on assets and ecosystems at the surface.

Impacts to water-dependent landscapes and assets are mostly caused by changes to groundwater in the regional watertable, which predominantly affect the ‘alluvium and watercourses in aquifer outcrop areas within and downstream of tenements’ system component identified in the conceptual model of causal pathways. The regional watertable represents the upper groundwater level within the near-surface aquifer, and may exist in different geological units or layers. Near the two additional coal resource developments it occurs in the alluvium, as well as the Main Range Volcanics and the Walloon Coal Measures. Springs and groundwater bores may be affected by hydrological changes in deeper geological layers, which may have repercussions for surface ecosystems surrounding springs.

The regional watertable in the Maranoa-Balonne-Condamine assessment extent occurs in the alluvial and basalt aquifers and parts of the deeper Great Artesian Basin (GAB) aquifers that outcrop in the north, north-west, north-east and east along the Great Dividing Range (Figure 7). The Assessment team used data from the OGIA model to determine the uppermost geological layers in each of the 1.5 km x 1.5 km OGIA model grid cells (~160,000 cells). Numerical groundwater modelling is described in companion product 2.6.2 for the Maranoa-Balonne-Condamine subregion (Janardhanan et al., 2016).

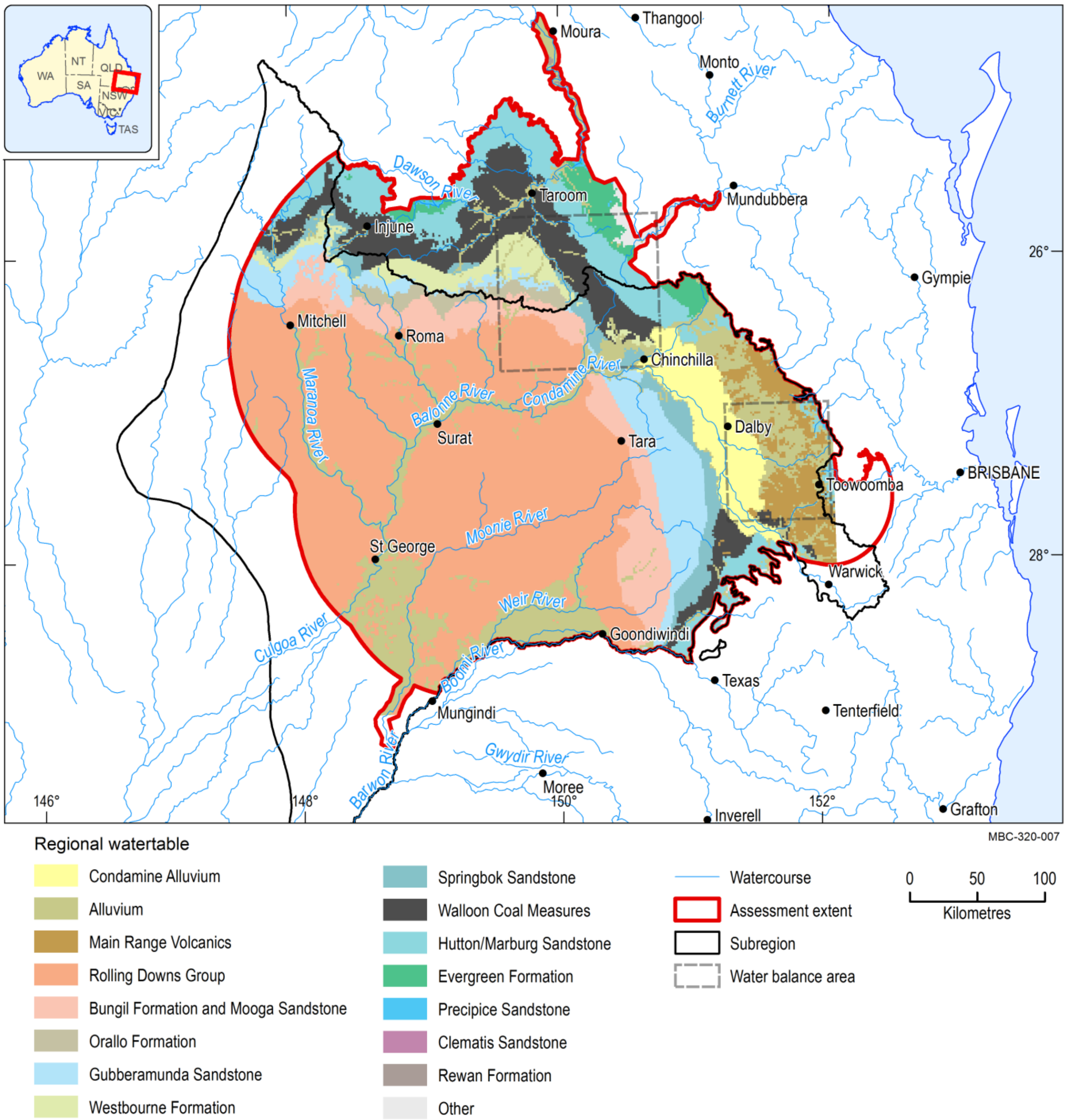

Figure 7 Regional watertable aquifers for the Maranoa-Balonne-Condamine subregion

Water balance areas for additional coal resource development are shown for reference and include all hydrologically connected changes in groundwater flows, such as evapotranspiration, extraction and recharge predicted by the numerical model. The Range water balance area is to the north and New Acland Coal Mine water balance area is to the south-west.
Data: Bioregional Assessment Programme (Dataset 2)

The spatial distribution of geological units in the modelled regional watertable and simplified surface geology in the vicinity of New Acland Coal Mine and The Range are shown in Figure 8 and Figure 9, respectively. The OGIA model is a simple, idealised representation of a complex three-dimensional geologic system that is converted into a three-dimensional mathematical representation of the physical system and flow processes. The model simplifies the regional hydrostratigraphy by grouping geologic formations with similar aquifer properties into model layers representing the major aquifers, aquitards and productive coal measures.

The modelled regional watertable in the vicinity of New Acland Coal Mine is represented by model layer 1, being either alluvium, Condamine Alluvium or Main Range Volcanics based on the surface geology in each assessment unit (Figure 8). The simplified surface geology shows that New Acland Coal Mine is located on an area of Walloon Coal Measures outcrop, which is not represented in the regional model. Similarly, the regional watertable does not include the area of outcropping Marburg Sandstone to the north-east of New Acland Coal Mine, which is represented as alluvium in model layer 1. Small patches of 'Other – sand plain' near the edges of areas mapped as Main Range Volcanics are represented in the regional watertable as alluvium. Modelled hydraulic conductivity and storage parameters for the model layers that represented the 'major aquifers' used in the uncertainty analysis are comparable and of the same order of magnitude.

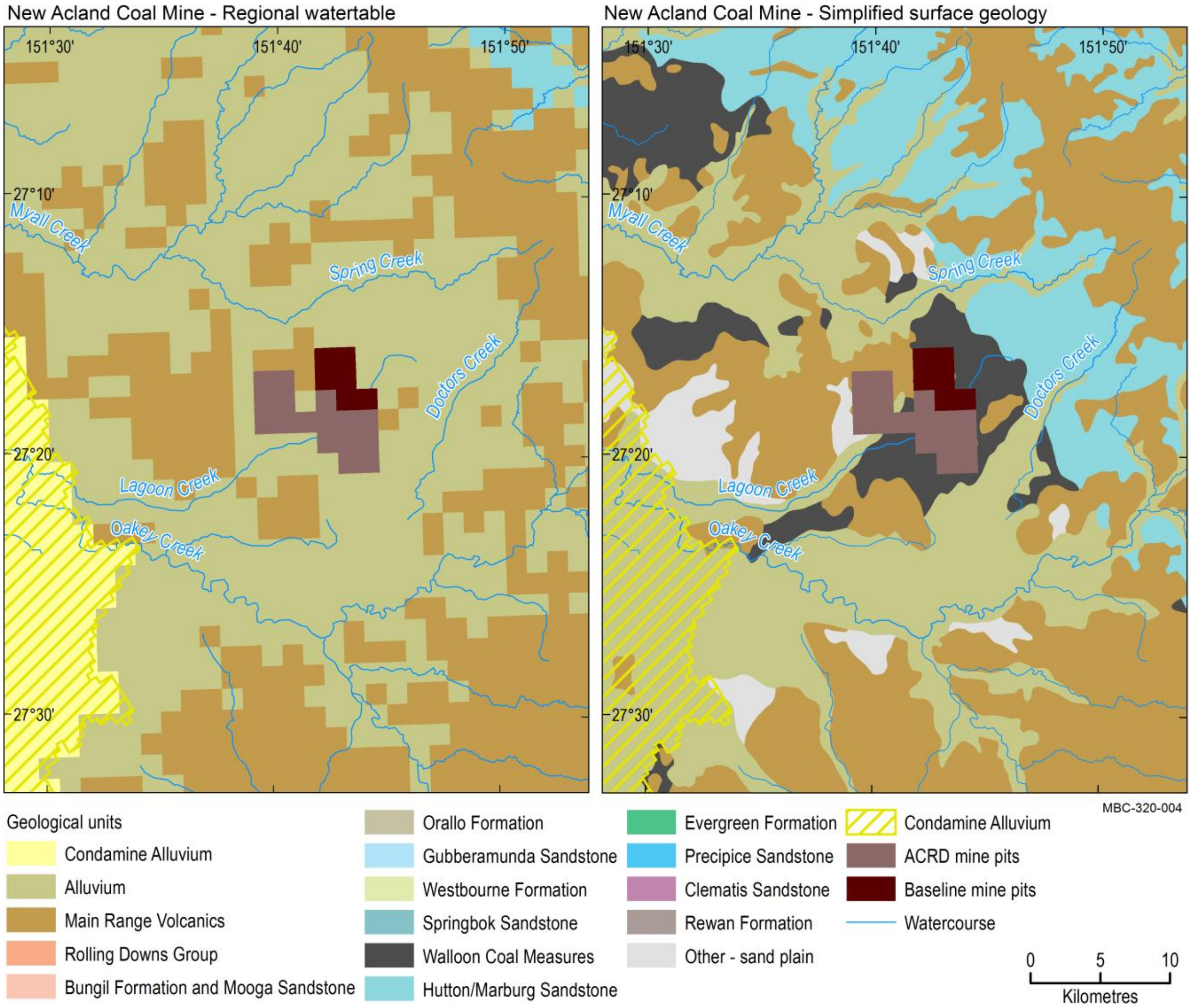

Figure 8 Geological units represented in the modelled regional watertable aquifers and surface geology in the vicinity of New Acland Coal Mine

CSG = coal seam gas. The surface geology of layers is simplified to be consistent with the geological units represented in the regional groundwater model.
Data: Bioregional Assessment Programme (Dataset 2); Geoscience Australia (Dataset 3)

The regional watertable in the vicinity of The Range includes areas of alluvium associated with Roche and Juandah creeks, which were represented by individual model grid cells (Figure 9). Areas of outcropping Walloon Coal Measures in the regional model were mapped as ‘Injune Creek Group’ and ‘sedimentary rocks 72357’. The Injune Creek Group in the Surat Basin is equivalent to the Westbourne and Eurombah formations, Springbok Sandstone and Walloon Coal Measures, which was represented in the regional model by layers 6 to 11 and shown as Walloon Coal Measures in Figure 9. The ‘Kumbarilla Beds’ in the Surat Basin is equivalent to the Bungil, Orallo and Westbourne formations and the Mooga, Gubberamunda and Springbok sandstones, which were represented in the regional groundwater model by layers 3 to 8 and shown as Springbok Sandstone in Figure 9.

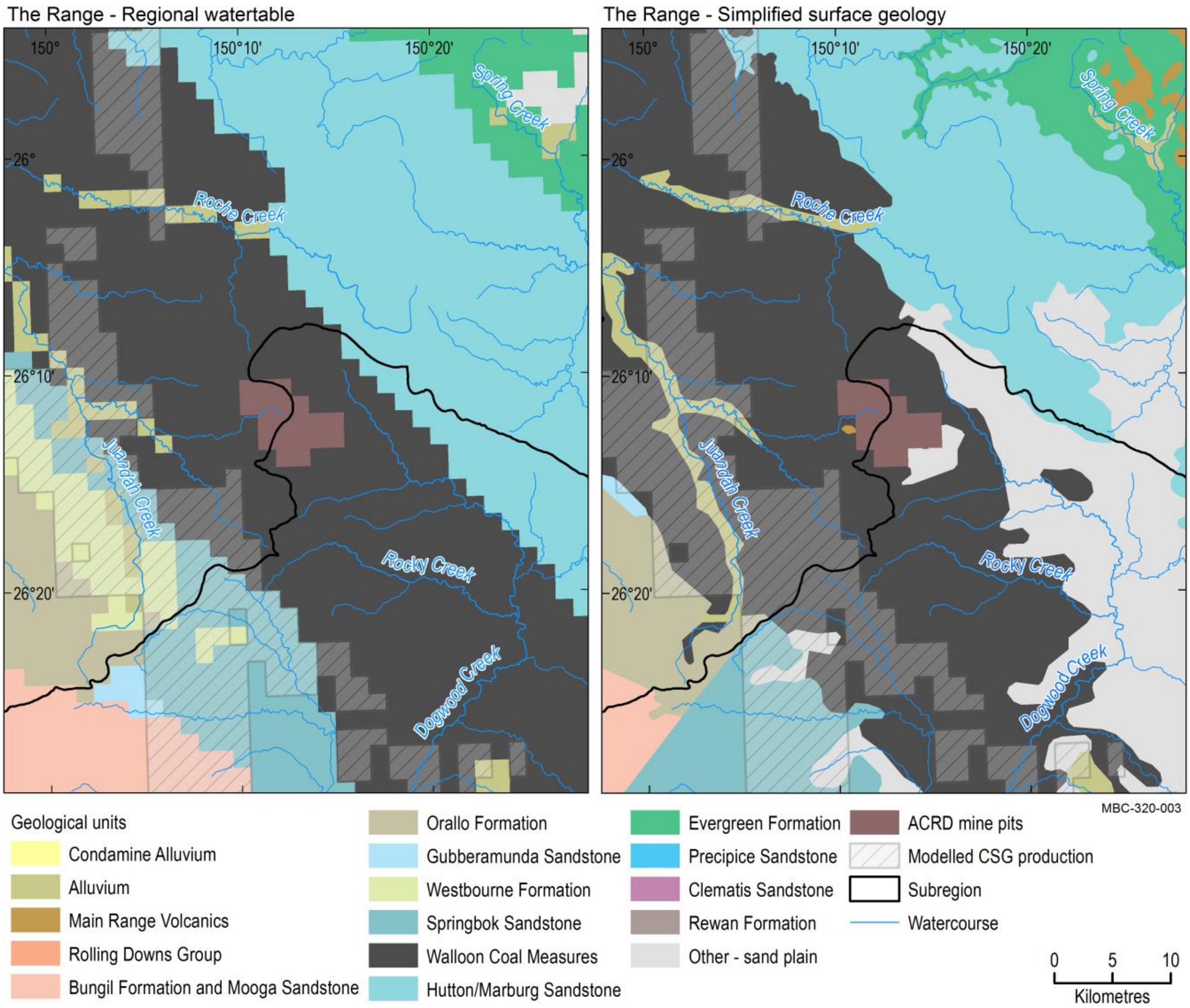

Figure 9 Geological units represented in the modelled regional watertable aquifers and surface geology in the vicinity of The Range

CSG = coal seam gas. The surface geology of layers is simplified to be consistent with the geological units represented in the regional groundwater model.
Data: Bioregional Assessment Programme (Dataset 2); Geoscience Australia (Dataset 3)

3.2.3.1.2 Groundwater model

This Assessment adapted the Office of Groundwater Impact Assessment’s (OGIA) 2012 model and the coal seam gas (CSG) development profile from OGIA’s 2014 annual report (OGIA, 2014). OGIA’s most recent model from 2016 was not available for this Assessment. The models are built for regional groundwater impact assessment in aquifers overlying and underlying the CSG target formations. OGIA also provided data relating to coal mines and their development footprints, which have been used to represent open-cut coal mines in the groundwater model at a regional scale using the 1.5 x 1.5 km grid cells. The area within modelled pits is not reported in this product.

OGIA is an independent entity established to assess and manage cumulative groundwater impacts from resource activities in areas of concentrated CSG development, known as cumulative management areas (CMAs). OGIA has undertaken cumulative assessments to capture the CSG footprints for the Surat and southern Bowen basins in 2012 (QWC, 2012) and 2016 (OGIA, 2016). These are reported through underground water impact reports (UWIRs) and are available from the Queensland Department of Natural Resources and Mines (2016). The UWIRs include predicted impacts on water supply bores and springs.

Most of the Maranoa-Balonne-Condamine subregion falls within the boundary of the geological Surat Basin, which forms part of the wider Great Artesian Basin (GAB). The variably confined layers of complex sandstone aquifers in the GAB are separated and confined by fine-grained mudstone and siltstone aquitards (Ransley and Smerdon, 2012). The intake beds for the GAB outcrop areas cover much of the subregion in the north and the east where the alluvial cover is absent. Important aquifer outcrop areas included in the regional watertable in the north and east of the subregion are:

- model layer 1 – Alluvium (Condamine) and Main Range Volcanics
- model layer 8 – Lower Springbok Sandstone
- model layer 10 – Walloon Coal Measures
- model layer 12 – Hutton/Marburg Sandstone.

Coal mining and CSG development in the Maranoa-Balonne-Condamine subregion targets the Walloon Coal Measures of the geological Surat and Clarence-Moreton basins.

All of the OGIA regional groundwater model layers were modelled as confined to improve numerical stability and reduce model run times. In the regional watertable, the OGIA model represented unconfined storage values using the specific yield (Sy) divided by the model layer thickness. By accounting for unconfined model layer thickness in this way, the storage coefficients used in the regional watertable minimise the potential overestimation of drawdown in the watertable.

In the Condamine Alluvium, the more-detailed Condamine Model was used to estimate impacts on groundwater levels that result from the change in groundwater flows between the Condamine Alluvium and the Walloon Coal Measures predicted by the regional model (QWC, 2012). The Condamine Model was not rerun for this Assessment. However, analysis of baseline drawdown predicted by the integrated models indicates that additional drawdown is *very unlikely* to exceed 0.2 m in the Condamine Alluvium, which is consistent with the regional model predictions in this area (see companion product 2.6.2 for the Maranoa-Balonne-Condamine subregion (Janardhanan et al., 2016)).

The range of model predictions for the impact and risk analysis were summarised by the 5th, 50th and 95th percentile estimates of drawdown in the regional watertable and deeper geological layers accessed by bores and springs. Previously, model predictions have been reported for the 95th percentile estimates of drawdown in each model layer (QWC, 2012; companion product 2.6.2 (Janardhanan et al., 2016)).

Maximum baseline drawdown, in excess of 700 m equivalent pressure changes, associated with baseline CSG production, is predicted near the towns of Chinchilla and Roma in model layer 10 – Walloon Coal Measures (see companion product 2.6.2 (Janardhanan et al., 2016)). This geological layer is the target of CSG production and is up to 1000 m below the surface in this area.

Baseline drawdown in the regional watertable is typically less than 20 m and occurs in the aquifer outcrop areas in the east and north of the subregion (Figure 10). The range of model predictions indicates that baseline drawdown in the regional watertable in excess of 0.2 m covers between 7,370 km^2 (5th percentile) and 17,132 km^2 (95th percentile). The regional watertable is typically up to 150 m thick in this area, but can be over 350 m thick in some areas.

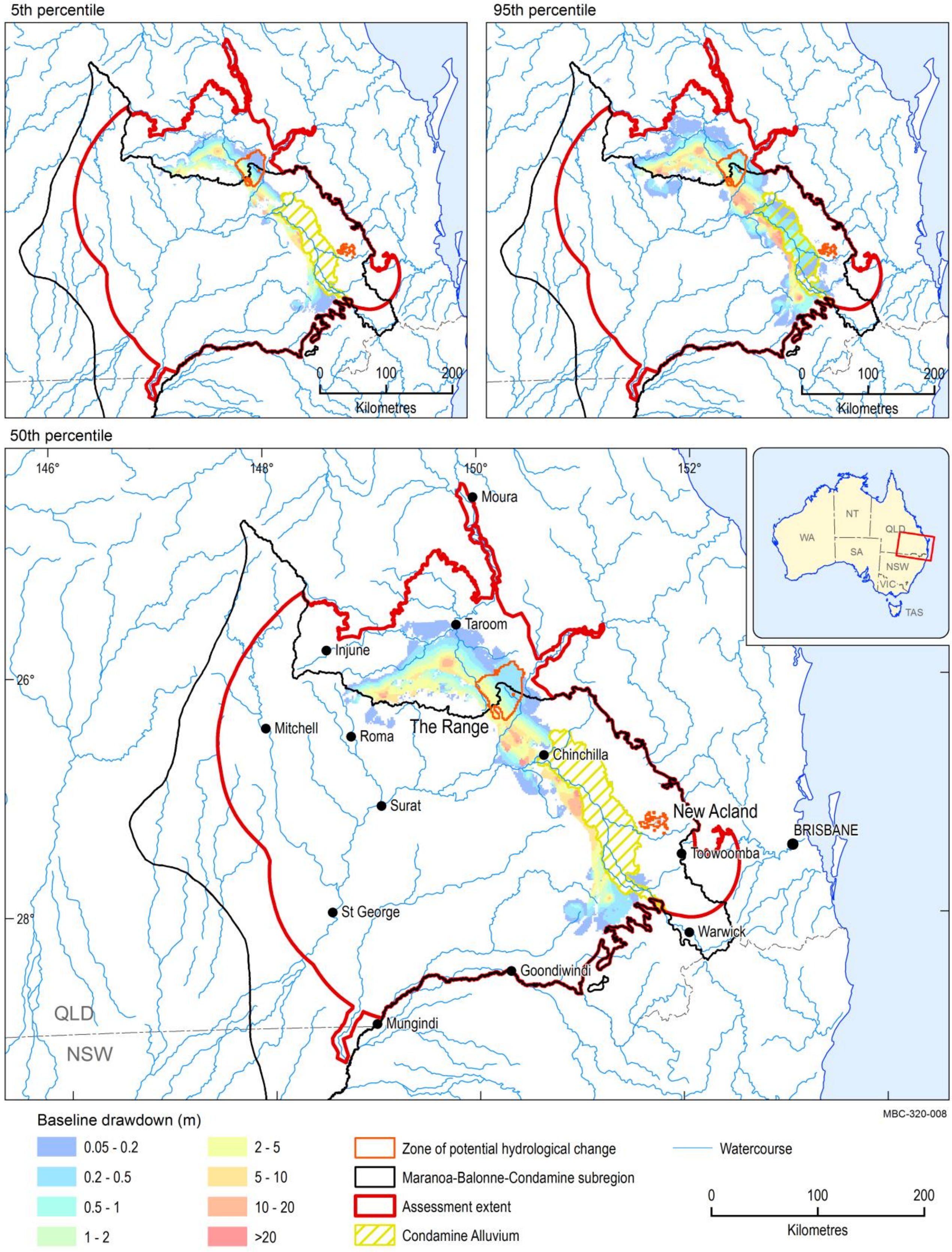

Figure 10 Baseline drawdown (m) in the regional watertable (5th, 50th and 95th percentiles)

Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Estimates of baseline drawdown in the Condamine Alluvium are only available for the 95th percentile as reported in QWC (2012). In a confined aquifer, drawdown relates to a change in water pressure and does not necessarily translate to changes in depth to watertable. The zone of potential hydrological change in the regional watertable is shown for reference.
Data: Bioregional Assessment Programme (Dataset 2, Dataset 4, Dataset 5); Office of Groundwater Impact Assessment (Dataset 6, Dataset 7)

3.2.3.2 Surface water

No surface water numerical modelling was undertaken for the Maranoa-Balonne-Condamine subregion. Some potential hydrological changes may, however, be specified conceptually based on scientific logic.

3.2.3.3 Representing predictive uncertainty

The models used in the Assessment produced a large number of predictions of groundwater drawdown rather than a single number. This resulted in a range or distribution of predictions, which are typically reported as probabilities – the percent chance of something occurring (Figure 11). This approach allowed an assessment of the likelihood of exceeding a given magnitude of change, and underpinned the assessment of the risk.

Groundwater models require information about physical properties such as the thickness of geological layers, how porous aquifers are, and whether faults are present. As the exact values of these properties are not always known, modellers used a credible range of values, which are based on various sources of data (commonly point-scale) combined with expert knowledge. The groundwater model was run hundreds of times using a different set of plausible values for those physical properties each time. Historical observations, such as groundwater level and changes in water movement and volume, were used to constrain and validate the model runs.

The complete set of model runs produced a range or distribution of predictions (Figure 11) that are consistent with available observations and the understanding of the modelled system. The range conveys the confidence in model results, with a wide range indicating that the expected outcome is less certain, while a narrow range provides a stronger evidence base for decision making. The distributions created from these model runs are expressed as probabilities that drawdown will exceed relevant thresholds, as there is no single 'best' estimate of change.

Model results are presented as the range of drawdown values for a defined probability or percentile and as the probability or percent chance of exceeding important threshold values. This enables the reader to understand the range of model predictions for defined probabilities, or to assess the probability or likelihood of exceeding defined regulatory thresholds.

In this Assessment, estimates of drawdown are shown as 95th, 50th or 5th percentile results, corresponding to a 5%, 50% or 95% chance of exceeding thresholds. Figure 12 illustrates this predictive uncertainty within a spatial context. Throughout this product, the term '*very likely*' is used to describe where there is a greater than 95% chance of something occurring, and '*very unlikely*' is used where there is a less than 5% chance.

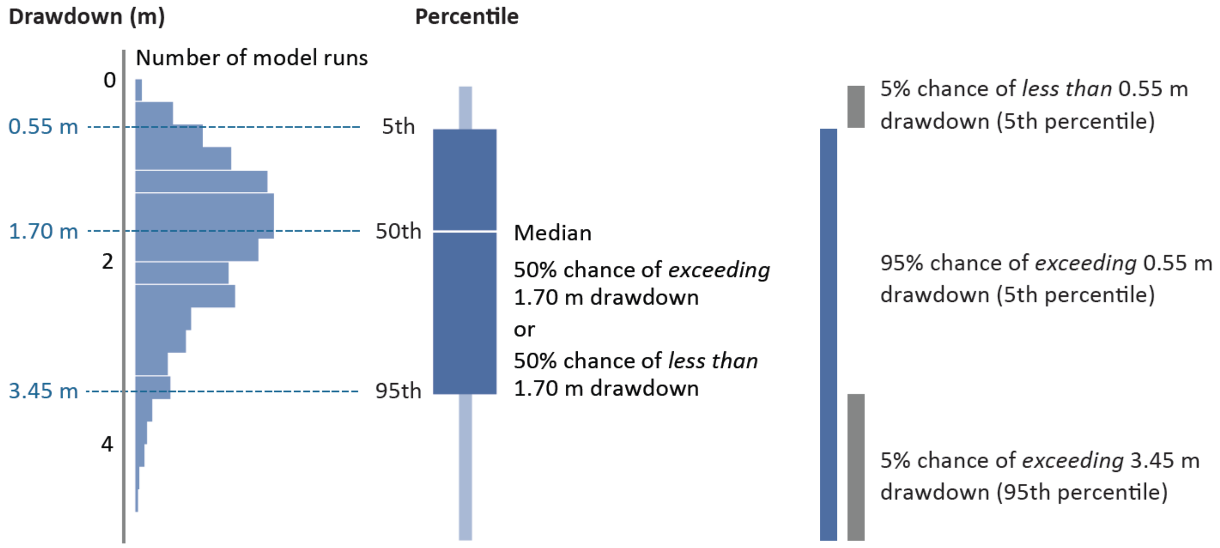

Figure 11 Illustrative example of probabilistic drawdown results using percentiles and percent chance

The chart on the left shows the distribution of results for drawdown, obtained from an ensemble of thousands of model runs that use many sets of parameters. These generic results are for illustrative purposes only and are not actual results from the Maranoa-Balonne-Condamine subregion.

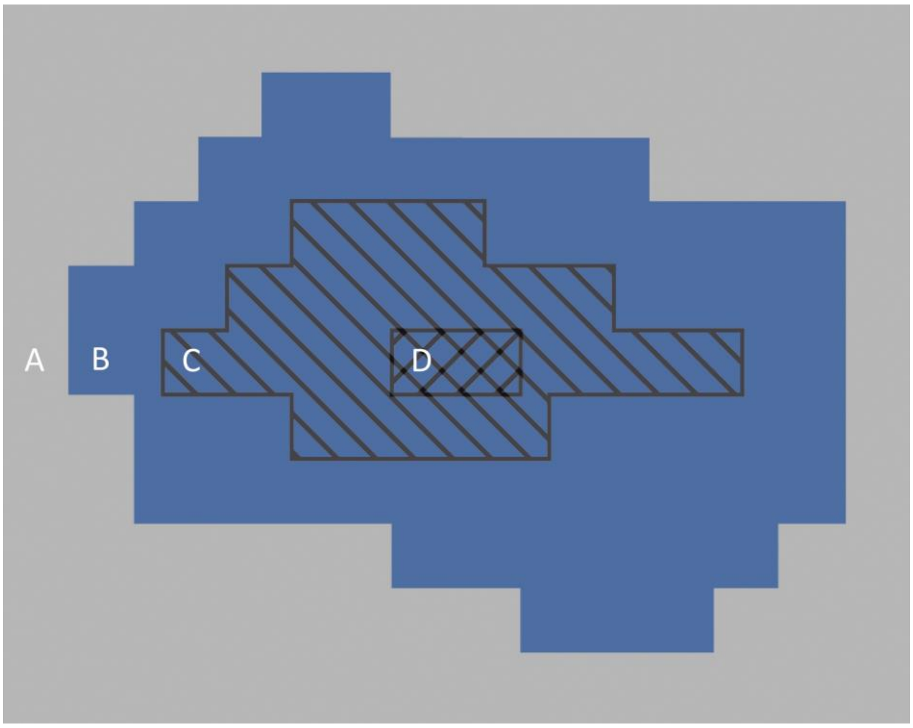

Figure 12 Illustrative example of key areas in the landscape defined by probabilistic results

The assessment extent was divided into smaller square assessment units and the probability distribution (Figure 11) was calculated for each. In this product results are reported with respect to the following key areas:
A. outside the zone of potential hydrological change, where hydrological changes (and hence impacts) are *very unlikely* (defined by maps showing the 95th percentile)
B. inside the zone of potential hydrological change, comprising the assessment units with at least a 5% chance of exceeding the threshold (defined by maps showing the 95th percentile). Further work is required to determine whether the hydrological changes in the zone translate into impacts for water-dependent assets and landscapes
C. with at least a 50% chance of exceeding the threshold (i.e. the assessment units where the median is greater than the threshold; defined by maps showing the 50th percentile)
D. with at least a 95% chance of exceeding the threshold (i.e. the assessment units where hydrological changes are *very likely*; defined by maps showing the 5th percentile).

3.2.4 Assessing potential impacts for landscape classes and assets

The approach for assessing potential impacts to landscape classes and water-dependent assets is discussed in companion submethodology M10 (as listed in Table 1) for analysing impacts and risks (Henderson et al., 2017). The zone of potential hydrological change focuses the attention of the analysis on areas where there may be changes in surface water and/or groundwater that are attributable to additional coal resource development.

The principal focus of BAs is water-dependent assets that are nominated by the community. These assets may have a variety of values, including ecological, sociocultural and economic values. The water-dependent asset register (companion product 1.3 for the Maranoa-Balonne-Condamine subregion (Mitchell et al., 2015) and Bioregional Assessment Programme, Dataset 8) provides a simple and authoritative listing of the assets within the assessment extent. The register is a compilation of assets identified in natural resource management databases and Commonwealth and state databases, and through the Maranoa-Balonne-Condamine assets workshop. The identified assets were assessed by the Assessment team for fitness for BA purpose, location within the assessment extent and water dependency. Assets that satisfy the requirements were considered in the impact and risk analysis reported in this product.

Landscape classification discretised the heterogeneous landscape into a manageable number of landscape classes for the impact and risk analysis. Landscape classes represent key surface ecosystems that have broadly similar physical, biological and hydrological characteristics. They are used to reduce the complexity inherent in assessing impacts on a large number of water-dependent assets by focusing on the hydrological drivers and interactions relevant to a regional-scale assessment. The landscape classes provide a meaningful scale for understanding potential ecosystem impacts and communicating them through their more aggregated system-level view. The landscape classification for the Maranoa-Balonne-Condamine subregion is described in companion product 2.3 (Holland et al., 2016) and the methodology that underpins it is described in companion submethodology M05 (as listed in Table 1) for developing a conceptual model of causal pathways (Henderson et al., 2016).

Potential hydrological changes were assessed by overlaying the extent of a landscape class or asset on the zone of potential hydrological change due to additional coal resource development. For the landscape classes or assets that lie outside the zone, hydrological changes (and hence impacts) are *very unlikely*, and were thus ruled out in terms of further assessment. Section 3.4.2 identifies landscape classes in the Maranoa-Balonne-Condamine subregion that were ruled out on this basis.

Where an asset or landscape class wholly or partially intersects the zone of potential hydrological change, there is the potential for impact. This does not mean there will be an impact, but rather, based on the magnitude of the hydrological change, the possibility of an impact cannot be ruled out and further investigation is required. The nature of the water dependency of the landscape class can be important for informing the Assessment. For example, if the water dependence of a landscape class is unrelated to groundwater access, such as woodland vegetation that do not access groundwater, then it is possible to rule out the landscape class from further consideration because it is unlikely to be impacted.

The zone of potential hydrological change defined for the regional watertable was used to assess potential impacts to key surface ecosystems (landscape classes (except springs), economic assets (except groundwater bores), ecological and sociocultural assets). To assess potential impacts to springs and groundwater bores that access deeper geological layers, the zone of potential hydrological change was defined for the deeper geological layers.

Potential impacts are reported in Section 3.4 for landscape classes and in Section 3.5 for assets.

In addition, impact profiles for landscape classes and assets are available at www.bioregionalassessments.gov.au. Each profile summarises the hydrological changes and potential impacts that pertain to that landscape class or asset (e.g. groundwater drawdown in the 'Floodplain remnant vegetation' landscape class in the zone of potential hydrological change). Users can aggregate and consider potential impacts for their own scale of interest.

Users can also explore the results for landscape classes and assets using a map-based interface at www.bioregionalassessments.gov.au/explorer/MBC/landscapes and www.bioregionalassessments.gov.au/explorer/MBC/assets.

3.2.4.1 Landscape classes

The natural and human-modified ecosystems in the subregion were classified into 34 landscape classes to enable a systematic and comprehensive analysis of potential impacts on, and risks to, the water-dependent assets nominated by the community. The classes were aggregated into five landscape groups based on their likely response to hydrological changes. The landscape classification was based on the geology, geomorphology, hydrogeology, land use and ecology of the subregion. For further details, see Section 2.3.3 (companion product 2.3 for the Maranoa-Balonne-Condamine subregion (Holland et al., 2016)) and companion submethodology M05 (as listed in Table 1) for developing a conceptual model of causal pathways (Henderson et al., 2016).

Springs and groundwater bores may be affected by hydrological changes in deeper geological layers, which may have ecological repercussions for surface ecosystems surrounding springs. The source aquifer was identified using existing datasets (e.g. OGIA (Office of Groundwater Impact Assessment, Dataset 9, Dataset 10) or Queensland Department of Natural Resources and Mines (Bioregional Assessment Programme, Dataset 11)). Where this information was not available, the Assessment team assumed that the bores or springs access the shallowest geological layer in that assessment unit (i.e. the regional watertable). This differs from the assumption under the Queensland water planning framework that all management units underlying a discharge spring are considered to be connected to it. This assessment is not a substitute for detailed, site-specific assessment of projects and impacts under state or Commonwealth environmental law. Such assessments may use finer-scale groundwater and surface water models in order to assess local-scale impacts. The implications of the BA assumption are context specific and are addressed in Section 3.4 for landscape classes and in Section 3.5 for assets where appropriate and also by identifying it as a knowledge gap.

Receptor impact models were not built for the Maranoa-Balonne-Condamine subregion as part of prioritising effort across the entire Bioregional Assessment Technical Programme, but also because modelled hydrological change was limited to groundwater changes. Receptor impact models could, however, have an important role in translating the hydrological change, as measured by hydrological response variables, into receptor impact variables that may be considered better indicators of potential ecosystem change. For those landscape classes within the zone of potential hydrological change that are considered water dependent, the construction of receptor impact models would commence with the development of qualitative mathematical models through an expert consultation process and would produce signed-directed graphs of key system components and interactions. These signed-directed graphs would identify important hydrological response variables and receptor impact variables. A full description of the receptor impact modelling methodology is described in companion submethodology M08 (as listed in Table 1) for receptor impact modelling (Hosack et al., 2017).

The results of these analyses are summarised in this product, with more detailed information available on www.bioregionalassessments.gov.au. The impact analysis databases are also available on www.data.gov.au.

3.2.4.2 Water-dependent assets

The water-dependent asset register (companion product 1.3 for the Maranoa-Balonne-Condamine subregion (Mitchell et al., 2015)) provides a simple and authoritative listing of the assets within the assessment extent that are potentially subject to water-related impacts. This register has been extended beyond the initial community and local natural resource management agency consultation by identifying additional assets in key Commonwealth and state databases, engagement through BA workshops, and other consultation processes around the identification of Indigenous assets.

The assets nominated by the community are assessed by the Assessment team for several things including their fitness for BA purposes, their location within the assessment extent, and their water dependency. These criteria are described in companion submethodology M03 (as listed in Table 1) for assigning receptors to water-dependent assets (O'Grady et al., 2016). Only those assets that satisfied these requirements were considered further and included in the water-dependent asset register (companion product 1.3 (Mitchell et al., 2015)).

The water-dependent asset register used for the impact and risk analysis was updated on 5 February 2016 and contains 2660 water-dependent assets (Bioregional Assessment Programme, Dataset 8). An additional 56 Indigenous assets were included in the water-dependent asset register, which was used for the impact and risk analysis (updated 5 February 2016). Sociocultural assets were considered to be water dependent based on the presence of floodplain and wetland areas and shallow groundwater within their spatial extent.

3.2.4.3 Information for modelling and impact analysis (IMIA)

A very large number of multi-dimensional and multi-scaled datasets are used in the impact and risk analysis for each BA, including hydrological model outputs, ecological, economic and sociocultural asset data from a wide range of sources. Part of the approach used to manage these datasets and produce meaningful results is to adopt a clear spatial framework as an organising principle. While the inherently spatial character of every BA is important and must be addressed, it is also essential that the temporal and other dimensions of the analysis do not lose resolution during data processing. For example, knowing where a potential impact may take place is obviously important, but so is knowing when hydrological response variables may change, which assets may be affected, and what level of impact may result.

The datasets for this Assessment were organised into an *impact analysis database* (Bioregional Assessment Programme, Dataset 12) to enable efficient management. The purpose of the database is to produce result datasets that integrate the available modelling and other evidence across the assessment extent of the BA. These databases are required to support three types of BA analyses: (i) analysis of hydrological changes, (ii) impact profiles for landscape classes and (iii) impact profiles for assets.

The datasets used in the impact and risk analysis database (Bioregional Assessment Programme, Dataset 12) include the assets, landscape classes, groundwater modelling results, coal resource development 'footprints' and other relevant geographic datasets, such as the boundaries of the subregion, assessment extent and zone of potential hydrological change. All data in the impact and risk analysis database (and the results derived from it) meet the requirements for transparency.

The data were structured to overcome the slow geoprocessing operations typical of complex queries of very large spatial datasets, such as those required for a BA. This structuring was achieved by:

- loading as many attributes as possible into relational tables, including some spatial information such as area and length data
- simplifying and partitioning the remaining spatial data using *assessment units* while, importantly, retaining spatial geometries below the resolution of the assessment units.

An *assessment unit* is a geographic area represented by a square polygon with a unique identifier. Assessment units are non-overlapping and completely cover the assessment extent (Figure 10 and Figure 12). The spatial resolution of the assessment units is closely related to that of the BA groundwater modelling and is, typically, 1 km x 1 km. Assessment units for the Maranoa-Balonne-Condamine subregion are identical to the 1.5 km x 1.5 km OGIA model grid cells (~160,000 cells) and were extended to cover the entire assessment extent. Areas outside the OGIA regional groundwater model boundary were assumed not to be impacted and were not analysed further.

Assessment units were used to partition asset and landscape class spatial data for impact analysis. The partitioned data can be combined and recombined into any aggregation supported by the conceptual modelling, causal pathways and model data. The interpolated modelled groundwater drawdowns (see Section 3.2.3.1) are at the same resolution as the assessment unit and contain a single value per assessment unit.

To manage issues of geospatial quality in source datasets and also technology integration, the impact and risk analysis database performed a series of geospatial operations on the source data geometry. These operations are PostGIS geometry validation, 1.0 m or less snap-to-grid, and (in some cases) 1 cm polygon buffering. The effect of these operations on area and length calculations is considered small. In general, the larger an individual geospatial feature, the smaller the relative impact and vice versa. For features with area greater than 10 km^2 and length greater than 10 km, variation from source data calculations ranges between 0.0% and 0.5%. This variation may approach 40% for smaller geospatial features. These geospatial operations account for all differences in length and area that may be found when comparing data reported in this product with that in the impact and risk analysis database.

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3.3 Potential hydrological changes

Summary

Drawdown in the regional watertable under the baseline has a greater than 5% chance of exceeding 0.2 m in an area of 17,132 km^2 where the deeper geological layers outcrop at the surface. Median baseline drawdown in the regional watertable is typically less than 20 m; it is less than 3 m in the vicinity of New Acland Coal Mine and less than 8.3 m in the vicinity of The Range coal mine.

Additional drawdown in the regional watertable has a greater than 5% chance of exceeding 0.2 m in an area of 1631 km^2. Subsequently, the extent in the zone of potential hydrological change is reported as 1544 km^2, which includes 1095 km of streams and excludes the 87 km^2 within the modelled open-cut mine pits that are not included in the analysis. Additional drawdown occurs within 15 km of New Acland Coal Mine Stage 3 and within 25 km of The Range coal mine. The regional watertable is in the alluvium, as well as the Main Range Volcanics, the Walloon Coal Measures and the Hutton/Marburg Sandstone geological layers near the two additional coal resource developments.

In the vicinity of New Acland Coal Mine, additional coal resource development is predicted to lower the regional watertable by at least an additional 0.2 m over an area of between 7 km^2 including 4 km of streams (5th percentile) and 134 km^2 including 55 km of streams (95th percentile). Additional drawdown in the regional watertable near The Range coal mine is predicted to lower the regional watertable by at least an additional 0.2 m over an area of between 377 km^2 including 231 km of streams (5th percentile) and 1409 km^2 including 1040 km of streams (95th percentile).

Potential risks to groundwater and surface water quality are localised within tenements; downstream watercourses and alluvial aquifers; and irrigated areas or target aquifers used to dispose of co-produced water, which are addressed by existing regulation and management practices.

Users can visualise more detailed results for hydrological changes using a map-based interface on the BA Explorer, available at www.bioregionalassessments.gov.au/explorer/MBC/hydrologicalchanges.

3.3.1 Defining the zone of potential hydrological change

The zone of potential hydrological change is the area within the subregion where changes in hydrology due to additional coal resource development exceed defined thresholds for groundwater and surface water changes. The zone is represented at the surface, or in the relevant geological layer from which landscapes or assets source water.

The impact and risk analysis presented in the remainder of this product focuses on landscape classes and assets that intersect this zone. Any landscape class or asset wholly outside the zone of potential hydrological change is considered *very unlikely* (less than 5% chance) to be impacted by hydrological changes due to additional coal resource development, and thus is 'ruled out' from any further analysis as part of this bioregional assessment (BA).

As surface water modelling was not undertaken in the Maranoa-Balonne-Condamine subregion, groundwater hydrological changes alone are used to define the zone.

3.3.1.1 Groundwater

The groundwater zone of potential hydrological change is defined as the area with a greater than 5% chance of exceeding 0.2 m drawdown in the source aquifer due to additional coal resource development (Figure 13). This 5% chance is determined based on an uncertainty analysis as described in Section 2.6.2.8 of companion product 2.6.2 for the Maranoa-Balonne-Condamine subregion (Janardhanan et al., 2016). It means that 95% of groundwater model runs exceeded this level of drawdown. Groundwater impacts due to coal mines and coal seam gas (CSG) projects are regulated under state legislation and state regulatory and management frameworks. The 0.2 m drawdown threshold adopted in BAs is consistent with the most conservative minimal impact threshold in the *NSW Aquifer Interference Policy* (DPI, 2012) and Queensland's *Water Act 2000*. See also Queensland's *Underground water impact report for the Surat Cumulative Management Area* (QWC, 2012).

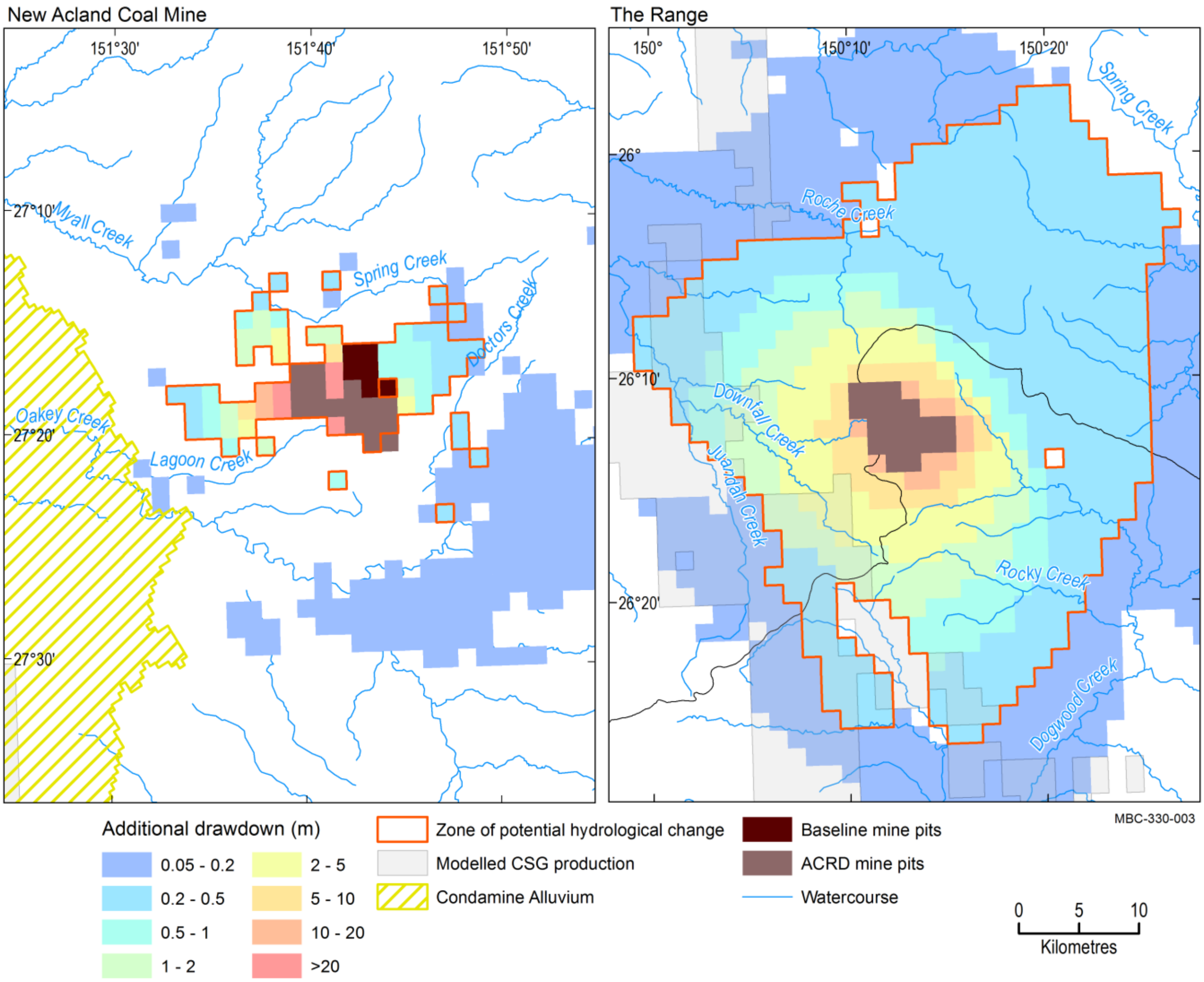

Figure 13 Zone of potential hydrological change in the regional watertable in the vicinity of New Acland Coal Mine and The Range coal mine

The zone of potential hydrological change is the area with a greater than 5% chance of exceeding 0.2 drawdown due to additional coal resource development in the relevant aquifers. Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. In a confined aquifer, drawdown relates to a change in water pressure and does not necessarily translate to changes in depth to watertable. The mine pits in the CRDP are the sum of those in the baseline and the additional coal resource development (ACRD).
CSG = coal seam gas
Data: Bioregional Assessment Programme (Dataset 1, Dataset 2, Dataset 3, Dataset 4); Office of Groundwater Impact Assessment (Dataset 5, Dataset 6)

3.3.1.2 Surface water

No surface water numerical modelling was undertaken for the Maranoa-Balonne-Condamine subregion; groundwater hydrological changes alone are used to define the zone.

3.3.1.3 Zone of potential hydrological change

Additional drawdown in the regional watertable, with a greater than 5% chance of exceeding 0.2 m, covers an area of 1631 km^2 (Figure 13). Subsequently, the extent in the zone of potential hydrological change is reported as 1544 km^2, which excludes the 87 km^2 within the modelled open-cut mine pits that are not included in the analysis. The zone of potential hydrological change in the regional watertable contains 1544 km^2 of vegetation and 1095 km of stream network.

The modelled open-cut mine pits (Figure 13) were not included in the analysis for the following reasons:

- modelled drawdowns within the modelled pits are highly uncertain due to the very steep hydraulic gradients at the mine pit interface
- changes in the drawdown are inevitable where the mine pit intersects the regional watertable
- other factors, such as physical removal of a wetland or creek, may have a larger impact on a landscape class than the predicted decrease in groundwater level
- impacts are predominantly site-scale, assumed to be adequately addressed through existing development approval processes, and hence not the primary focus of BAs.

Note that there is no exclusion zone identified for CSG wells or infrastructure associated with CSG development.

In the impacts on landscape classes and assets sections (Section 3.4 and Section 3.5, respectively), the initial assessment summarises what is in the zone of potential hydrological change and, within that, what is in the mine pit exclusion zone. Areas were differentiated by attribute class (e.g. bore purpose; hydrological response variable class) for areas in the zone of potential hydrological change, but no differentiation by attribute class was undertaken for features in the modelled open-cut mine pits.

3.3.2 Potential groundwater changes

In assessing potential impacts on groundwater, changes were summarised by the hydrological response variable *dmax* – the maximum difference in drawdown, obtained by choosing the maximum of the time series of differences between two futures. Drawdowns were reported for a single regional watertable, which includes the alluvial and basalt aquifers and parts of the deeper Great Artesian Basin (GAB) aquifers represented in the groundwater model.

These *dmax* values were presented for the baseline (difference in results between the baseline and a 'no-development' model run) and due to additional coal resource development (difference in results between the CRDP run and the baseline run).

Regulatory authorities in Queensland and NSW have specified cumulative drawdown thresholds ranging from 0.2 m to 5 m. The Surat underground water impact report (QWC, 2012) identifies potentially affected springs as 'springs where the water pressure in aquifers underlying the spring sites is predicted to decline by more than 0.2 m at any time in the future'. Queensland's *Water Act 2000* specifies bore trigger thresholds for drawdown of '5 m for consolidated aquifers (such as sandstone) and 2 m for unconsolidated aquifers (such as sands)' (QWC, 2012). In NSW, 'make good' provisions apply for most aquifers where an activity results in drawdowns greater than 2 m. The exceptions are high-priority groundwater-dependent ecosystems (GDEs) and culturally significant sites in the GAB, where make good provisions apply if drawdowns exceed 0.2 m. These thresholds have therefore been used to define drawdown classes (≥0.2 m, ≥2 m and ≥5 m) for summarising the modelling results across all BAs.

The 5th, 50th and 95th percentiles of drawdown under the baseline are shown in the vicinity of New Acland Coal Mine (Figure 14) and The Range coal mine (Figure 15). Median baseline drawdown in the zone of potential hydrological change is predominantly less than 2 m. Median baseline drawdown in excess of 2 m covers approximately 25% of the surface area (373 km^2) and streams (301 km) in the zone (Figure 16 and Table 4).

Table 4 and Table 5 summarise the surface area and length of stream network where the 5th, 50th and 95th percentile estimates of baseline and additional drawdown exceed 0.2, 2 and 5 m within the zone in the vicinity of the two additional coal resource developments: New Acland Coal Mine Stage 3 and The Range coal mine.

Drawdown due to additional coal resource development that exceeds 0.2 m in the regional watertable is predicted within 15 km of New Acland Coal Mine Stage 3 (Figure 17) and within 25 km of The Range coal mine (Figure 18). Median drawdown due to additional coal resource development in excess of 2 m is near the modelled mine pits and includes less than 10% of the surface area (144 km^2) and streams (57 km) in the zone (Figure 16 and Table 5).

Median additional drawdown is up to 65 m in the vicinity of New Acland Coal Mine Stage 3 and up to 10.2 m in the vicinity of The Range coal mine. This indicates that additional drawdown is deeper, but more confined near New Acland Coal Mine Stage 3, and shallower and broader near The Range coal mine. Drawdown near the two mines is reported separately below.

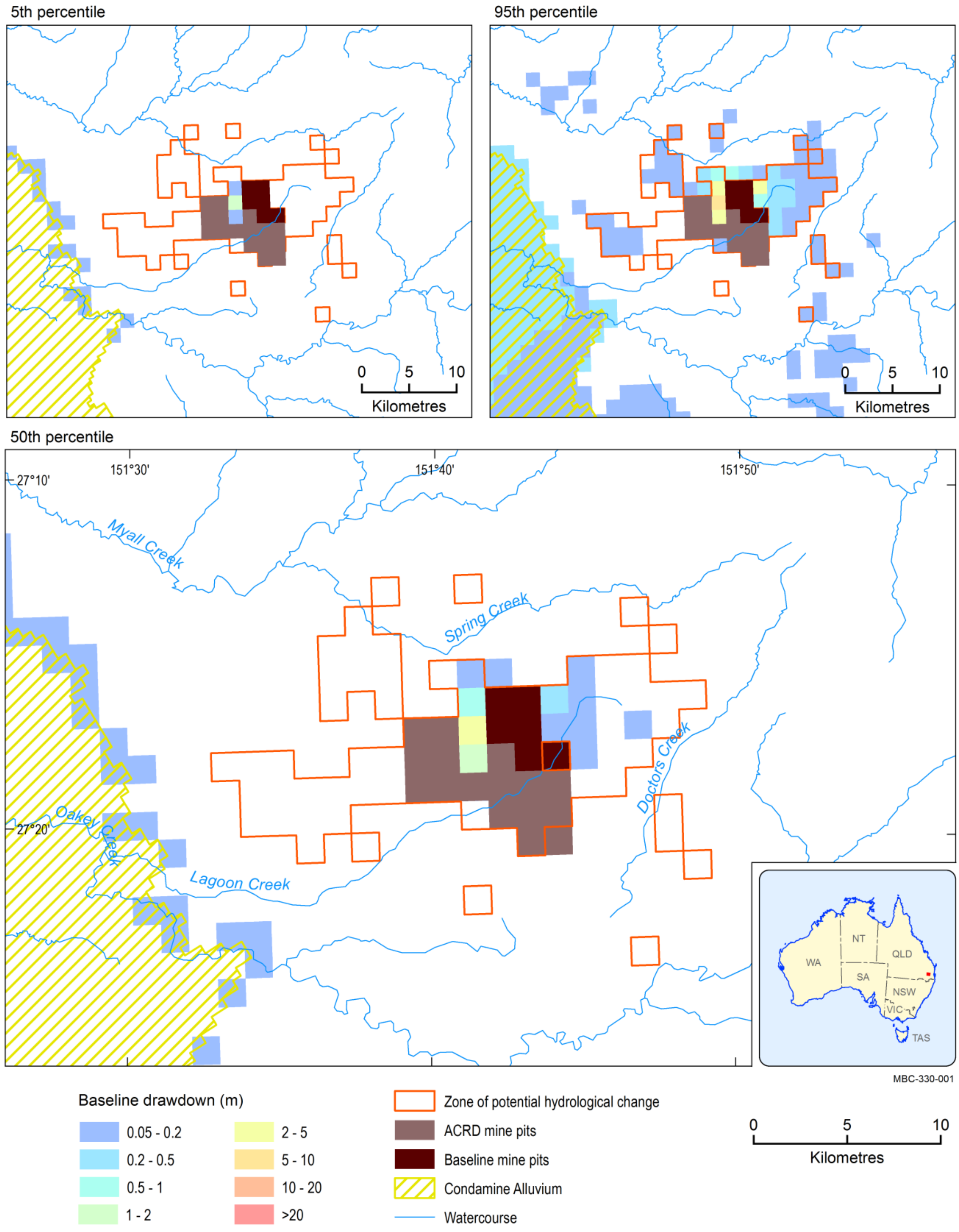

Figure 14 Baseline drawdown (m) in the regional watertable in the vicinity of New Acland Coal Mine Stage 3 (5th, 50th and 95th percentiles)

Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. In a confined aquifer, drawdown relates to a change in water pressure and does not necessarily translate to changes in depth to watertable. The mine pits in the CRDP are the sum of those in the baseline and the additional coal resource development (ACRD). Data: Bioregional Assessment Programme (Dataset 1, Dataset 2, Dataset 3, Dataset 4); Office of Groundwater Impact Assessment (Dataset 5, Dataset 6)

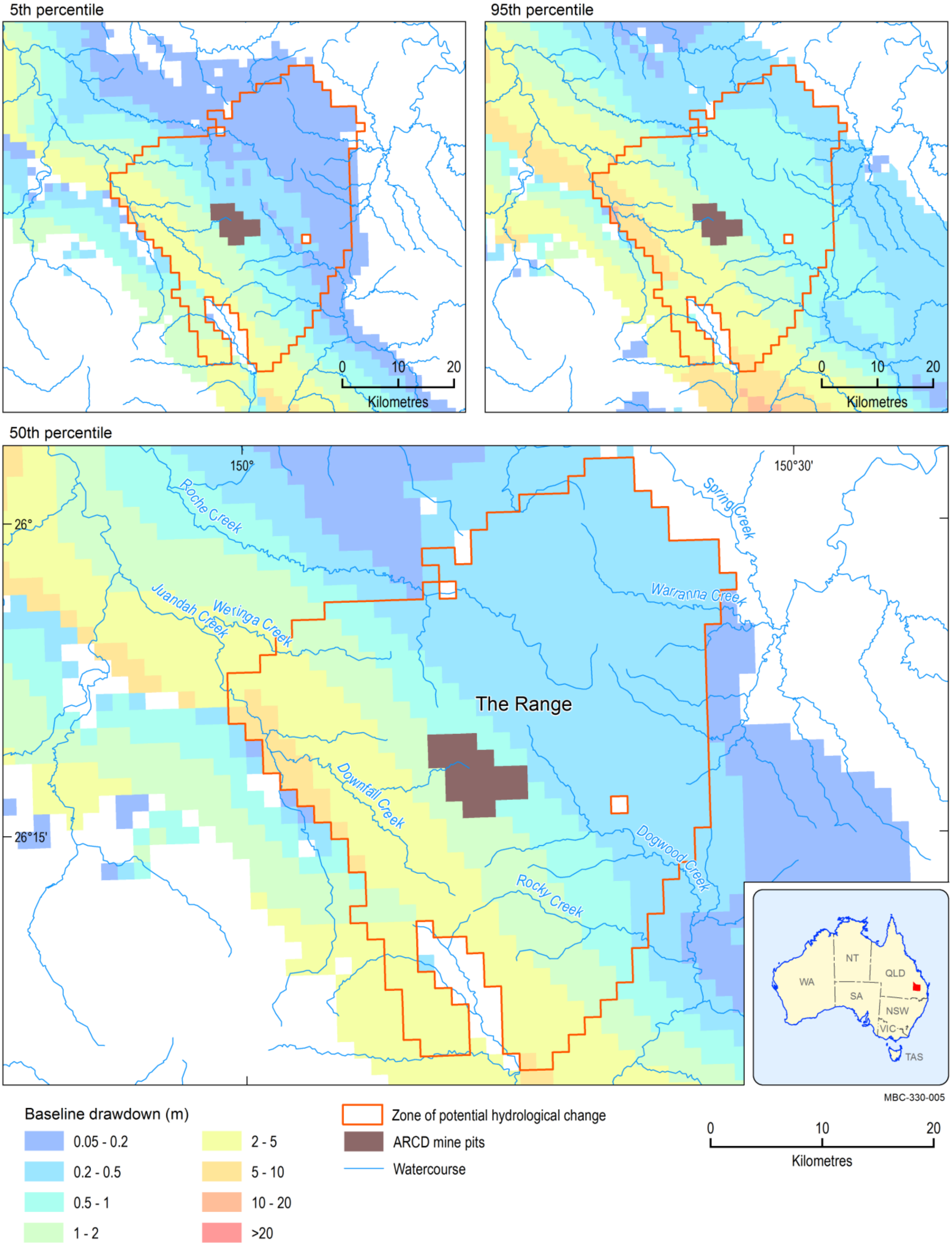

Figure 15 Baseline drawdown (m) in the regional watertable in the vicinity of The Range coal mine (5th, 50th and 95th percentiles)

Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. In a confined aquifer, drawdown relates to a change in water pressure and does not necessarily translate to changes in depth to watertable. ACRD = additional coal resource development
Data: Bioregional Assessment Programme (Dataset 1, Dataset 2, Dataset 3, Dataset 4); Office of Groundwater Impact Assessment (Dataset 5)

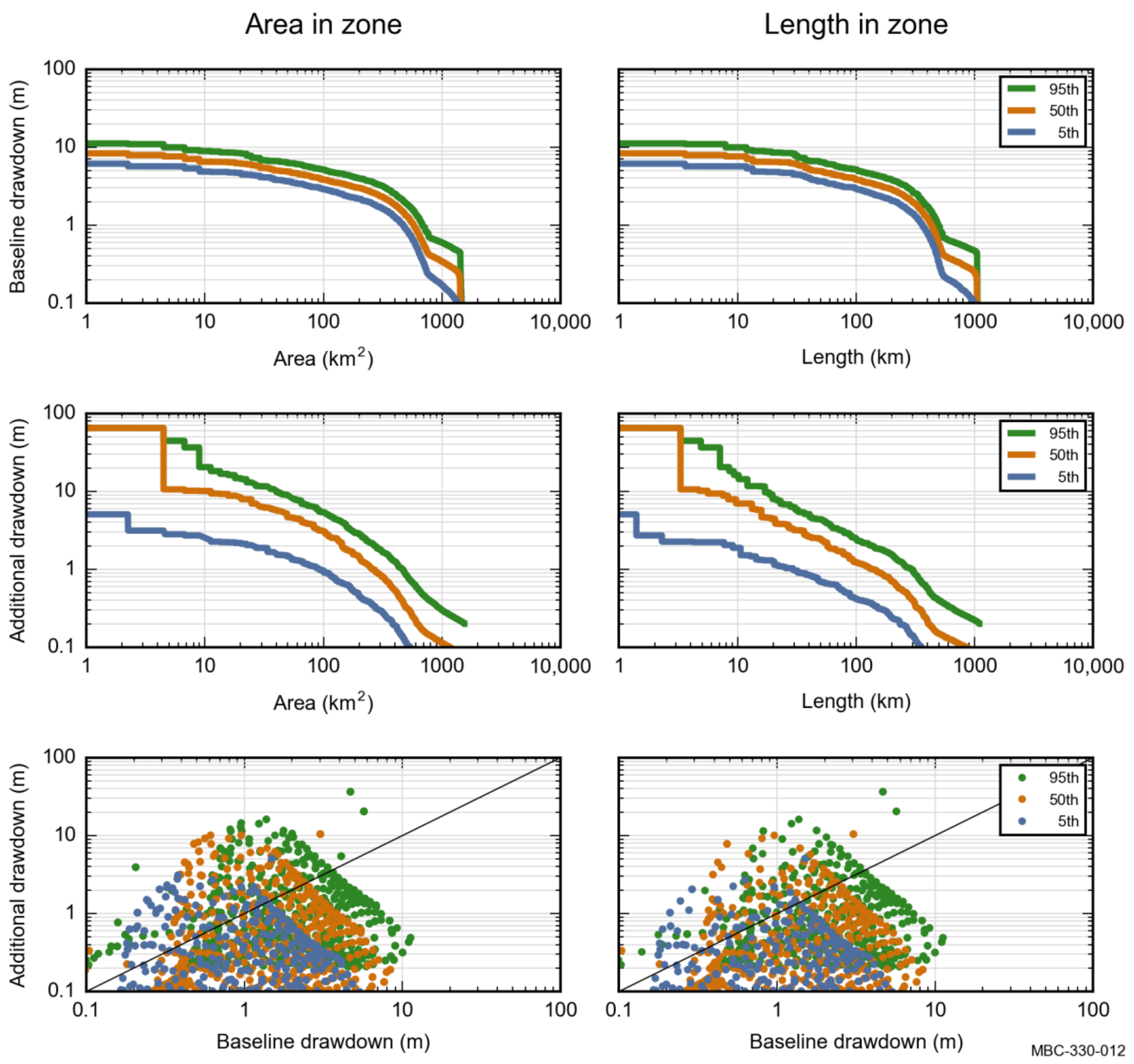

Figure 16 Zone of potential hydrological change: the top two rows show area (km^2) or stream length (km) within the zone that exceeds the 5th, 50th and 95th percentile estimates of baseline drawdown and additional drawdown, and the bottom row shows baseline drawdown compared to additional drawdown in each assessment unit

Colours represent the 5th, 50th and 95th percentile. Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. Areas within modelled mine pits are not included in this analysis.
Data: Bioregional Assessment Programme (Dataset 7)

Table 4 Surface area and stream length potentially exposed to varying levels of baseline drawdown in the vicinity of the two additional coal resource developments, New Acland Coal Mine Stage 3 and The Range coal mine

Extent	Additional coal resource development	Extent in zone of potential hydrological change (excluding modelled open-cut mine pits)	Extent in modelled open-cut mine pits	Extent[a] with baseline drawdown ≥0.2 m			Extent[a] with baseline drawdown ≥2 m			Extent[a] with baseline drawdown ≥5 m		
				5th	50th	95th	5th	50th	95th	5th	50th	95th
Area (km^2)	New Acland Coal Mine Stage 3	134	44.8	2.2	9.0	31.3	0	2.2	9.0	0	0	2.2
	The Range coal mine	1409	42.7	866	1409	1409	236	370	467	9.0	42.6	103
	Total in regional watertable	**1544**	**87.4**	**869**	**1418**	**1441**	**236**	**373**	**476**	**9.0**	**42.6**	**105**
Stream length (km)	New Acland Coal Mine Stage 3	55.2	12.7	1.4	3.5	13.5	0	1.4	3.5	0	0	1.4
	The Range coal mine	1040	8.4	600	1040	1040	214	298	359	13.4	45.7	102
	Total in regional watertable	**1095**	**21.1**	**601**	**1044**	**1053**	**214**	**299**	**363**	**13.4**	**45.7**	**103**

[a]This extent does not include the extent in modelled open-cut mine pits.
The extent potentially exposed to ≥0.2, ≥2 and ≥5 m baseline drawdown is shown for the 5th, 50th and 95th percentiles of the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. In a confined aquifer, drawdown relates to a change in water pressure and does not necessarily translate to changes in depth to watertable.
Due to rounding, some totals may not correspond with the sum of the separate numbers.
Data: Bioregional Assessment Programme (Dataset 7)

Table 5 Surface area and stream length potentially exposed to varying levels of additional drawdown in the vicinity of the two additional coal resource developments, New Acland Coal Mine Stage 3 and The Range coal mine

Extent	Additional coal resource development	Extent in zone of potential hydrological change (excluding modelled open-cut mine pits)	Extent in modelled open-cut mine pits	Extent[a] with additional drawdown ≥0.2 m			Extent[a] with additional drawdown ≥2 m			Extent[a] with additional drawdown ≥5 m		
				5th	50th	95th	5th	50th	95th	5th	50th	95th
Area (km^2)	New Acland Coal Mine Stage 3	134	44.8	6.7	33.6	134	2.2	11.2	29.1	2.2	9.0	20.2
	The Range coal mine	1409	42.7	377	584	1409	22.5	132	242	0	40.4	89.8
	Total in regional watertable	**1544**	**87.4**	**384**	**617**	**1544**	**24.7**	**144**	**272**	**2.2**	**49.4**	**110**
Stream length (km)	New Acland Coal Mine Stage 3	55.2	12.7	3.8	21.1	55.2	1.4	6.2	10.3	1.4	5.4	9.5
	The Range coal mine	1040	8.4	231	386	1040	7.6	50.9	126	0	10.3	30.6
	Total in regional watertable	**1095**	**21.1**	**235**	**407**	**1095**	**9.0**	**57.1**	**137**	**1.4**	**15.8**	**40.1**

[a]This extent does not include the extent in modelled open-cut mine pits.
The extent potentially exposed to ≥0.2, ≥2 and ≥5 m additional drawdown is shown for the 5th, 50th and 95th percentile estimates of the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. In a confined aquifer, drawdown relates to a change in water pressure and does not necessarily translate to changes in depth to watertable.
Due to rounding, some totals may not correspond with the sum of the separate numbers.
Data: Bioregional Assessment Programme (Dataset 7)

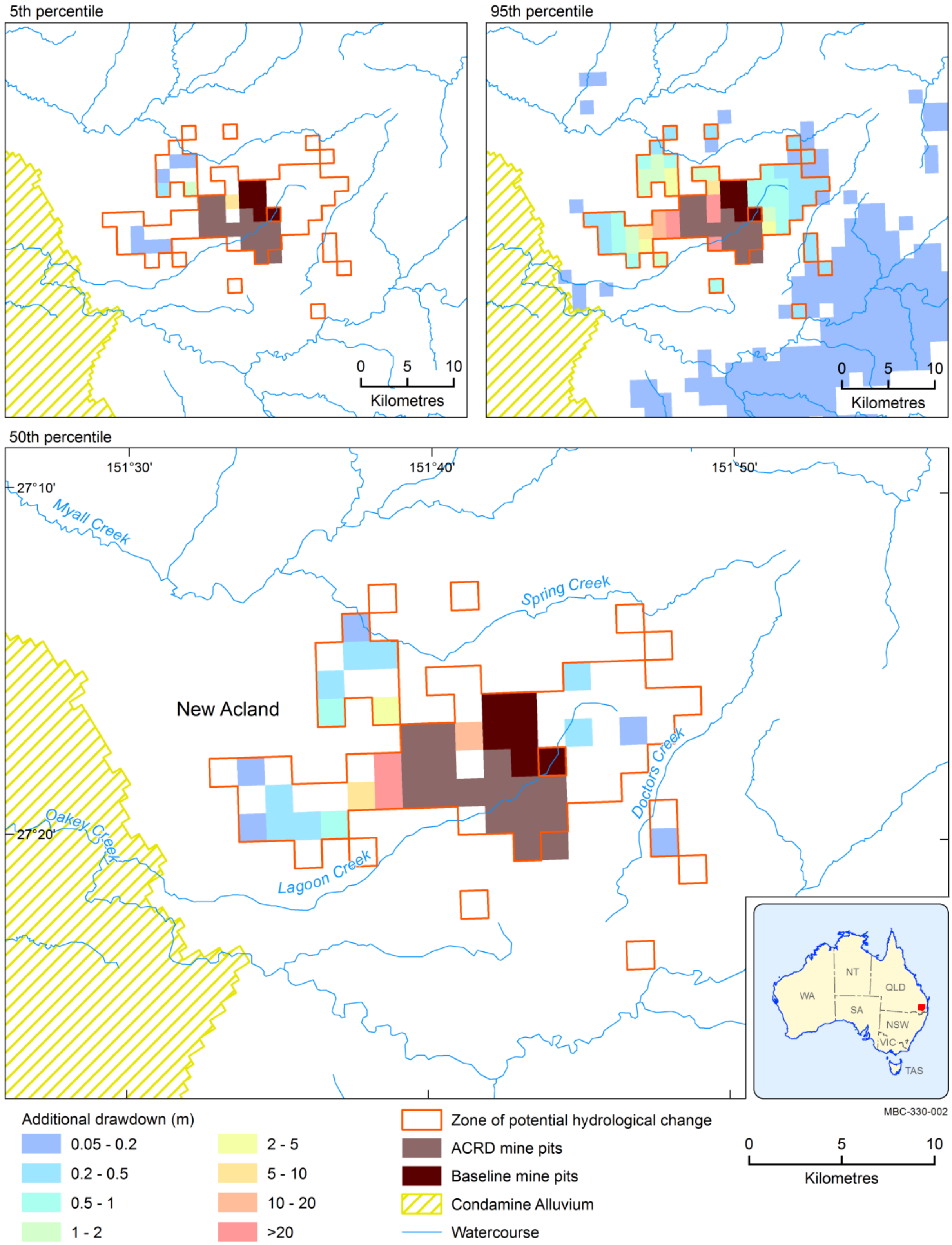

Figure 17 Additional drawdown (m) in the regional watertable in the vicinity of New Acland Coal Mine Stage 3 (5th, 50th and 95th percentiles)

Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. In a confined aquifer, drawdown relates to a change in water pressure and does not necessarily translate to changes in depth to watertable. The mine pits in the CRDP are the sum of those in the baseline and the additional coal resource development (ACRD).
Data: Bioregional Assessment Programme (Dataset 1, Dataset 2, Dataset 3, Dataset 4); Office of Groundwater Impact Assessment (Dataset 5)

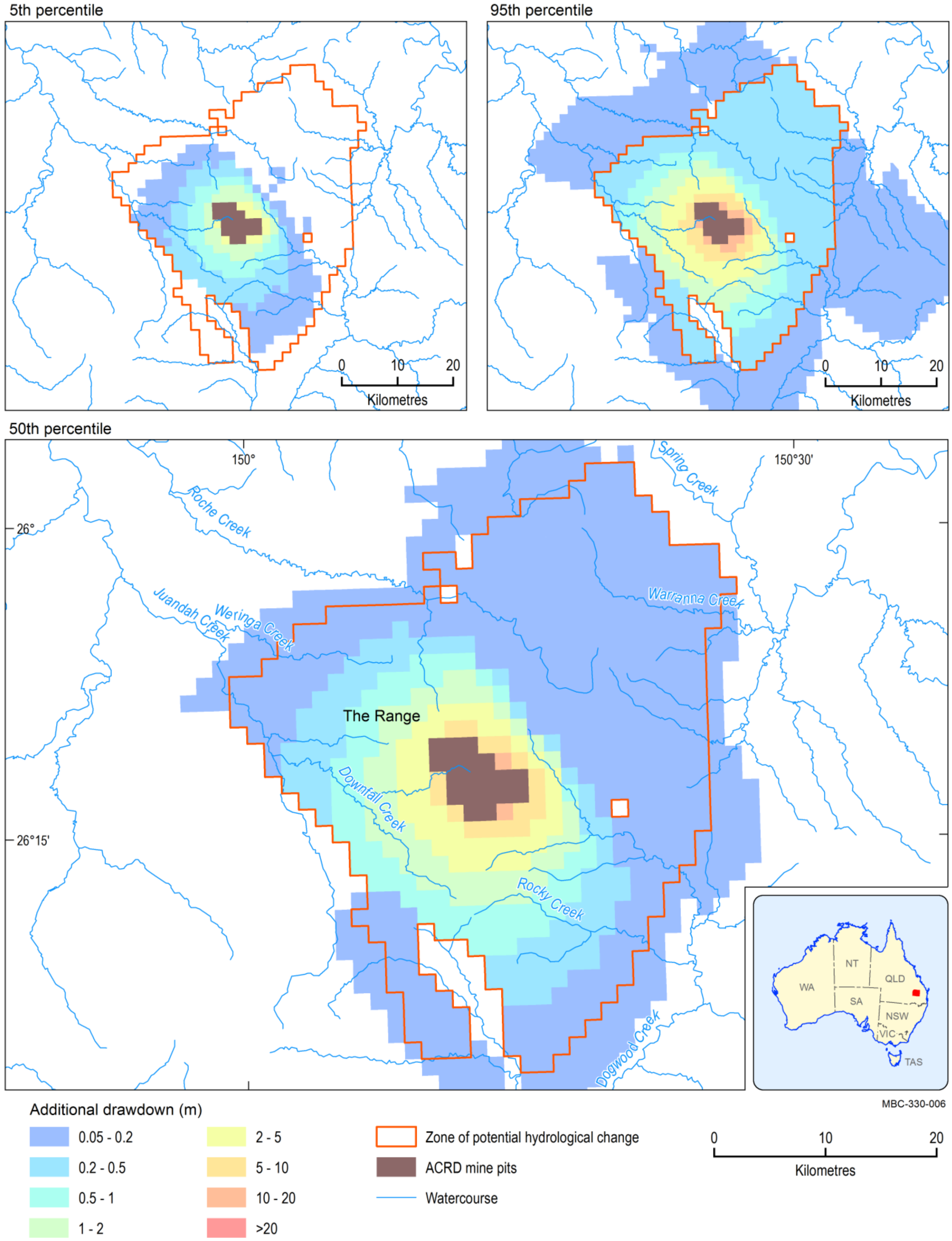

Figure 18 Additional drawdown (m) in the regional watertable in the vicinity of The Range coal mine (5th, 50th and 95th percentiles)

Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. In a confined aquifer, drawdown relates to a change in water pressure and does not necessarily translate to changes in depth to watertable. ACRD = additional coal resource development
Data: Bioregional Assessment Programme (Dataset 1, Dataset 2, Dataset 3, Dataset 4); Office of Groundwater Impact Assessment (Dataset 5)

The range of model predictions in the vicinity of New Acland Coal Mine Stage 3 indicates that the extent of baseline drawdown in the regional watertable in excess of 0.2 m within the zone is between 2 km^2 including 1 km of streams and 31 km^2, which includes 13 km of streams. Baseline drawdown in excess of 5 m in the regional watertable is *very unlikely* to exceed 2 km^2, which includes 1 km of streams (95th percentile). Median baseline drawdown is up to 3.0 m in the regional watertable, which is located near the modelled mine pits (Figure 14).

Additional drawdown in this area is predicted to lower the regional watertable by an additional 0.2 m over an area of between 7 km^2 including 4 km of streams (5th percentile) and 134 km^2 including 55 km of streams (95th percentile). The area affected by additional drawdown in the regional watertable in excess of 5 m ranges from 2 km^2 including 1 km of streams (5th percentile) to 20 km^2 including 9 km of streams (95th percentile). Median additional drawdown is up to 65 m in the regional watertable next to the modelled mine pits (Figure 17).

In the vicinity of New Acland Coal Mine, the regional watertable is represented in the model by model layer 1, thereby including only alluvium (including Condamine Alluvium) or Main Range Volcanics geologic units (Figure 7). The integrated Condamine and regional models (QWC, 2012), used to estimate baseline drawdown, indicate that additional drawdown is very unlikely to exceed 0.2 m in the Condamine Alluvium (see companion product 2.6.2 for the Maranoa-Balonne-Condamine subregion (Janardhanan et al., 2016)).

Geological mapping shows that New Acland Coal Mine Stage 3 overlies outcropping Walloon Coal Measures, as well as Main Range Volcanics and Cenozoic units (Figure 43 in companion product 2.3 (Holland et al., 2016)). The regional model does not include this area of outcropping Walloon Coal Measures in the regional watertable as it is not the role of a regional model to represent these local-scale geological features. The extent of the zone of potential hydrological change in the regional watertable would change if these outcropping areas were represented in the regional model.

Economic groundwater bores and springs access the regional watertable and deeper aquifers in the vicinity of the New Acland Coal Mine. Figure 19 and Figure 20 show the spatial distribution of median baseline and additional drawdown in these deeper layers. In the vicinity of New Acland Coal Mine, the zone of potential hydrological change covers 134 km^2 of the regional watertable, 849 km^2 of model layer 10 – Walloon Coal Measures and 750 km^2 of model layer 12 – Hutton/Marburg Sandstone.

Extraction of groundwater to enable dewatering of open-cut mine pits at New Acland Coal Mine has the greatest cumulative impact on water levels in model layer 10 – Walloon Coal Measures. Near the mine, median drawdown in this layer is up to 3.6 m under the baseline and up to 24.9 m due to additional coal resource development. Further west, near the eastern edge of the Condamine Alluvium, median baseline drawdown due to CSG development is less than 2 m in this layer. However, this does not overlap with the baseline drawdown near the mine.

Median additional drawdown in the vicinity of the New Acland Coal Mine is up to 65 m in the regional watertable near the modelled mine pits, up to 24.9 m in model layer 10 – Walloon Coal Measures and up to 1.7 m in model layer 12 – Hutton/Marburg Sandstone (Figure 20). Additional drawdown in this area is associated with the cumulative effects of the proposed mine pits.

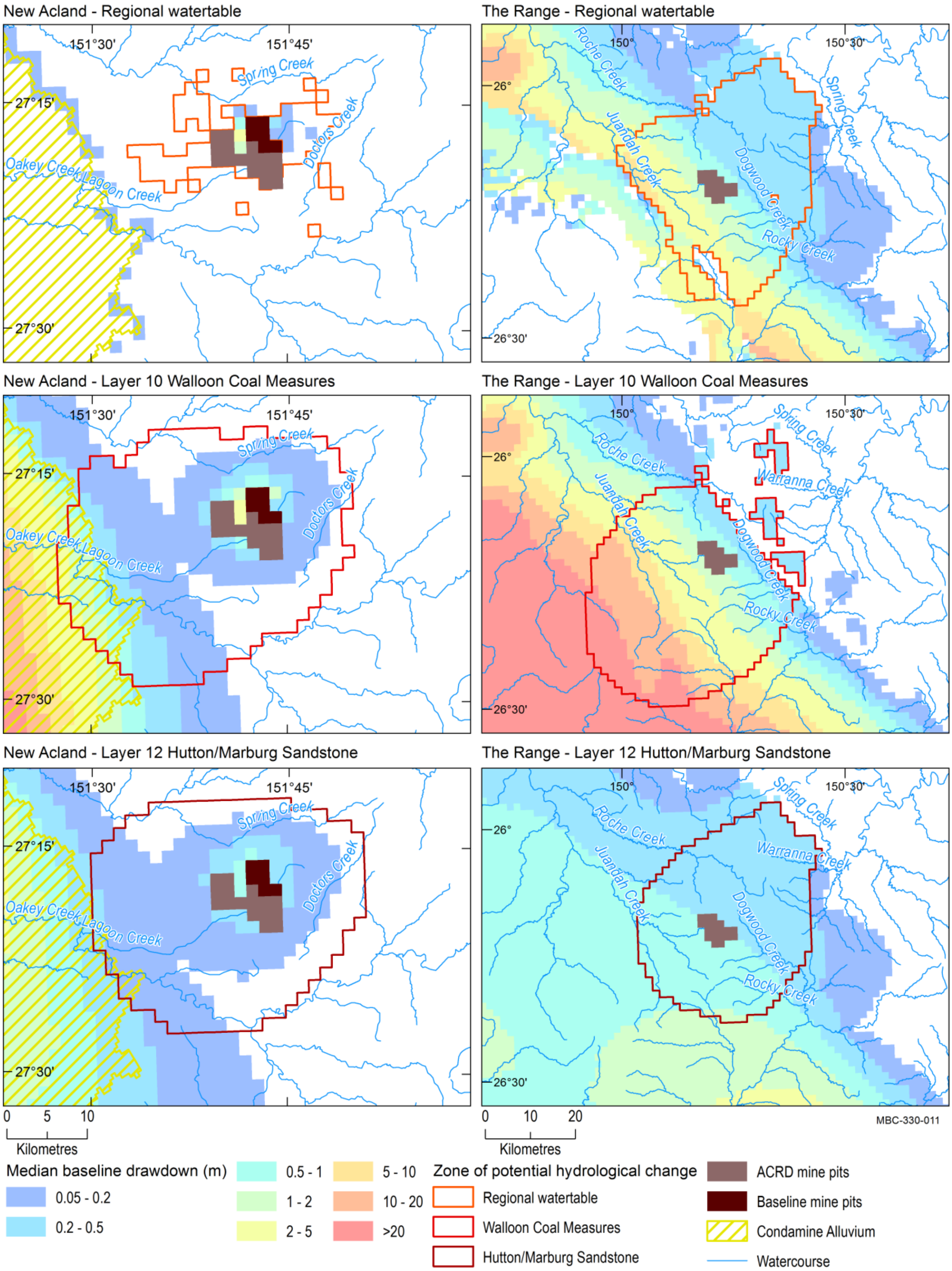

Figure 19 Median baseline drawdown (m) in the regional watertable, model layer 10 – Walloon Coal Measures and model layer 12 – Hutton/Marburg Sandstone aquifers in the vicinity of New Acland Coal Mine and The Range coal mine

Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. In a confined aquifer, drawdown relates to a change in water pressure and does not necessarily translate to changes in depth to watertable. The mine pits in the CRDP are the sum of those in the baseline and the additional coal resource development (ACRD).
Data: Bioregional Assessment Programme (Dataset 1, Dataset 2, Dataset 3, Dataset 4, Dataset 8); Office of Groundwater Impact Assessment (Dataset 5)

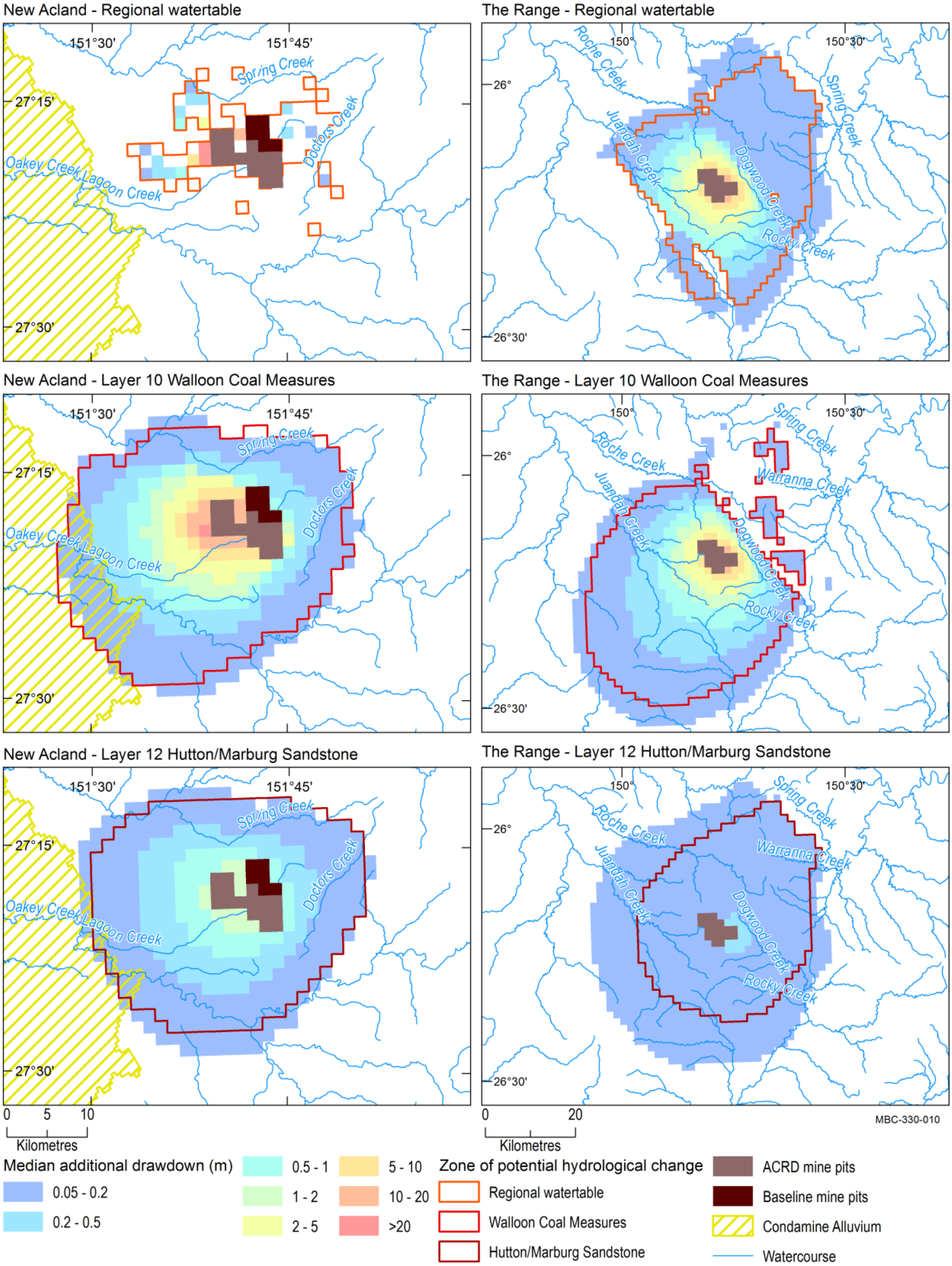

Figure 20 Median additional drawdown (m) in the regional watertable, model layer 10 – Walloon Coal Measures and model layer 12 – Hutton/Marburg Sandstone aquifers in the vicinity of New Acland Coal Mine and The Range coal mine

Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. In a confined aquifer, drawdown relates to a change in water pressure and does not necessarily translate to changes in depth to watertable. The mine pits in the CRDP are the sum of those in the baseline and the additional coal resource development (ACRD).
Data: Bioregional Assessment Programme (Dataset 1, Dataset 2, Dataset 3, Dataset 4, Dataset 8); Office of Groundwater Impact Assessment (Dataset 5)

The range of model predictions in the vicinity of The Range coal mine indicates that the extent of baseline drawdown in the regional watertable in excess of 0.2 m within the zone is between 866 km^2 including 600 km of streams and 1409 km^2, which includes 1040 km of streams. Baseline drawdown in excess of 5 m in the regional watertable is *very unlikely* to cover more than 103 km^2, which includes 102 km of streams (95th percentile). Median baseline drawdown is up to 8.3 m in the regional watertable, which is located along the western edge of the zone and is associated with baseline CSG production (Figure 15).

Additional drawdown in this area is predicted to lower the regional watertable by an additional 0.2 m over an area of between 377 km^2 including 231 km of streams (5th percentile) and 1409 km^2 including 1040 km of streams (95th percentile). The area affected by additional drawdown in the regional watertable in excess of 2 m ranges from 22 km^2 including 8 km of streams (5th percentile) to 242 km^2 including 126 km of streams (95th percentile). Median additional drawdown is up to 10.2 m in the regional watertable next to the modelled mine pits (Figure 18).

In the vicinity of The Range coal mine, the regional watertable includes outcropping areas of Springbok Sandstone, Walloon Coal Measures and Hutton/Marburg Sandstone, which is generally consistent with surface geological mapping in this area (Figure 40 in companion product 2.3 (Holland et al., 2016)). Figure 19 and Figure 20 show the spatial distribution of median baseline and additional drawdown in these deeper layers. In the vicinity of The Range coal mine, the zone of potential hydrological change covers 1409 km^2 of the regional watertable, 1696 km^2 of model layer 10 – Walloon Coal Measures and 1361 km^2 of model layer 12 – Hutton/Marburg Sandstone.

Median baseline drawdown in the regional watertable near The Range coal mine is 8.3 m and drawdown due to additional coal resource development is 10.2 m. Extraction of groundwater to enable baseline CSG production has the greatest impact on water levels in model layer 10 – Walloon Coal Measures, the target of CSG production, in this area. Median drawdown in this layer is up to 82.0 m under the baseline and up to 10.2 m due to additional coal resource development. Median drawdown in the underlying model layer 12 – Hutton/Marburg Sandstone is less, being up to 1.1 m under the baseline and less than 0.2 m due to additional coal resource development.

3.3.3 Potential surface water changes

No surface water numerical modelling was undertaken for the Maranoa-Balonne-Condamine subregion. Some potential hydrological changes may, however, be specified conceptually based on scientific logic as described in Section 3.2.2 on causal pathways.

3.3.4 Potential water quality changes

Regional changes in surface water and groundwater flows due to additional coal resource development could potentially lead to changes in the quality of surface water and groundwater. Although water quality changes were not modelled explicitly as part of this BA, the implications for water quality in the Maranoa-Balonne-Condamine subregion are considered in this section in light of the modelled hydrological changes due to the additional coal resource development.

Relevant factors for assessing the potential for changes in regional groundwater and surface water quality from the two additional coal resource developments in the Maranoa-Balonne-Condamine subregion are:

- New Acland Coal Mine Stage 3:
  - a proposed expansion of the existing New Acland open-cut mine, which will increase production from 4.8 to 7.5 Mt/y of thermal coal (New Hope Group, 2012, 2014). Approximately 10% of the New Acland mining lease area is mined at any one time, with ongoing rehabilitation to ensure the land is returned to a commercially viable agricultural state (EPA, 2006; New Hope Group, 2013).
  - water demand is projected to increase from 1370 to 3300 ML/y (Psi-Delta, 2010; New Hope Group, 2014). Mine-affected water is sourced from overland flow as part of the mine's zero discharge requirements. Other water sources include up to 5550 ML/y from the Toowoomba Regional Council Wetella Wastewater Reclamation Facility (WWRF) and 1412 ML/y of licensed groundwater extractions (New Hope Group, 2014).
  - surface water runoff from disturbed and mine-affected areas will be captured and treated before potential release off-site. Controlled releases during periods of extended rainfall can be made to Lagoon Creek, based on the salinity of the released water and the flow in the receiving waters (New Hope Group, 2014). Surface water runoff from undisturbed areas will be diverted away and released directly into adjacent waterways.
- The Range coal mine:
  - a proposed new open-cut coal mine, which is expected to produce 5 to 7 Mt/y of coal (DEHP, 2013). Approximately 8 million cubic metres of topsoil will be removed from three open-cut pits, which will be used for progressive rehabilitation.
  - water demand is projected to be 1350 to 2868 ML/y (DEHP, 2013). Capture, storage and reuse of mine-affected water will be managed by mine water dams, including sediment dams, to treat water prior to release or potential release off-site. Other potential water sources include the proposed SunWater Wolleebee Creek to Glebe Weir pipeline or co-produced water (DEHP, 2013).

- surface water runoff from disturbed sites will be captured and used to meet mine water needs as part of zero discharge requirements. Surface water runoff from undisturbed areas will be diverted away and released directly into adjacent waterways (DEHP, 2013).

In the following sections, the causal pathways that could potentially lead to regional impacts on water quality are identified and the risk of impact is assessed qualitatively. The extent of influence and existing regulation and management practices are used to inform the assessment of risk.

3.3.4.1 Groundwater quality

Changes in groundwater quality from coal resource development can occur as an indirect result of subsurface depressurisation and dewatering of aquifers and changes to subsurface physical pathways between aquifers, which may modify groundwater flow paths and flow rates between aquifers of different quality water. Changes in groundwater quality can also occur as a direct result of coal resource development and operational water management, such as when water is deliberately injected into an aquifer or coal seam to manage surplus water, counter the effects of groundwater depressurisation or facilitate the process of CSG extraction. Unless hydrologically isolated from their surroundings, the creation of coal stockpiles, rock dumps and tailings dams on coal mine sites can result in leaching of contaminants to groundwater. In all these cases, a hazard arises when the quality of the receiving water is changed such that it reduces its beneficial-use value. BAs are concerned with the risk from non-accidental changes to water quality off site, which may be cumulative where different mining operations are in proximity.

Table 6 lists potential causes of changes in groundwater quality from coal resource development in the Maranoa-Balonne-Condamine subregion and identifies the potential for off-site impacts. Groundwater quality (including aquifer properties and groundwater composition) is potentially affected by eight causal pathways in the Maranoa-Balonne-Condamine subregion. Effects on groundwater quality are localised within tenements, downstream watercourses and irrigated areas or target aquifers used to dispose of co-produced water. Risks are addressed by Mine Water Management Plans within tenements and by Healthy Water Management Plans in downstream watercourses. In the remainder of this section, the risk to water quality off site is considered in the context of the scale of the effect and existing regulatory controls.

Table 6 Causal pathways for potential changes in groundwater quality and off-site impacts

Causal pathway	Water quality concern	Scale	Potential off-site impacts
'Discharging extracted water into surface water system'	Short-term changes to surface water – groundwater interactions that may affect alluvial aquifers	Local	Potential impacts are addressed by Mine Water Management Plans within tenements and by Healthy Water Management Plans in downstream watercourses
'Extracting overburden to access coal'	Medium to long term changes to groundwater recharge patterns and aquifer interconnectivity	Local	Potential impacts contained within tenements. Regulatory controls in place to minimise risk
'Failure of well integrity', 'Hydraulic fracturing' and 'Unplanned groundwater changes'	Long-term changes to aquifer properties, groundwater composition and quality from leaky wells, hydraulic stimulation and mis-perforation of the coal seam	Local	Potential impacts are subject to management controls (such as compliance with standards and regulations) and monitoring
'Processing and using extracted water'	Short-term changes to groundwater recharge that may affect irrigated areas Short-term changes to surface water – groundwater interactions that may affect alluvial aquifers	Local	Potential impacts contained within tenements, downstream watercourses and irrigated areas. Regulatory controls in place to minimise risk
'Reinjecting co-produced water into aquifer'	Long-term effects within target aquifers	Local	Potential to offset impacts of CSG production. Regulatory controls in place and under revision to minimise future risk
'Storing extracted water'	Medium- to long-term changes to groundwater quality and quantity/volume from dam construction and other water management structures that change recharge from natural surface drainage and runoff	Local	Potential impacts are addressed by Mine Water Management Plans within tenements and by Healthy Water Management Plans in downstream watercourses

CSG = coal seam gas

CSG operations and coal mines have the potential to change surface water – groundwater interactions. These changes are likely to be within tens of metres of a watercourse and so are not represented in the regional groundwater model. Changes to groundwater quality from environmentally relevant activities such as CSG operations and coal mines are addressed by the Healthy Water Management Plans being developed under Queensland's *Environmental Protection Act 1994* legislation. The plans assess risks to water quality, and identify water quality targets based on local data (including electrical conductivity, nutrients, turbidity, pH) to inform regulatory conditions on environmentally relevant activities such as CSG and coal mines. These plans will improve the monitoring and assessment of threats to surface water quality in the subregion.

Preferential flow paths can also be affected by changes to surface water – groundwater interactions (including changes to aquifer interconnectivity, mine expansion too close to a river or lake, preferential drainage and recharge associated with post-closure water filling the pit). Mine expansion that links aquifers and leads to preferential drainage can affect groundwater quality, but is likely to be limited to the extent of the mine tenements due to the hydraulic gradients toward the mine pits. Changes to surface water – groundwater interactions can also change the timing and volume of baseflow contributions to streams, which can affect the stream ecosystem within and downstream of tenements. These changes are likely to be restricted to areas where direct interactions between watercourses and unconfined aquifers are possible.

While not specifically identified for each development, wells are necessary parts of CSG extraction, and monitoring bores and production bores are typical of coal mining developments. Well integrity can be an issue, with well failure considered an inevitable consequence of CSG extraction. The code of practice for constructing and abandoning coal seam gas wells and associated bores in Queensland (DNRM, 2013) was developed to ensure that all CSG wells and CSG water bores are constructed and abandoned to a minimum acceptable standard resulting in long term well integrity, containment of gas and the protection of groundwater resources.

Potential effects of leaky wells are likely to be localised, with numerical modelling suggesting that changes to hydraulic gradients are restricted to less than 1 km, but will continue until remedial actions are taken. Hydraulic stimulation involves high-pressure injection of water (and other materials including chemical compounds and sand) to induce changes in aquifer properties to aid the release and flow of gas from the coal seams towards the well. This may also lead to unplanned groundwater changes through mis-perforation of the coal seam. The lateral extent to which aquifer properties and groundwater quality are changed diminishes with distance from the well and is likely to be limited to aquifers within tenements. The groundwater composition and quality of the fractured aquifer and neighbouring aquifers can be compromised and is subject to management controls (such as compliance with standards and regulations) and monitoring.

Disposal of co-produced water by aquifer reinjection has the potential to offset impacts of groundwater depressurisation from CSG production in aquifers in the Maranoa-Balonne-Condamine subregion. Potential impacts include changes to the volume and timing of groundwater discharge to springs and watercourses in aquifer outcrop areas and possible changes to aquifer composition. Aquifer reinjection is not modelled numerically as projects are still at the feasibility testing and trial injection stages. Current studies target the Gubberamunda, Precipice and Hutton sandstone aquifers (APLNG, 2012; Arrow Energy, 2013; Santos, 2013).

Dam construction and other water management structures that change natural surface drainage and runoff have the potential to affect groundwater recharge patterns, in turn affecting groundwater quality and quantity/volume. However, this is likely to be limited to watercourses within and downstream of tenements.

3.3.4.2 Surface water quality

Changes in surface water quality from coal resource development can occur following disruptions to surface drainage from the removal of vegetation and disturbance of soil in construction of roads, site facilities, excavation of open-cut pits and landscaping of the site during production and rehabilitation. Bare surfaces increase the risk of erosion with potential to increase total suspended solids in waterways. The discharge of mine water into the stream network as part of operational water management is potentially hazardous, if the quality of the discharged water lowers the quality of the receiving water below its current beneficial-use level.

Depressurisation and dewatering of aquifers and changes to subsurface physical pathways between aquifers can lead to a change in baseflow to streams and potentially affect the water quality of the stream. Table 7 lists potential causes of changes in surface water quality from coal resource development in the Maranoa-Balonne-Condamine subregion and identifies the potential for off-site impacts, having regard to the relevance of the causal pathway in the subregion and the likely scale of the effect.

Table 7 Causal pathways for potential changes in surface water quality and off-site impacts

Causal pathway	Water quality concern	Scale	Potential off-site impacts
'Altering surface water system'	Medium- to long-term effects due to diversion of creek lines and runoff	Local	Potential impacts are addressed by Mine Water Management Plans within tenements and by Healthy Water Management Plans in downstream watercourses
'Failure of well integrity'	Long-term changes to surface water quality due to bore leakage to the surface	Local	Potential impacts are subject to management controls (such as compliance with standards and regulations) and monitoring
'Processing and using extracted water'	Short-term effects due to increased discharge to rivers to enable re-use of co-produced water for irrigation	Local	Potential impacts are addressed by Healthy Water Management Plans in downstream watercourses
'Storing extracted water'	Medium- to long-term effects due to construction of water management structures	Local	Potential impacts are addressed by Mine Water Management Plans within tenements and by Healthy Water Management Plans in downstream watercourses

It is likely that the extent of hydrological changes associated with baseline CSG production is limited to watercourses within and downstream of CSG tenements (Figure 21). As the two mines in the additional coal resource development are located in headwater streams, potential effects of open-cut coal mining under the baseline and under the CRDP on the surface water system can likely be managed by site-based risk management and regulation. Surface water quality in the subregion is managed by the Healthy Water Management Plans under Queensland's *Environmental Protection Act 1994* legislation, which will be accredited under the Commonwealth's *Basin Plan 2012* (MDBA, 2012).

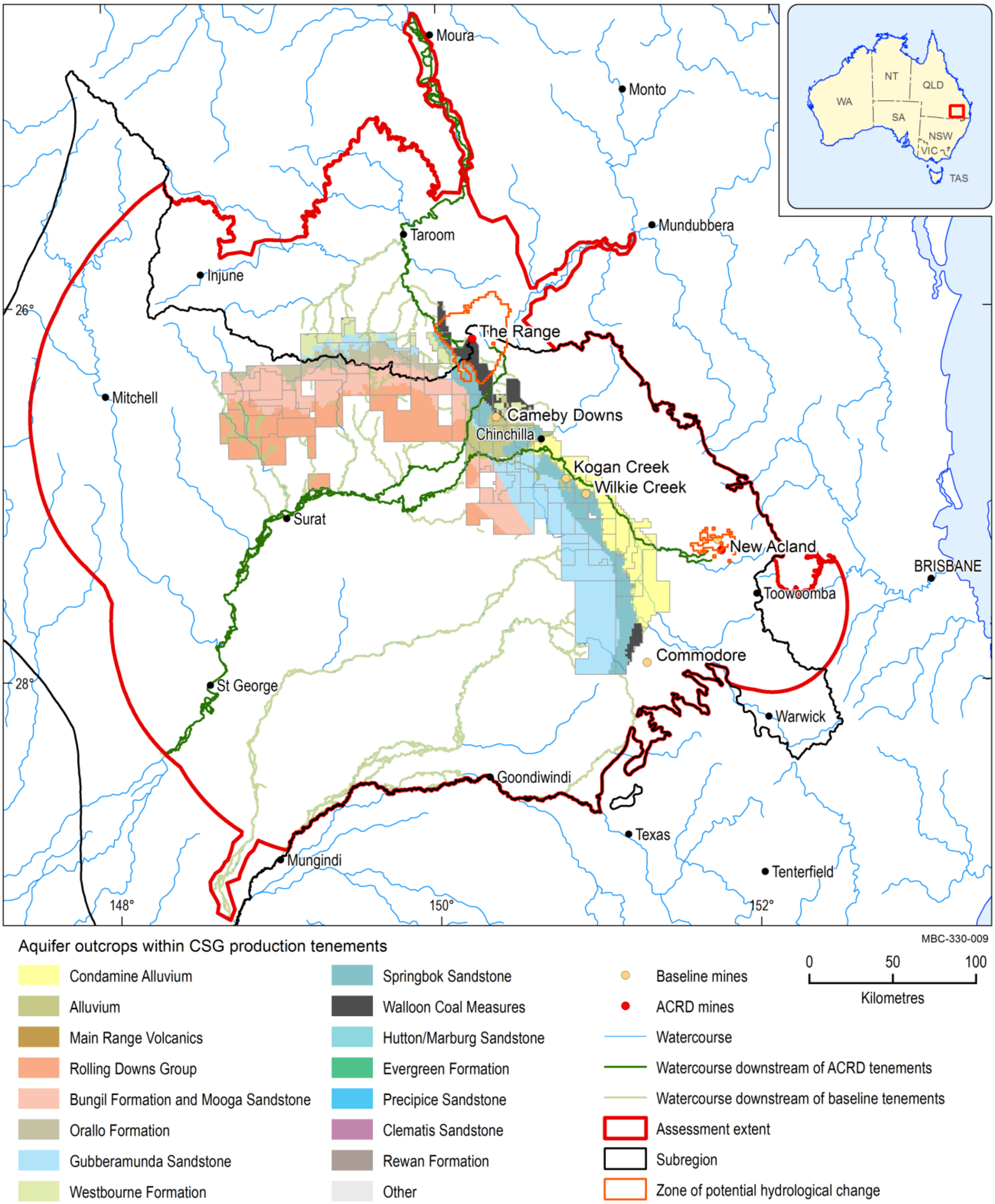

Figure 21 Parts of 'watercourses within and downstream of tenements' and 'alluvium and watercourses in aquifer outcrop areas within and downstream of tenements' system components that are associated with the baseline and additional coal resource development, overlaid on aquifer outcrop areas

Spatial extent of 'watercourses within and downstream of tenements' system component includes streams identified as 'Watercourse downstream of baseline tenements' and 'Watercourse downstream of ACRD tenements'. Spatial extent of 'alluvium and watercourses in aquifer outcrop areas within and downstream of tenements' system component includes areas where these streams overlay 'Aquifer outcrop areas within CSG production tenements'. Refer to Table 3 and Figure 6 for information on system components. The mines in the CRDP are the sum of those in the baseline and the additional coal resource development (ACRD).
CSG = coal seam gas
Data: Bioregional Assessment Programme Office of Groundwater Impact Assessment (Dataset 5); (Dataset 9, Dataset 10); Department of Natural Resources and Mines (Dataset 11)

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Dataset 4 Bioregional Assessment Programme (2015) MBC Groundwater model mine pit cells. Bioregional Assessment Derived Dataset. Viewed 20 April 2016, http://data.bioregionalassessments.gov.au/dataset/0e47f3ed-0c3b-4fa4-8e95-003edef6a313.

Dataset 5 Office of Groundwater Impact Assessment (2012) MBC Groundwater model layer boundaries. Bioregional Assessment Source Dataset. Viewed 14 April 2016, http://data.bioregionalassessments.gov.au/dataset/32b986d0-c3d0-4a01-a5a9-6fffde638e11.

Dataset 6 Office of Groundwater Impact Assessment (2012) Baseline drawdown Layer 1 - Condamine Alluvium. Bioregional Assessment Source Dataset. Viewed 22 April 2016, http://data.bioregionalassessments.gov.au/dataset/49b2cbac-c570-461d-b6e6-8e2e584aeaea.

Dataset 7 Bioregional Assessment Programme (2017) MBC Impact and Risk Analysis Database 20170224 v01. Bioregional Assessment Derived Dataset. Viewed 25 February 2017, http://data.bioregionalassessments.gov.au/dataset/69075f3e-67ba-405b-8640-96e6cb2a189a.

Dataset 8 Bioregional Assessment Programme (2016) MBC Groundwater model uncertainty analysis. Bioregional Assessment Derived Dataset. Viewed 22 April 2016, http://data.bioregionalassessments.gov.au/dataset/484c800e-55e0-465a-9243-c440311c51f3.

Dataset 9 Bioregional Assessment Programme (2015) Production Tenures within the Surat CMA Bioregional Assessment Derived Dataset. Viewed 11 May 2016, http://data.bioregionalassessments.gov.au/dataset/0e93c000-6e4d-46d4-90de-b1a1a53ab177.

Dataset 10 Bioregional Assessment Programme (2015) MBC Potentially affected watercourses. Bioregional Assessment Derived Dataset. Viewed 19 February 2016, http://data.bioregionalassessments.gov.au/dataset/2d1b8127-b602-4e60-b6ab-d7d505702e0d.

Dataset 11 Department of Natural Resources and Mines (2014) QLD Mining Lease 20140516. Bioregional Assessment Source Dataset. Viewed 26 February 2016, http://data.bioregionalassessments.gov.au/dataset/bb75dd72-ff3a-43bd-b160-9722e323a492.

3.4 Impacts on and risks to landscape classes

Summary

The heterogeneous natural and human-modified ecosystems in the Maranoa-Balonne-Condamine subregion were classified into 34 landscape classes, which were aggregated into five landscape groups based on their likely response to hydrological changes. Landscapes that are outside the zone of potential hydrological change are *very unlikely* (less than 5% chance) to be impacted and include more than 35,000 km^2 of the remnant vegetation, 59,000 km of the streams, 1,600 km^2 of the wetlands and 93,000 km^2 of productive landscapes within the assessment extent. The extent of landscape classes in the modelled open-cut mine pits is not reported in this analysis.

It is *very unlikely* that drawdown due to additional coal resource development exceeds 0.2 m in the source aquifers of the 177 springs in the assessment extent. This includes 153 springs that are hydrologically connected to Great Artesian Basin (GAB) aquifers and 24 springs that access non-GAB aquifers, such as the basalt aquifers of the Main Range Volcanics.

The extent of floodplain or lowland riverine landscapes in the zone of potential hydrological change includes 20 km^2 of remnant vegetation and 299 km of streams, including riparian forests, marshes, billabongs, tree swamps, anabranches and overflows. Median additional drawdown is in addition to, and of a similar magnitude to, natural watertable fluctuation (<2 m).

The extent of GAB groundwater-dependent ecosystems (GDEs) in the zone includes 76 km^2 of remnant vegetation and 319 km of streams that are hydrologically connected to GAB aquifers. None of the 153 springs that access GAB aquifers in the assessment extent are within 50 km of where there is at least a 5% chance of exceeding 0.2 m additional drawdown in the source aquifer identified for each spring. Median additional drawdown is in addition to, and of a similar magnitude to, natural watertable fluctuation (<2 m).

The extent of non-floodplain or upland riverine landscapes in the zone includes 12 km^2 of remnant vegetation and 477 km of temporary upland streams. None of the 24 non-GAB springs that access the Main Range Volcanics basalt aquifers are in the zone. Local impact assessment and modelling is required to supplement regional groundwater model predictions of localised cumulative drawdown (<5 m) that may affect ecosystems dependent on permeable rock or basalt aquifers, including open woodlands with shrub and grass layers and stygofauna within the aquifer.

The extent of human-modified landscapes in the zone includes 685 km^2 of land that is predominantly used for agricultural production, mining and urban development. Median additional drawdown in excess of 2 m may affect 92 km^2, including 0.2 km^2 classified as

'Intensive uses' and 'Production from irrigated agriculture and plantations' that may be reliant on groundwater.

Users can visualise more detailed results for landscape classes using a map-based interface on the BA Explorer, available at www.bioregionalassessments.gov.au/explorer/MBC/landscapes.

3.4.1 Overview

This section focuses on landscape classes with potential ecological impacts. Economic and sociocultural impacts are addressed in Section 3.5. Landscape classification was used to characterise the diverse range of water-dependent assets into a smaller number of landscape classes for further analysis and is described in companion product 2.3 for the Maranoa-Balonne-Condamine subregion (Holland et al., 2016).

The assessment extent was classified into 34 landscape classes, based on key landscape properties related to patterns in geology, geomorphology, hydrology, ecology and land use. The landscape classification describes the main ecological and human systems (including agricultural production systems, industrial and urban uses), and provides a high-level conceptualisation of the subregion at the surface (Figure 22).

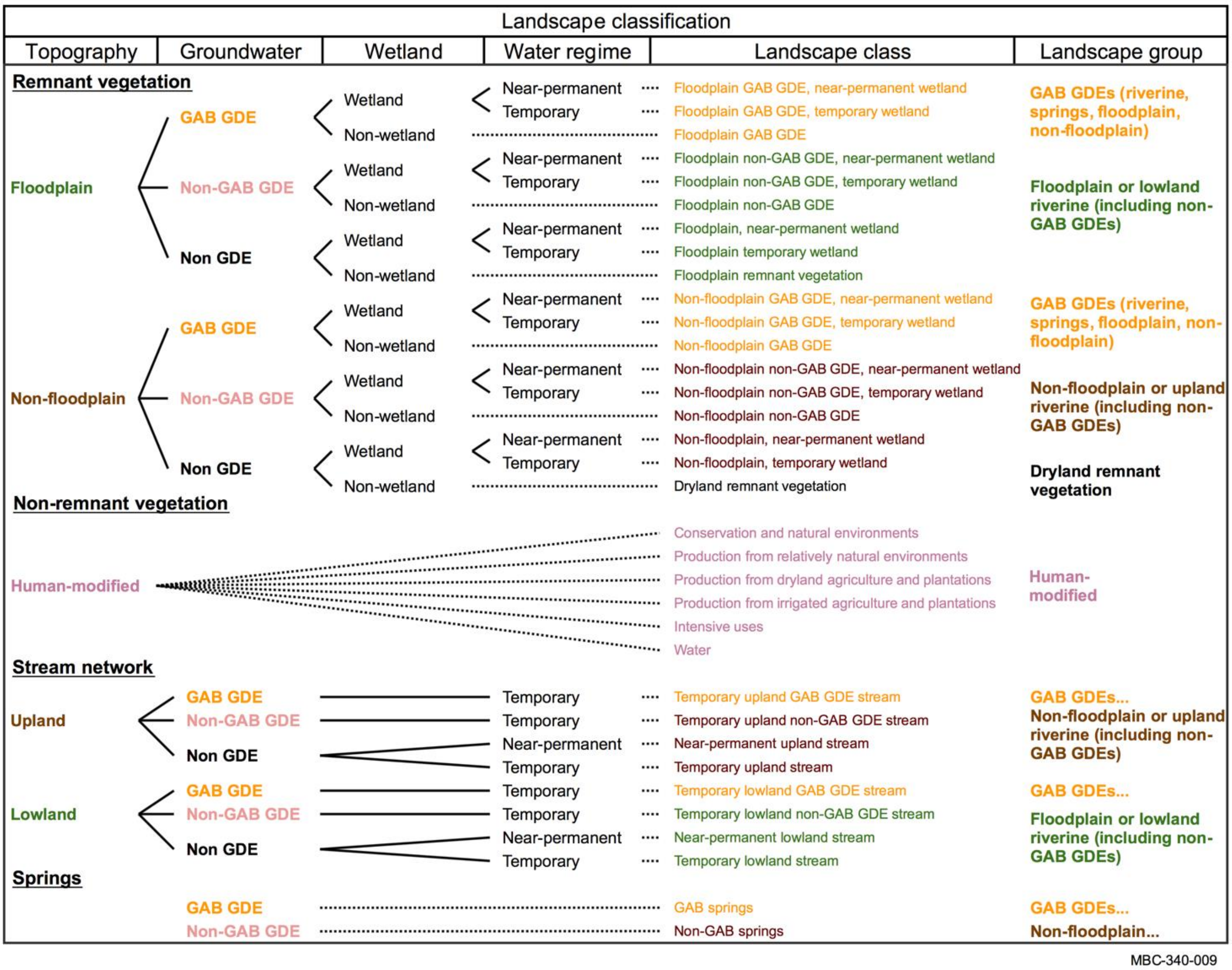

Figure 22 Schematic of the landscape classification for the Maranoa-Balonne-Condamine subregion

GAB = Great Artesian Basin, GDE = groundwater-dependent ecosystem, GAB GDEs… = GAB GDEs (riverine, springs, floodplain, non-floodplain), Non-floodplain… = Non-floodplain or upland riverine (including non-GAB GDEs)

Landscape classes were aggregated into five landscape groups based on their likely response to hydrological changes (Figure 23). One landscape group, 'Dryland remnant vegetation', which contains a large proportion of the remnant vegetation in the assessment extent, was not considered to be water dependent and was therefore ruled out of potential impacts due to additional coal resource development.

Landscape groups in the vicinity of New Acland Coal Mine are predominantly 'Human-modified' and 'Dryland remnant vegetation', covering over 95% of the zone of potential hydrological change. Watercourses within and downstream of the zone of potential hydrological change in the vicinity of the New Acland Coal Mine include Doctors, Lagoon, Oakey and Spring creeks that flow to the north-west into the Condamine River. These creeks are classified as temporary upland and temporary lowland streams that are associated with non-GAB aquifers, such as the Main Range Volcanics and alluvium (Figure 23).

In the vicinity of The Range coal mine, 93% of the area is classified as 'Dryland remnant vegetation', which is predominantly to the east of the mine, or 'Human-modified', predominantly to the west of the mine. Watercourses and groundwater-dependent ecosystems (GDEs) are classified into three landscape groups in the vicinity of The Range coal mine: 'GAB GDEs (riverine, springs, floodplain, non-floodplain)' to the north-east; 'Floodplain or lowland riverine (including non-GAB GDEs)' to the south-east; and 'Non-floodplain or upland riverine (including non-GAB GDEs)' to the west. GAB GDEs to the north-east overlie an area of Hutton Sandstone aquifer outcrop and include Warranna Creek, which flows to the Auburn River in the Burnett river basin. Dogwood and Rocky creeks are temporary lowland streams that flow to the south-west toward the confluence of Dogwood Creek with the Condamine and Balonne rivers. Temporary upland streams to the west of The Range coal mine flow through human-modified landscapes and flow into Juandah Creek on the western edge, which flows to the Dawson River in the north.

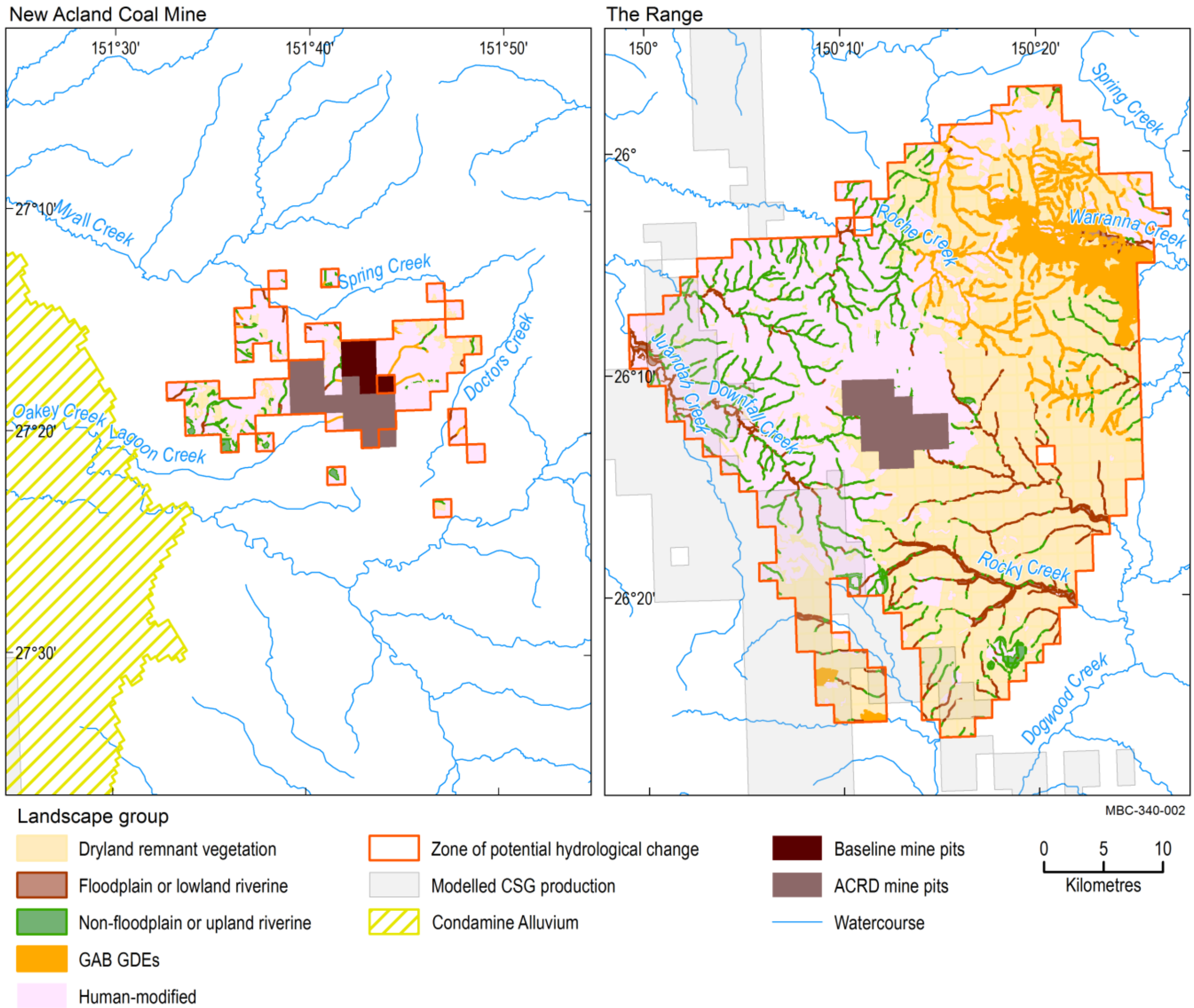

Figure 23 Landscape groups within the zone of potential hydrological change

The mine pits in the coal resource development pathway are the sum of those in the baseline and the additional coal resource development.
ACRD = additional coal resource development, CSG = coal seam gas, GAB = Great Artesian Basin, GDE = groundwater-dependent ecosystem
Data: Bioregional Assessment Programme (Dataset 1, Dataset 2, Dataset 3, Dataset 4)

3.4.2 Landscape classes that are unlikely to be impacted

Within the assessment extent of the Maranoa-Balonne-Condamine subregion, landscapes outside the zone of potential hydrological change, where impacts are *very unlikely* (Table 8), include:

- 35,281 km^2 of remnant vegetation, including 5846 km^2 classified as 'Floodplain or lowland riverine'; 1670 km^2 classified as 'GAB GDEs'; 2815 km^2 classified as 'Non-floodplain or upland riverine'; and 24,949 km^2 classified as 'Dryland remnant vegetation'
- 59,841 km of streams, including 28,850 km of lowland streams; 23,548 km of upland streams; and 7443 km of streams that access GAB aquifers
- 1612 km^2 of wetlands, including 1326 km^2 classified as 'Floodplain or lowland riverine'; 11 km^2 as 'GAB GDEs'; and 276 km^2 as 'Non-floodplain or lowland riverine'
- 177 springs, including 153 springs that are hydrologically connected to GAB aquifers and 24 springs that access non-GAB aquifers, such as the basalt aquifers of the Main Range Volcanics
- 93,044 km^2 of productive landscapes used for grazing and dryland agriculture.

Springs, near-permanent or temporary wetlands, and lowland streams are part of 12 landscape classes located outside the zone of potential hydrological change. These landscape classes include 694 km^2 of wetland vegetation and 329 km of near-permanent streams, which cover less than 0.1% of the assessment extent.

None of the subregion's 177 springs, which includes 153 GAB springs and 24 non-GAB springs, are contained within the zone of potential hydrological change. Further, none of the GAB springs are within 50 km of where there is at least a 5% chance of exceeding 0.2 m drawdown due to additional coal resource development in the GAB source aquifer identified for each spring (Office of Groundwater Impact Assessment, Dataset 5; Bioregional Assessment Programme, Dataset 6).

GAB springs refer to active spring ecosystems that have been identified and verified by field mapping by the Queensland Government (Fensham et al., 2012). Other GDEs included in the landscape classification, including those associated with the stream network, are derived from GDE mapping rule sets based on local and expert knowledge, but are not necessarily verified by field observations (DSITI, 2015).

The 2016 *Underground water impact report for the Surat Cumulative Management Area* (OGIA, 2016) identifies 16 spring complexes, including 4 listed under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), and 19 watercourse springs as potentially impacted by groundwater drawdown in excess of 0.2 m associated with baseline CSG production. These 16 spring complexes are connected to GAB aquifers and are located outside of the zone of potential hydrological change. The 2012 *Underground water impact report for the Surat Cumulative Management Area* (QWC, 2012) identified 13 spring complexes, including 5 listed under the EPBC Act, and 22 watercourse springs as potentially impacted by groundwater drawdown in excess of 0.2 m associated with baseline CSG production.

None of the 24 non-GAB springs in the assessment extent that are associated with the Main Range Volcanics basalt aquifers are potentially impacted due to additional coal resource development. The *Underground water impact report for the Surat Cumulative Management Area* (OGIA, 2016) does not consider potential impacts to non-GAB springs:

> Springs associated with the Main Range Volcanics to the north, south and west of Toowoomba are associated with local flow systems and are disconnected from the regional flow regimes in the underlying GAB formations.

As it is *very unlikely* that there will be any impacts on those landscape classes outside the zone of potential hydrological change, they are ruled out and not considered further. The following sections provide information on landscape classes within each landscape group that are potentially impacted by hydrological changes due to additional coal resource development.

Table 8 Extent of landscape classes contained in the assessment extent, outside the zone of potential hydrological change and in the zone of potential hydrological change that is outside of the open-cut coal mine pits associated with the two additional coal resource developments, New Acland Coal Mine Stage 3 and The Range coal mine

Landscape group	Landscape class	Length, area or number	Extent[a] in assessment extent	Extent outside zone of potential hydrological change	Extent in zone of potential hydrological change (excluding modelled open-cut mine pits)
Floodplain or lowland riverine (including non-GAB GDEs)	Floodplain remnant vegetation	Area (km^2)	2,086	2,066	19.7
	Floodplain, near-permanent wetland	Area (km^2)	147	147	0
	Floodplain, non-GAB GDE	Area (km^2)	2,455	2,454	0.3
	Floodplain, non-GAB GDE, near-permanent wetland	Area (km^2)	61.0	61.0	0
	Floodplain, non-GAB GDE, temporary wetland	Area (km^2)	442	442	0
	Floodplain, temporary wetland	Area (km^2)	675	675	0.1
	Subtotal	Area (km^2)	**5,866**	**5,846**	**20.1**
	Near-permanent, lowland stream	Length (km)	170	170	0
	Temporary, lowland non-GAB GDE stream	Length (km)	268	262	2.6
	Temporary, lowland stream	Length (km)	28,716	28,419	296
	Subtotal	Length (km)	**29,154**	**28,850**	**299**
GAB GDEs (riverine, springs, floodplain or non-floodplain)	Floodplain, GAB GDE	Area (km^2)	290	289	0.8
	Floodplain, GAB GDE, near-permanent wetland	Area (km^2)	0.3	0.3	0
	Floodplain, GAB GDE, temporary wetland	Area (km^2)	8.7	8.7	0
	Non-floodplain, GAB GDE	Area (km^2)	1,446	1,370	75.3
	Non-floodplain, GAB GDE, near-permanent wetland	Area (km^2)	0	0	0
	Non-floodplain, GAB GDE, temporary wetland	Area (km^2)	1.6	1.6	0
	Subtotal	**Area (km^2)**	**1,746**	**1,670**	**76.1**
	Temporary, lowland GAB GDE stream	Length (km)	3,585	3,517	64.7
	Temporary, upland GAB GDE stream	Length (km)	4,183	3,926	254
	Subtotal	**Length (km)**	**7,768**	**7,443**	**319**
	GAB springs	Number	153	153	0
	Subtotal	**Number**	**153**	**153**	**0**

Landscape group	Landscape class	Length, area or number	Extent[a] in assessment extent	Extent outside zone of potential hydrological change	Extent in zone of potential hydrological change (excluding modelled open-cut mine pits)
Non-floodplain or upland riverine (including non-GAB GDEs)	Non-floodplain non-GAB GDE	Area (km^2)	2,551	2,539	11.1
	Non-floodplain non-GAB GDE, near-permanent wetland	Area (km^2)	2.9	2.9	0
	Non-floodplain non-GAB GDE, temporary wetland	Area (km^2)	32.8	32.8	0
	Non-floodplain, near-permanent wetland	Area (km^2)	46.6	46.0	0.5
	Non-floodplain, temporary wetland	Area (km^2)	195	194	0.9
	Subtotal	**Area (km^2)**	**2,829**	**2,815**	**12.5**
	Temporary upland non-GAB GDE stream	Length (km)	2,119	2,110	7.7
	Near-permanent upland stream	Length (km)	159	159	0
	Temporary upland stream	Length (km)	21,757	21,278	469
	Subtotal	**Length (km)**	**24,035**	**23,548**	**477**
	Non-GAB springs	Number	24	24	0
	Subtotal	**Number**	**24**	**24**	**0**
Dryland remnant vegetation	Dryland remnant vegetation	Area (km^2)	25,708	24,949	750
	Subtotal	**Area (km^2)**	**25,708**	**24,949**	**750**
Human-modified	Conservation and natural environments	Area (km^2)	554	551	1.8
	Intensive uses	Area (km^2)	788	784	0.8
	Production from dryland agriculture and plantations	Area (km^2)	18,992	18,824	140
	Production from irrigated agriculture and plantations	Area (km^2)	3,476	3,476	0.8
	Production from relatively natural environments	Area (km^2)	69,833	69,247	541
	Water	Area (km^2)	164	163	0.8
	Subtotal	**Area (km^2)**	**93,807**	**93,044**	**685**
All	Total area	**Area (km^2)**	**129,956**	**128,325**	**1544**
All	Total length	**Length (km)**	**60,958**	**59,841**	**1095**
All	Total number	**Number**	**177**	**177**	**0**

[a]Extent of each landscape class is either an area of vegetation (km^2), length of stream network (km) or number of springs (number).
GAB = Great Artesian Basin, GDE = groundwater-dependent ecosystem
Data: Bioregional Assessment Programme (Dataset 7)

3.4.3 'Floodplain or lowland riverine (including non-GAB GDEs)' landscape group

3.4.3.1 Description

Floodplains can be broadly defined as a collection of landscape and ecological elements exposed to inundation or flooding along a river system (Figure 24). The floodplain landscapes of the Maranoa-Balonne-Condamine subregion are predominantly lowland-dryland systems incorporating a range of wetland types such as riparian forests, marshes, billabongs, tree swamps, anabranches and overflows (Rogers, 2011). Floodplains are underlain by alluvial aquifers, which are formed from deposited sediments such as gravel, sand, silt and/or clay within river channels or on floodplains. Water is stored and transmitted to varying degrees through inter-granular voids meaning that alluvial aquifers are generally unconfined, shallow and have localised flow systems (DSITI, 2015). Groundwater expressed at the surface supports GDEs occupying drainage lines, riverine water bodies, and lacustrine and palustrine wetlands. Ecosystems associated with the subsurface expression of groundwater include fringing riverine communities and woodlands occupying less frequently flooded floodplain sites.

The zone of potential hydrological change intersects with temporary lowland streams ('Temporary lowland stream' and 'Temporary lowland non-GAB GDE stream' landscape classes) and can be described as showing limited alluvial development (i.e. width of alluvium of between 100 to 400 m). These alluvial land forms support predominantly river red gum (*Eucalyptus camaldulensis*) and *E. teriticornis* fringing drainage lines and more extensive stands of poplar box (*E. populnea*) further from the channel itself. There are also small stands of brigalow (*Acacia harpophylla*) and *Dichanthium sericeum* and/or *Astrebla* spp. grassland on these alluvial plains. Given the temporary nature of the surface water regime across this landscape group, it is likely that these vegetation communities require reduced flooding frequency, duration and depth in comparison to more permanent lowland riverine systems such as those fringing the Condamine River (Holloway et al., 2013).

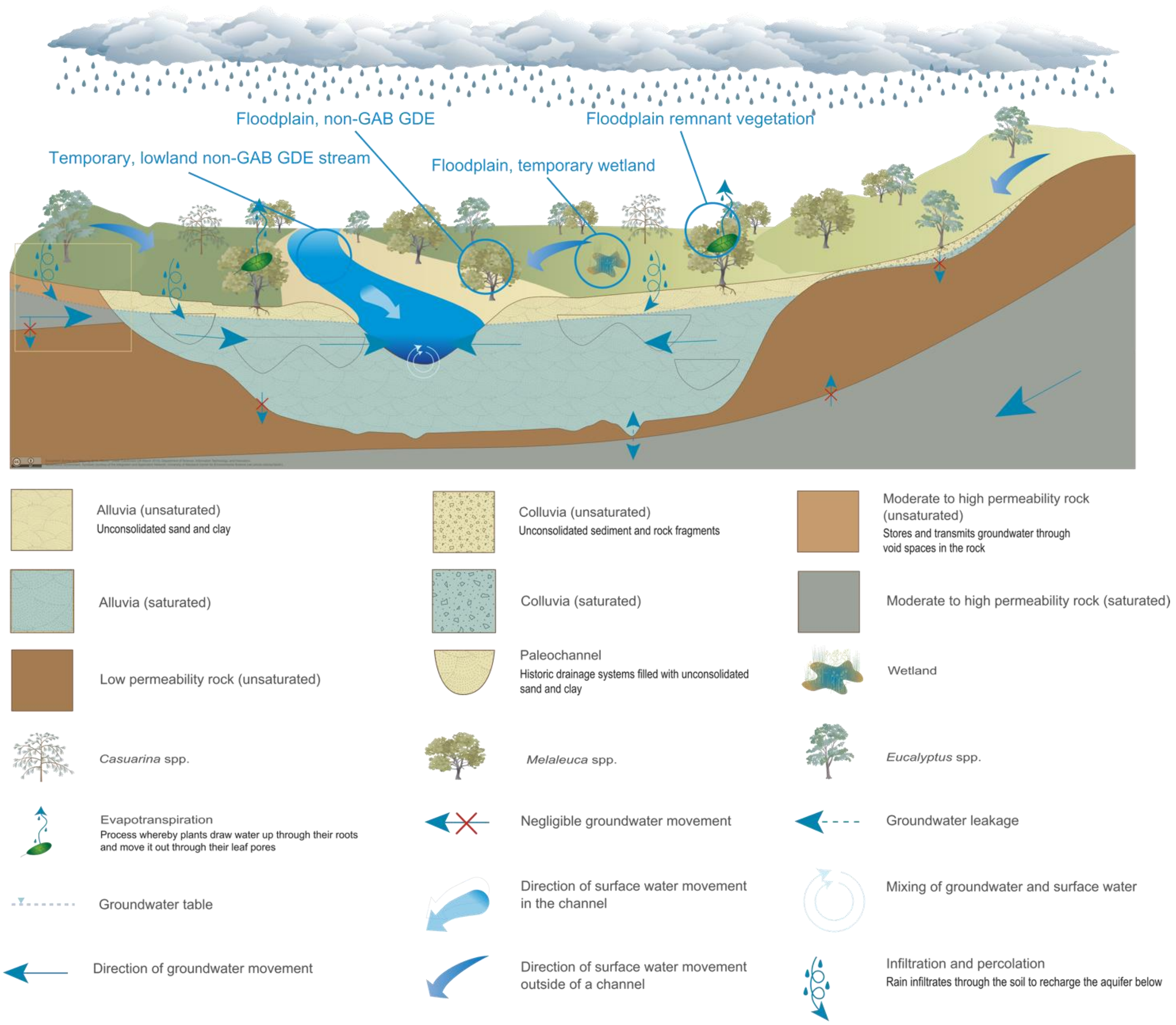

Figure 24 Pictorial conceptual model of landscapes in the 'Floodplain or lowland riverine (including non-GAB GDEs)' landscape group typical of those found within the zone of potential hydrological change

The model includes four of the nine landscape classes in this landscape group that are located within the zone of potential hydrological change. This model is typical of a 'losing' riverine system whereby the predominant flow path in the hyporheic zone is downwards.
GAB = Great Artesian Basin, GDE = groundwater-dependent ecosystem
Source: DEHP (2013a)

Drawdown in the regional watertable can affect groundwater-dependent vegetation and surface water – groundwater interactions in watercourses. However, good hydraulic connection between the alluvium and the river, which is typical of floodplain and lowland riverine environments, minimises potential groundwater level changes near watercourses. The representation of watercourses by the OGIA regional model:

> effectively assumes that all surface watercourses act as discharge boundaries and hence cannot leak is considered to be a conservative assumption from an impact point of view. This assumption is consistent with work undertaken by Hillier (2010) which suggested that alluvial strata within the GAB typically act as a drain for the underlying sediments (GHD, 2012, p. 57).

Previous research has revealed links between groundwater depth and tree condition, but critical thresholds that lead to rapid and potentially irreversible change have been difficult to quantify. Maximum rooting depth in a global study was 5.2±0.8 m for sclerophyllous shrubland and forest, 7.0±1.2 m for trees and 9.5±2.4 m for desert vegetation (Canadell et al., 1996), indicating that semi-arid floodplain trees are likely to have relatively deep root systems. Kath et al. (2014) used data from two dominant floodplain species, river red gum (*E. camaldulensis*) and poplar box (*E. populnea*) at 118 sites in the Condamine river basin to present evidence for a critical drawdown threshold in the range from 12.1 to 22.6 m for river red gum and 12.6 to 26.6 m for poplar box beyond which canopy condition declined abruptly. Another study in a water-limited riparian environment found that transpiration decreased in response to a 9-m decline in groundwater levels, but that changes to foliage density were more influenced by variability between seasons and site conditions (Pfautsch et al., 2015). Tree water uptake of groundwater when growing over deeper watertables is generally less than where the watertable is shallower (e.g. Zencich et al., 2002; O'Grady et al., 2006a, 2006b). The rate of drawdown can also be critical to vegetation survival. Plant roots can remain in contact with a declining watertable if the rate of decline does not exceed potential root growth rate; 3 to 15 mm/day for arid shrub and grass species (Naumberg et al., 2005).

A knowledge gap in the ecohydrology of groundwater-dependent vegetation is how sensitive vegetation is to changes in the rate of groundwater drawdown across different watertable depths and whether this response is linear. Connectivity between the alluvium and the stream channel that arises from longitudinal, lateral and vertical exchange of water is important in floodplain landscapes. This connectivity can be described by surface water hydrological response variables that span the low-flow (no-flow periods, in-channel freshes) and high-flow (bankfull and overbank flows) components of the surface water flow regime. Surface water flow regimes are defined by the timing, frequency, duration, magnitude, discharge volumes and the rates of the rise and fall of the flow events (Bunn and Arthington, 2002; Poff, 2010; Boulton et al., 2014). The following section gives a brief summary of the literature used to guide the qualitative analysis of changes to the surface water regime used in this assessment.

Low flows or flow pulses, sometimes referred to as instream freshes, play a critical role in maintaining longitudinal connectivity, linking instream habitats and allowing for the movement of fish and invertebrates. Longitudinal fragmentation prevents the transport of nutrients, biota and organic material downstream, and creates pool environments along the river channel, the quality of which may vary considerably depending on geomorphic condition, health of the extant riparian vegetation, length of the dry period and input of organic matter (Bond et al., 2008). Short-term flow pulses may also contribute to the maintenance of water quality in interconnected pools through provision of freshwater inputs and the transport of nutrients (Dunlop et al., 2013). Flow pulses may also maintain vertical connection with groundwater by recharging local groundwater and shallow aquifers, thus helping to sustain vegetation along the river's edge, although this is likely to be only a minor part of the flow regime. Extended periods of no flow or an increase in the frequency of no-flow periods are likely to increase the levels of stress in the system, through deteriorating water quality (e.g. increases in turbidity, reduced dissolved oxygen and increased temperatures, crowding of biota, and reduced hydrological connectivity) (Bond and Cottingham, 2008).

Moderate increases in streamflow (above baseflow) are termed freshes or pulse flows, can last for several days, increase within-stream flow variability and play an important role in the regulation of water quality through the input of freshwater and flushing of deeper pools (Robson et al., 2009). Watts et al. (2009) characterise these flows as pulse flows, and identify small or large pulses and overbank flows. Small pulses exceed baseflow and inundate some or all of the stream bed, for time periods ranging from hours to days. Large pulses are confined to the channel but do not exceed bankfull and typically occur over periods of days to weeks. Flow pulses play an important role in re-setting stream environments through active bedload transport, maintaining channel dimensions and scouring streambeds and banks (Watts et al., 2009). Larger in-channel freshes may represent important spawning triggers (King et al., 2009; NSW DPI, 2014) or inundate benches, anabranches and snags increasing habitat availability (Anon, 2016).

Larger pulses increase lateral connectivity within the streambed and provide access to new habitats, including river benches (Robson et al., 2009). Localised velocity profiles can increase habitat heterogeneity, especially around snags and along river banks creating habitat for fish and downstream drift in macroinvertebrates (Boulton et al., 2014). Vertical and lateral surface water – groundwater interactions may also increase, improving water quality of bank aquifers and increasing recharge to groundwater.

Connectivity between the river channel and the floodplain is essential for ecosystem health (Watts et al., 2009). Overbank flows inundate the floodplains and refresh water in isolated palustrine wetlands, provide opportunities for the migration of riparian and floodplain biota (Boulton et al., 2014) and modify channel geomorphology. Overbank flooding leads to deposition of nutrients and sediments on floodplains (Watts et al., 2009) and provides important wetland habitat for fish (NSW DPI, 2014) and frogs (Watts et al., 2009). The depth, duration, frequency and timing of inundation influences plant growth and survival and plays an important role in determining the spatial structure and health of vegetation communities on the floodplain. Overbank flooding maintains the health of floodplain vegetation through provision of freshwater, leaching of soil salinity and regeneration of floodplain species (Holland et al., 2009; Roberts and Marston, 2011; Doble et al., 2012; Colloff, 2014; Casanova, 2015). However, there is considerable uncertainty associated with the degree of connection between floodplains and alluvial aquifers at local and regional scales (Anon, 2013).

The selection of hydrological response variables was based on current literature on the response of vegetation condition to changes in the hydrological regime and is summarised in Table 9. This includes field observations (e.g. O'Grady et al., 2006a), experiments (e.g. Holland et al., 2009) and empirical modelling studies (e.g. Kath et al., 2014). Hydrological response variables identified for the 'Floodplain or lowland riverine (including non-GAB GDEs)' landscape group are maximum drawdown in the regional watertable, annual amplitude of drawdown, rate of annual drawdown and change to groundwater quality.

Maximum drawdown in the regional watertable (or source aquifer) estimated by the regional groundwater model is the only hydrological response variable that is available for this subregion (refer to companion product 2.6.2 for the Maranoa-Balonne-Condamine subregion (Janardhanan et al., 2016)). While estimates of absolute changes in depth to groundwater were not available, the sensitivity of landscape classes to hydrological changes was inferred using 'threshold type' responses. This approach assumes that vegetation condition is stable until a critical depth to groundwater level occurs, after which vegetation condition is affected (Kath et al., 2014; Horton et al., 2001; Sommer and Froend, 2014). Critical depth to groundwater thresholds observed for floodplain trees (e.g. *E. camaldulensis* and *E. populnea*) relevant to the subregion are 12 to 27 m (Kath et al., 2014; Reardon-Smith 2011), which is similar to *E. camaldulensis* in other river systems (Horner et al., 2009).

Additional drawdown that is less than 2 m, is unlikely to exceed the critical depth to groundwater threshold values identified in the literature, meaning that tree condition is unlikely to be impacted. These thresholds indicate that where additional drawdown is predicted to be less than 2 m (i.e. in addition to, but of a similar magnitude to, natural watertable fluctuation (less than 2 m)), remnant vegetation and streams are unlikely to be impacted due to additional coal resource development.

Table 9 Ecological relevance of hydrological changes for landscape classes in the 'Floodplain or lowland riverine (including non-GAB GDEs)' landscape group that are contained within the zone of potential hydrological change

Landscape class	Ecological relevance of hydrological changes
Floodplain remnant vegetation	Typically, poplar box (*E. populnea*) woodlands located away from the channel with limited access to groundwater. This landscape class is not potentially impacted by groundwater drawdown, but may be affected by changes to the surface water regime, which are not modelled.
Floodplain, temporary wetland	Temporary floodplain wetlands that are not groundwater dependent, but may rely on inflow from upstream GDEs, such as lowland groundwater-dependent streams. This landscape class is not potentially impacted by groundwater drawdown, but may be affected by changes to the surface water regime, which are not modelled.
Floodplain, non-GAB GDE	Groundwater-dependent fringing, riparian forests, typically dominated by river red gum (*E. camaldulensis*) and *E. tereticornis* that rely on relatively shallow alluvial groundwater. Potentially impacted by drawdown in addition to, but of a similar magnitude to, natural watertable fluctuation (<2 m). A 2 m drawdown threshold is used for this landscape class.
Temporary, lowland non-GAB GDE stream	Temporary, lowland streams associated with the surface expression of groundwater that are sensitive to increased watertable depth in the alluvial aquifer. Potentially impacted by drawdown in addition to, but of a similar magnitude to, natural watertable fluctuation (<2 m). A 2 m drawdown threshold is used for this landscape class.
Temporary, lowland stream	Lowland streams that are not groundwater dependent and so are less sensitive to increased watertable depth. This landscape class is not potentially impacted by groundwater drawdown, but may be affected by changes to the surface water regime, which are not modelled.

GAB = Great Artesian Basin, GDE = groundwater-dependent ecosystem

3.4.3.2 Potential hydrological impacts

3.4.3.2.1 Groundwater

Outside the modelled open-cut mine pits, floodplain or lowland riverine landscapes that are potentially impacted cover 20 km^2 (which is 0.3% of the 'Floodplain or lowland riverine' landscape group in the assessment extent) of remnant vegetation and 299 km (1.0%) of streams, which are predominantly not groundwater dependent (Figure 25 and Table 8). Temporary lowland streams in the zone of potential hydrological change include Dogwood and Rocky creeks to the south-west of The Range coal mine that flow into the Condamine and Balonne rivers.

Median additional drawdown is less than 2 m, with the exception of 0.2 km^2 of remnant vegetation and 20 km of streams near the open-cut coal mine pits (Table 11), where median additional drawdown in the regional watertable is up to 65 m near New Acland Coal Mine and up to 10.2 m near The Range coal mine. Median baseline drawdown in the zone of potential hydrological change is predominantly greater than 2 m, containing 8 km^2 of remnant vegetation and 112 km of streams (Figure 25 and Table 10).

Drawdown under the baseline is greater than due to additional coal resource development for most remnant vegetation and streams in the 'Floodplain or lowland riverine' landscape group (Figure 26). This is consistent with their location near the outer edges of the zone of potential hydrological change, where additional drawdown is less.

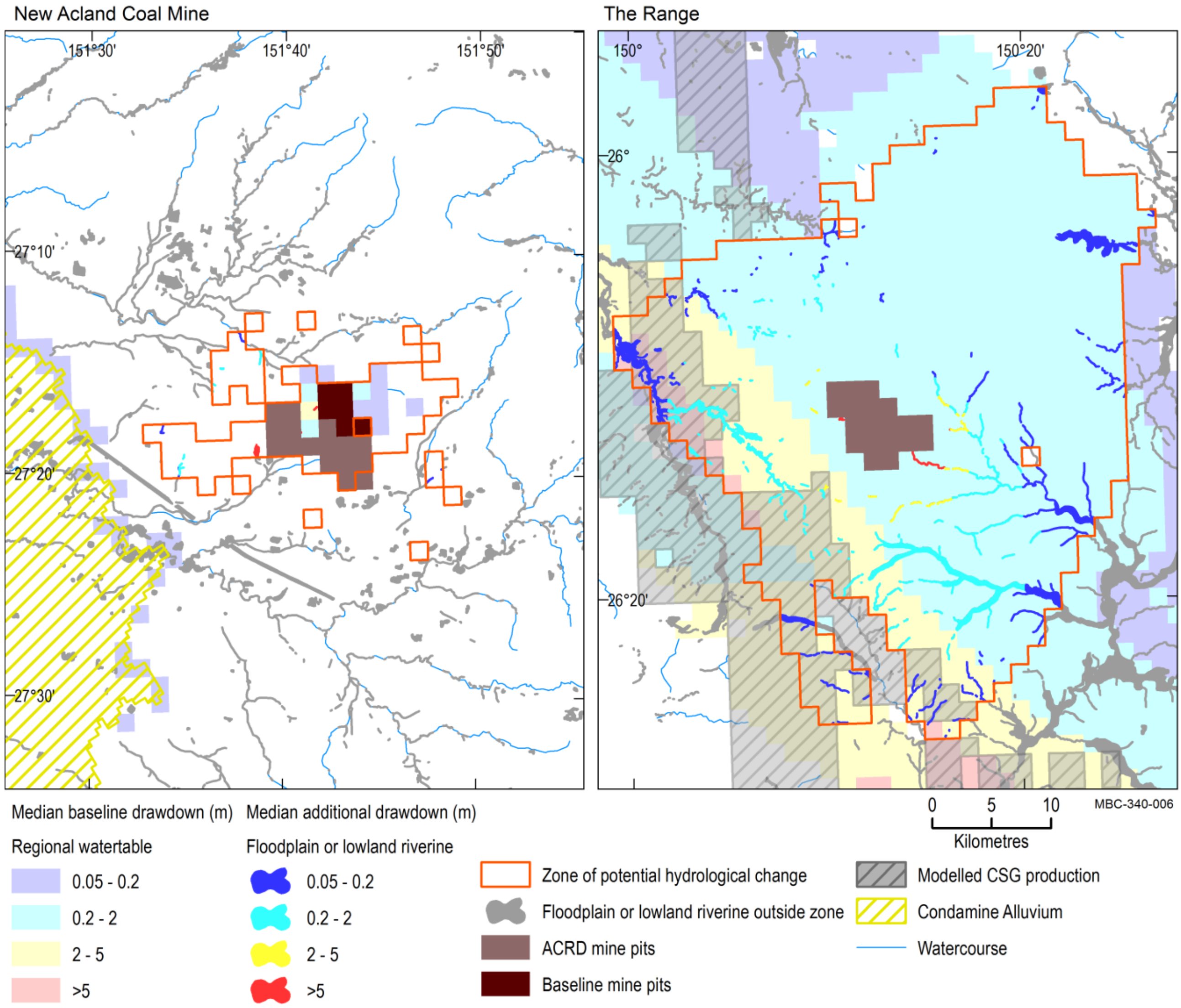

Figure 25 'Floodplain or lowland riverine (including non-GAB GDEs)' landscape group: location of remnant vegetation or stream network contained within the zone of potential hydrological change in the Maranoa-Balonne-Condamine subregion

Median is the 50th percentile. Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. The mine pits in the CRDP are the sum of those in the baseline and the additional coal resource development. Landscape classes within modelled pits are not included in this analysis.
ACRD = additional coal resource development, CSG = coal seam gas, GAB = Great Artesian Basin, GDE = groundwater-dependent ecosystem
Data: Bioregional Assessment Programme (Dataset 1, Dataset 2, Dataset 3, Dataset 4, Dataset 8, Dataset 9)

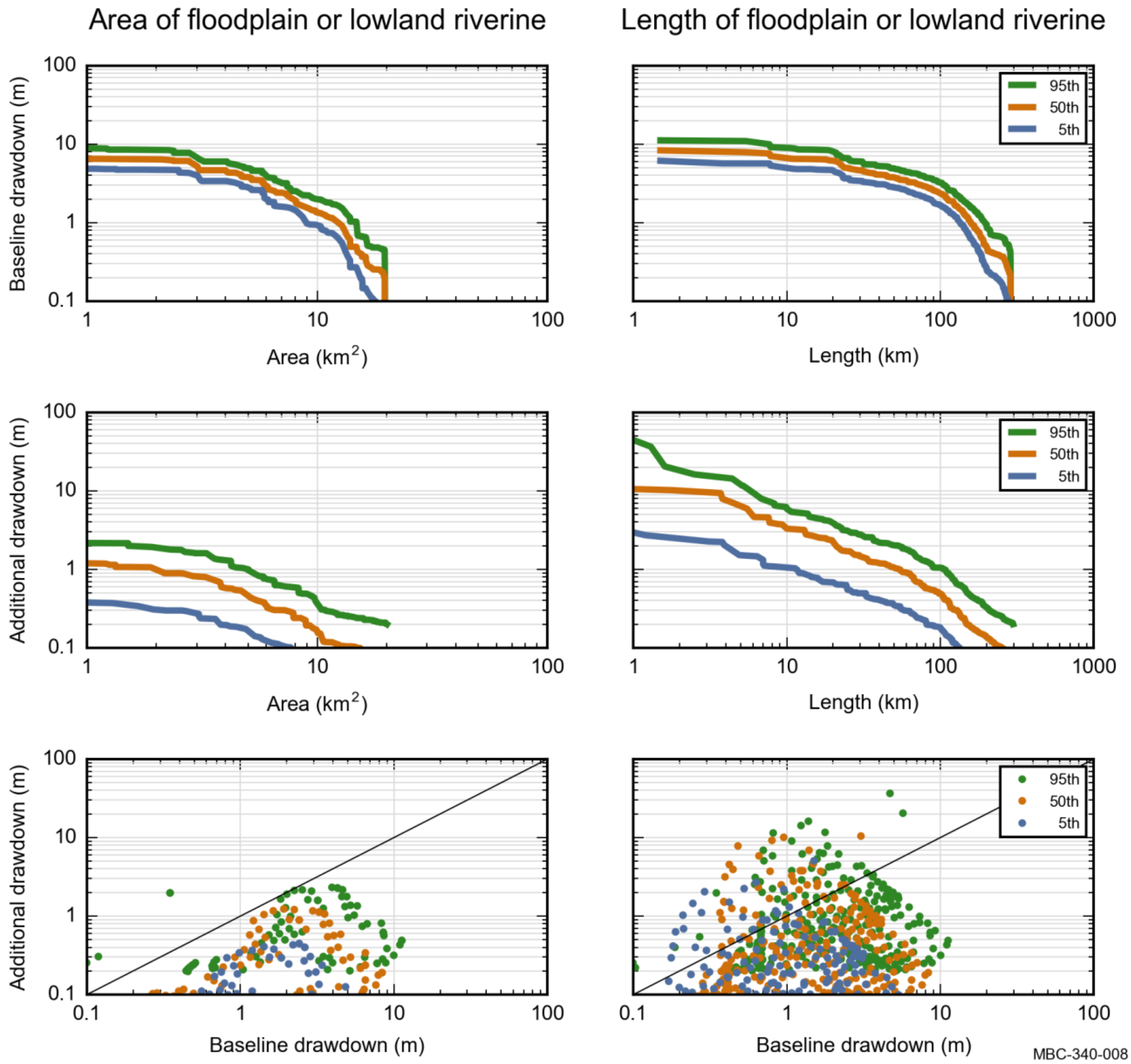

Figure 26 'Floodplain or lowland riverine (including non-GAB GDEs)' landscape group: the top two rows show area (km^2) or stream length (km) within the zone that exceeds the 5th, 50th and 95th percentile estimates of baseline drawdown and additional drawdown, and the bottom row shows baseline drawdown (m) compared to additional drawdown (m) in each assessment unit

Colours represent the 5th, 50th and 95th percentile. Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. Areas within modelled open-cut mine pits are not included in this analysis.
GAB = Great Artesian Basin, GDE = groundwater-dependent ecosystem
Data: Bioregional Assessment Programme (Dataset 7)

Table 10 'Floodplain or lowland riverine (including non-GAB GDEs)' landscape group: area (km^2) or stream network length (km) that exceeds the 5th, 50th and 95th percentile estimates of baseline drawdown in the zone of potential hydrological change

Landscape class	Length or area	Extent in assessment extent	Extent in zone of potential hydrological change (excluding modelled open-cut mine pits)	Extent[a] with baseline drawdown ≥0.2 m			Extent[a] with baseline drawdown ≥2 m			Extent[a] with baseline drawdown ≥5 m		
				5th	50th	95th	5th	50th	95th	5th	50th	95th
Floodplain remnant vegetation	Area (km^2)	2,086	19.7	14.6	19.4	19.5	5.8	7.5	9.3	0.8	3.0	4.7
Floodplain, near-permanent wetland	Area (km^2)	147	0	0	0	0	0	0	0	0	0	0
Floodplain, non-GAB GDE	Area (km^2)	2,455	0.3	0.03	0.03	0.03	0.01	0.03	0.03	0	0	0
Floodplain, non-GAB GDE, near-permanent wetland	Area (km^2)	61.0	0	0	0	0	0	0	0	0	0	0
Floodplain, non-GAB GDE, temporary wetland	Area (km^2)	442	0	0	0	0	0	0	0	0	0	0
Floodplain, temporary wetland	Area (km^2)	675	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0	0.1	0.1
Subtotal	**Area (km^2)**	**5,866**	**20.1**	**14.8**	**19.6**	**19.6**	**5.9**	**7.6**	**9.5**	**0.8**	**3.0**	**4.8**
Near-permanent, lowland stream	Length (km)	170	0	0	0	0	0	0	0	0	0	0
Temporary, lowland non-GAB GDE stream	Length (km)	268	2.6	0	0	0	0	0	0	0	0	0
Temporary, lowland stream	Length (km)	28,716	296	232	286	287	84.5	112	136	7.8	23.6	47.0
Subtotal	**Length (km)**	**29,154**	**299**	**232**	**286**	**287**	**84.5**	**112**	**136**	**7.8**	**23.6**	**47.0**

[a]Extent could be length or area and excludes modelled open-cut mine pits.
Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Landscape classes within modelled open-cut mine pits are not included in this analysis. Due to rounding, some totals may not correspond with the sum of the separate numbers.
GAB = Great Artesian Basin, GDE = groundwater-dependent ecosystem
Data: Bioregional Assessment Programme (Dataset 7)

Table 11 'Floodplain or lowland riverine (including non-GAB GDEs)' landscape group: area (km^2) or stream network length (km) that exceeds the 5th, 50th and 95th percentile estimates of additional drawdown in the zone of potential hydrological change

Landscape class	Length or area	Extent in assessment extent	Extent in zone of potential hydrological change (excluding modelled open-cut mine pits)	Extent[a] with baseline drawdown ≥0.2 m			Extent[a] with baseline drawdown ≥2 m			Extent[a] with baseline drawdown ≥5 m		
				5th	50th	95th	5th	50th	95th	5th	50th	95th
Floodplain remnant vegetation	Area (km^2)	2,086	19.7	3.5	8.6	19.7	0	0.01	1.3	0	0.01	0.01
Floodplain, near-permanent wetland	Area (km^2)	147	0	0	0	0	0	0	0	0	0	0
Floodplain non-GAB GDE	Area (km^2)	2,455	0.3	0.03	0.2	0.3	0	0.2	0.2	0	0.2	0.2
Floodplain, non-GAB GDE, near-permanent wetland	Area (km^2)	61.0	0	0	0	0	0	0	0	0	0	0
Floodplain, non-GAB GDE, temporary wetland	Area (km^2)	442	0	0	0	0	0	0	0	0	0	0
Floodplain, temporary wetland	Area (km^2)	675	0.1	0	0	0.1	0	0	0	0	0	0
Subtotal	**Area (km^2)**	**5,866**	**20.1**	**3.6**	**8.9**	**20.1**	**0**	**0.2**	**1.5**	**0**	**0.2**	**0.2**
Near-permanent, lowland stream	Length (km)	170	0	0	0	0	0	0	0	0	0	0
Temporary, lowland non-GAB GDE stream	Length (km)	268	2.6	0	1.8	2.6	0	0.6	0.6	0	0.6	0.6
Temporary, lowland stream	Length (km)	28,716	296	80.6	147	296	3.9	19.7	52.6	0.4	4.9	13.1
Subtotal	**Length (km)**	**29,154**	**299**	**80.6**	**149**	**299**	**3.9**	**20.3**	**53.1**	**0.4**	**5.5**	**13.7**

[a]Extent could be a length or area and excludes modelled open-cut mine pits.
Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. Landscape classes within modelled open-cut mine pits are not included in this analysis. Due to rounding, some totals may not correspond with the sum of the separate numbers.
GAB = Great Artesian Basin, GDE = groundwater-dependent ecosystem
Data: Bioregional Assessment Programme (Dataset 7)

3.4.3.2.2 Surface water

No surface water numerical modelling was undertaken for the Maranoa-Balonne-Condamine subregion. Some potential hydrological changes may, however, be specified conceptually based on scientific logic as described in Section 3.3.

3.4.3.3 Potential ecosystem impacts

Floodplain or lowland landscapes in the zone of potential hydrological change in the vicinity of New Acland Coal Mine include fringing riverine vegetation communities that are likely to have some degree of groundwater dependence. However, most of the remnant vegetation in this area is classified as 'Floodplain remnant vegetation', which is not groundwater dependent and so is not likely to be affected by additional drawdown that is in addition to, and of a similar magnitude to, natural watertable fluctuation (<2 m) (Table 9).

The proposed footprint of the New Acland Stage 3 Coal Mine is located in the headwaters of Lagoon Creek and will reduce surface water flows in the associated streams. However, the mine footprint intersects with small, temporary, higher order streams, which means that it may only affect a relatively small volume of surface water flows (Figure 25). The watercourses flow to the north-west and join the Condamine River near Dalby. Most watercourses within and downstream of the New Acland Coal Mine are classified as temporary streams.

The zone of potential hydrological change near The Range coal mine contains a small area (0.2 km^2, or less than 0.1% of the landscape group in the assessment extent) of fringing riverine and wetland vegetation communities (floodplain, non-GAB GDEs) that are likely to be dependent on groundwater. This community near the modelled open-cut mine pits is predicted to experience localised additional drawdown (>5 m) by the regional groundwater model. Local impact assessment and modelling is required to provide more detail to supplement results from the regional model.

Median additional drawdown near the edge of the zone of potential hydrological change in the vicinity of The Range coal mine is in addition to, and of a similar magnitude to, natural watertable fluctuation (<2 m) and is therefore unlikely to affect these fringing riverine and wetland vegetation communities. Vegetation classified as 'Floodplain remnant vegetation' is not likely to be groundwater dependent and is therefore unlikely to be directly affected by additional drawdown.

Drawdown due to additional coal resource development near The Range coal mine is located in the headwaters of Juandah and Dogwood creeks, which means that it may only affect a relatively small volume of surface water flows downstream (Figure 25). Juandah Creek flows north-west into the Dawson River upstream of Taroom, while Dogwood Creek flows south-west to its confluence with the Condamine and Balonne rivers between Surat and Chinchilla (Figure 9).

3.4.4 'GAB GDEs (riverine, springs, floodplain or non-floodplain)' landscape group

3.4.4.1 Description

Ecosystems that are hydrologically connected to GAB aquifers include springs, streams, floodplains and non-floodplain areas (Figure 27). This landscape group contains very small areas of wetland habitat (10 km^2, <1% of all wetlands in the assessment extent). GAB GDEs can occur on both floodplain and non-floodplain areas and include near-permanent and temporary wetlands where groundwater is expressed at the surface. Groundwater recharge into the GAB aquifers occurs along sandstone outcrop areas that can include hilly upland areas, where rainwater percolates into the GAB aquifers between confining layers (Figure 27). However, fractures, inter-granular pores and weathered zones can cause groundwater to discharge locally at or near the surface in these areas (DSITI, 2015). The discharge of localised recharge is termed 'rejected recharge'. Approximately 1.3% of the vegetation and 13% of the stream network in the assessment extent are hydrologically connected to GAB aquifers (Table 8).

GAB springs may form surface water bodies that support aquatic ecosystems and typically contain endemic species and plant communities that have significant ecological, economic and cultural values (Fensham and Fairfax, 2003). GAB springs can be associated with faults or aquitards, thinning of the confining layer or topographic conditions, such as a change of slope or a depression into an aquifer, that allow groundwater to discharge at the surface (QWC, 2012). Based on their hydrogeological setting, GAB springs can be classed as recharge or discharge springs. Recharge springs form where GAB aquifers outcrop at the surface, typically in the recharge zones on the eastern margins of the GAB (Figure 27) (Fensham and Fairfax, 2003). All other springs associated with GAB aquifers, known as discharge springs, are associated with faults or where GAB aquifers are expressed at the surface, and tend to occur down gradient of recharge areas (Figure 27) (Fensham and Fairfax, 2003). There are 153 GAB springs identified in the assessment extent (Table 8).

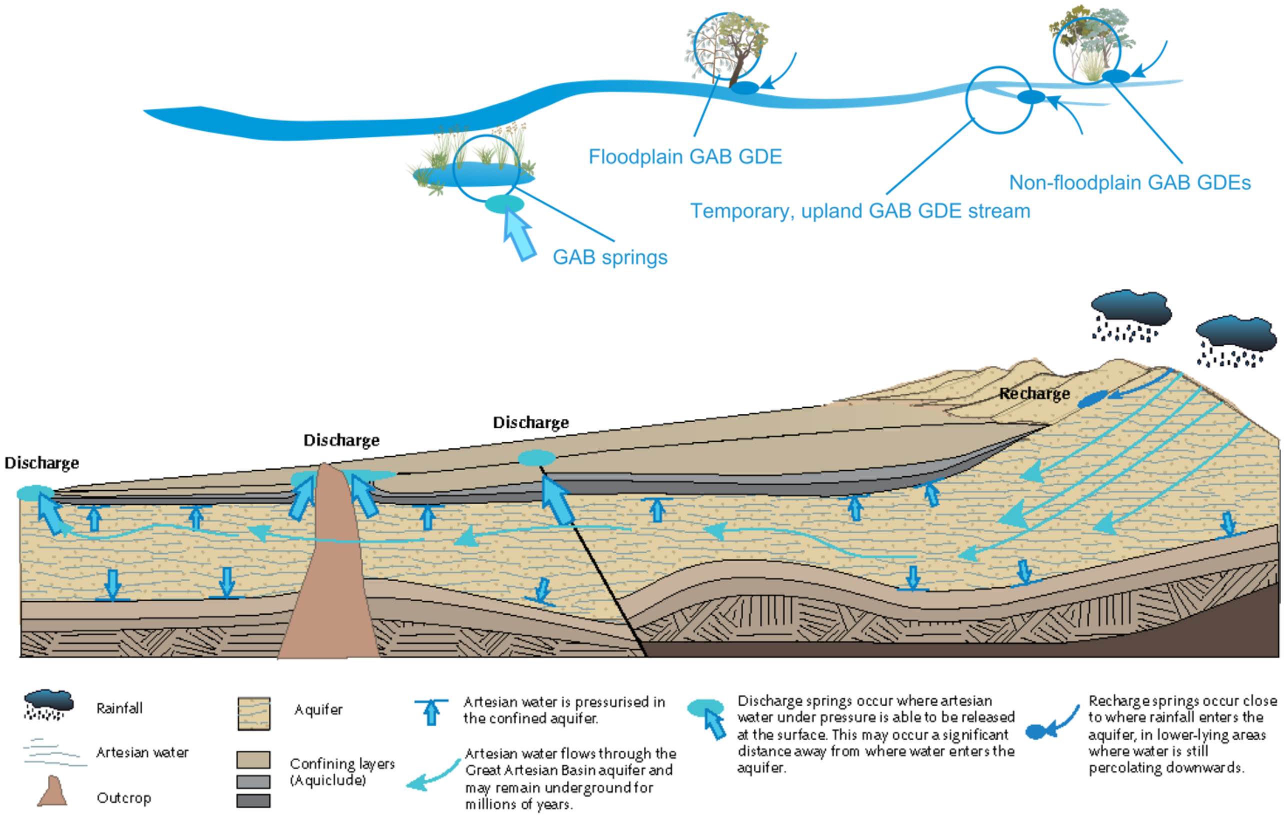

Figure 27 Pictorial conceptual model of the hydrogeological characteristics associated with the 'GAB GDEs (riverine, springs, floodplain or non-floodplain)' landscape group

GAB = Great Artesian Basin, GDE = groundwater-dependent ecosystem
Source: DEHP (2013b), symbols courtesy of the Integration and Application Network (ian.umces.edu/symbols/)

The zone of potential hydrological change contains four landscape classes in the 'GAB GDEs (riverine, springs, floodplain or non-floodplain)' landscape group (Table 8). These are 'Floodplain GAB GDE', 'Non-floodplain GAB GDE', 'Temporary lowland GAB GDE stream' and 'Temporary upland GAB GDE stream'. The 'Floodplain, GAB GDE' and 'Temporary, lowland GAB GDE stream' landscape classes occur where local discharge from sandstone outcrop areas supports vegetation overlying or adjacent to alluvial sediments. Floodplain and lowland GAB GDEs have greater lateral connectivity with the alluvial sediments and stream channels, as well as accessing groundwater sources derived from the neighbouring sandstone outcropping areas. Temporary, lowland GAB GDE streams support riparian poplar box (*E. populnea*) woodlands.

Non-floodplain GAB GDEs include woodland communities reliant on groundwater discharge from sandstone outcrops (land zones 9 and 10), sandy plains and lateritic duricrusts (land zones 5 and 7) (DSITI, 2015). Groundwater that is accessed by the root zones of *Corymbia* and *Eucalyptus* dominated woodlands originates from localised recharge areas upslope of the GDEs. These GDEs are often adjacent to temporary upland GAB GDE streams; aquatic systems that may also receive 'rejected recharge'.

The selection of hydrological response variables for the 'GAB GDEs (riverine, springs, floodplain or non-floodplain)' landscape group is based on the ecohydrological conceptualisation developed for the Queensland GDE mapping and literature on the response of floodplain vegetation condition to changes in the hydrological regime (Table 12).

Hydrological response variables identified by the Assessment team for the 'GAB GDEs (riverine, springs, floodplain or non-floodplain)' landscape group are maximum drawdown in the regional watertable, annual amplitude of drawdown, rate of annual drawdown and change to groundwater quality. Groundwater discharge to streams also supports the maintenance of flow regimes to support the channel habitat. The temporary nature of many streams in this landscape group means that changes to the magnitude and duration of high and low flows, and frequency of flood pulses will affect lateral and longitudinal connectivity within the channel and floodplain environment.

Springs may be affected by hydrological changes in deeper geological layers, which may have ecological repercussions for surface ecosystems surrounding springs. Springs in the subregion

> provide unique ecological habitats and contain rare and threatened species. In addition, groundwater discharge can sustain waterholes and watercourses where the discharge plays an important role in maintaining stream ecosystem functions and processes (OGIA, 2016, p. 103).

To protect these sensitive ecosystems, Queensland's *Water Act 2000* requires prevention or mitigation options to be developed for springs where predicted pressure reductions in the source aquifer are greater than 0.2 m. This is consistent with NSW's *Aquifer Interference Policy*, where high-priority GDEs and culturally significant sites in the GAB are managed using a 0.2 m drawdown threshold (DPI, 2012). This 0.2 m drawdown threshold is also close to the practical resolution limits of modelled and measured drawdown, within the bounds of seasonal and climatic variability.

Table 12 Ecological relevance of hydrological changes for landscape classes in the 'GAB GDEs (riverine, springs, floodplain, non-floodplain)' landscape group that are contained within the zone of potential hydrological change

Landscape class	Ecological relevance of hydrological changes
Floodplain, GAB GDE	Typically, poplar box (*E. populnea*) woodlands adjacent to channels that are reliant on the subsurface expression of groundwater from GAB aquifers. Potentially impacted by drawdown in addition to, but of a similar magnitude to, natural watertable fluctuation (<2 m). A 2 m drawdown threshold is used for this landscape class.
Non-floodplain, GAB GDE	*Corymbia* and *Eucalyptus* dominated woodlands that are reliant on the subsurface expression of groundwater from GAB aquifers. Potentially impacted by drawdown in addition to, but of a similar magnitude to, natural watertable fluctuation (<2 m). A 2 m drawdown threshold is used for this landscape class.
Temporary, lowland GAB GDE stream	Temporary streams and/or watercourse springs in lowland areas with significant alluvial development that are reliant on the surface expression of groundwater from GAB aquifers. These ecosystems are sensitive to changes in groundwater flows in GAB aquifers. A 0.2 m drawdown threshold is used for this landscape class.
Temporary, upland GAB GDE stream	Temporary streams and/or watercourse springs in upland areas that are reliant on the surface expression of groundwater from GAB aquifers. These ecosystems are sensitive to changes in groundwater flows in GAB aquifers. A 0.2 m drawdown threshold is used for this landscape class.

GAB = Great Artesian Basin, GDE = groundwater-dependent ecosystem

3.4.4.2 Potential hydrological impacts

3.4.4.2.1 Groundwater

Potentially impacted GAB GDEs cover 76 km^2 (which is 4.4% of the landscape group in the assessment extent) of remnant vegetation and 319 km (4.1%) of streams in the zone of potential hydrological change (outside of modelled open-cut mine pits) (Figure 28 and Table 8). Most of the remnant vegetation (75 km^2) and watercourses (254 km) that access GAB aquifers in the zone of potential hydrological change are to the north-east of The Range coal mine in an area of Hutton Sandstone aquifer outcrop.

None of the 153 GAB springs in the assessment extent are within 50 km of where there is at least a 5% chance of exceeding 0.2 m drawdown due to additional coal resource development predicted in the source aquifer identified for each spring (Office of Groundwater Impact Assessment, Dataset 5; Bioregional Assessment Programme, Dataset 6).

The median (50th percentile) estimate of greater than 0.2 m drawdown due to additional coal resource development is smaller and includes less than 1 km^2 of remnant vegetation and 3 km of streams in this landscape group (Table 14). Figure 28 and Figure 29 show that most of the streams classified as 'GAB GDEs' in the north-eastern part of the zone of potential hydrological change have a median drawdown due to additional coal resource development of less than 0.2 m. Median baseline drawdown in the zone of potential hydrological change is predominantly less than 2 m, containing 3 km^2 of remnant vegetation and 5 km of stream network (Table 13).

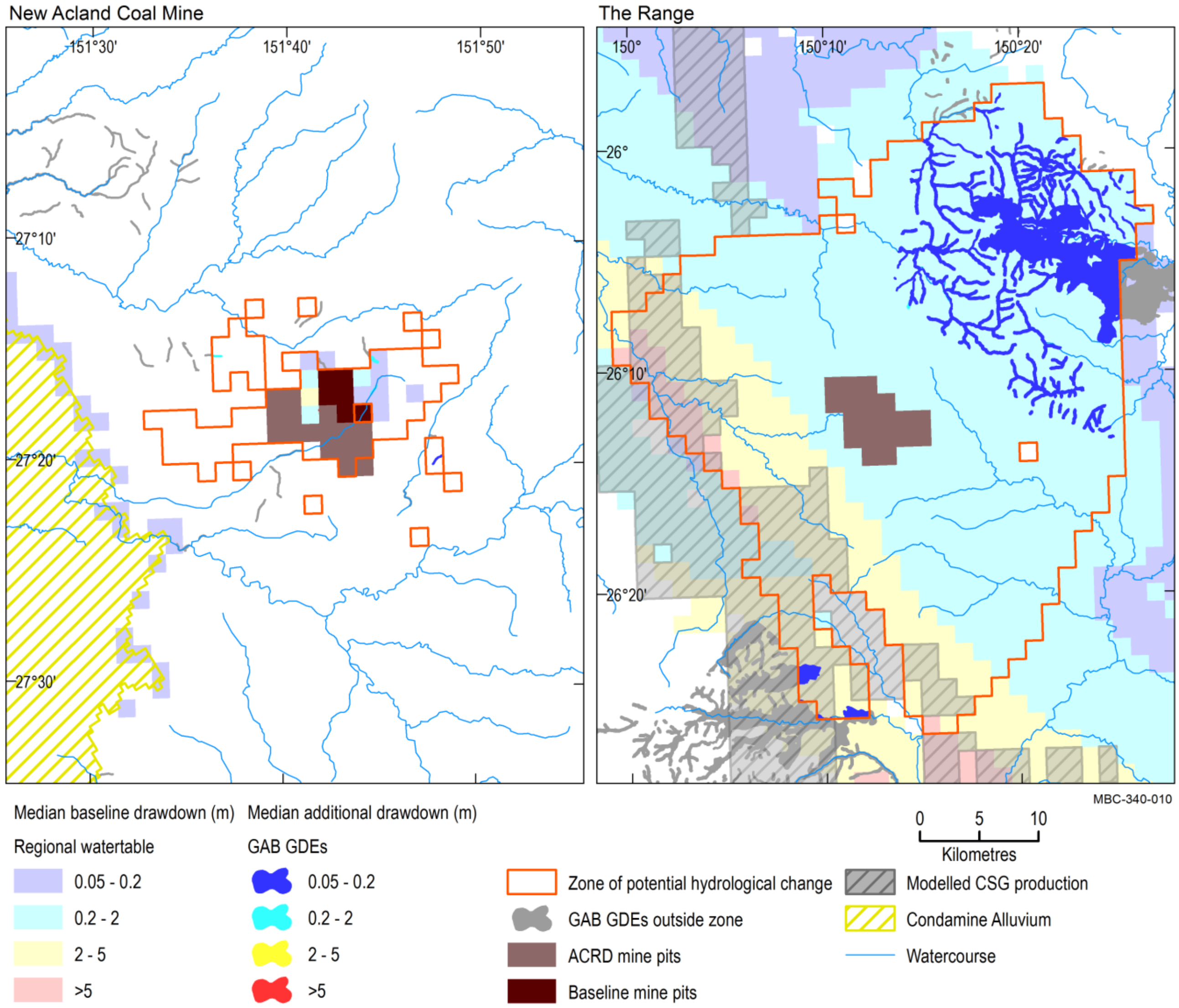

Figure 28 'GAB GDEs (including riverine, springs, floodplain or non-floodplain)' landscape group: location of remnant vegetation or stream network contained within the zone of potential hydrological change in the Maranoa-Balonne-Condamine subregion

Median is the 50th percentile. Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. The mine pits in the CRDP are the sum of those in the baseline and the additional coal resource development. Landscape classes within modelled open-cut mine pits are not included in this analysis.

ACRD = additional coal resource development, CSG = coal seam gas, GAB = Great Artesian Basin, GDE = groundwater-dependent ecosystem

Data: Bioregional Assessment Programme (Dataset 1, Dataset 2, Dataset 3, Dataset 4, Dataset 8, Dataset 9)

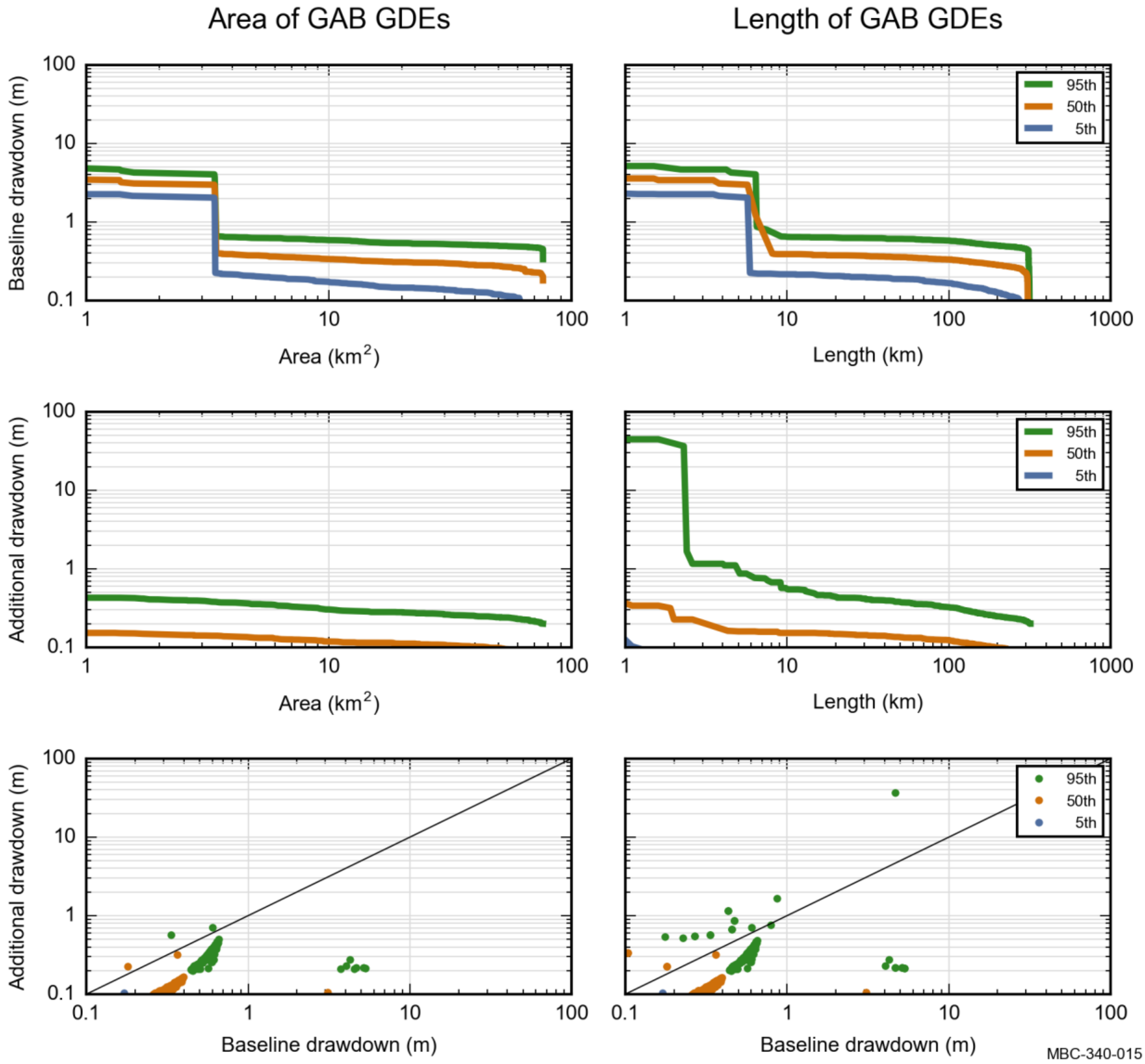

Figure 29 'GAB GDEs (including riverine, springs, floodplain or non-floodplain)' landscape group: the top two rows show area (km^2) or stream length (km) within the zone that exceeds the 5th, 50th and 95th percentile estimates of baseline drawdown and additional drawdown, and the bottom row shows baseline drawdown (m) compared to additional drawdown (m) in each assessment unit

Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. Landscape classes within modelled open-cut pits are not included in this analysis. GAB = Great Artesian Basin, GDE = groundwater-dependent ecosystem
Data: Bioregional Assessment Programme (Dataset 7)

Table 13 'GAB GDEs (riverine, springs, floodplain or non-floodplain)' landscape group: area (km^2), stream network length (km) and number of springs (number) that exceed the 5th, 50th and 95th percentile estimates of baseline drawdown in the zone of potential hydrological change

Landscape class	Length, area or number	Extent in assessment extent	Extent in zone of potential hydrological change (excluding modelled open-cut mine pits)	Extent[a] with baseline drawdown ≥0.2 m			Extent[a] with baseline drawdown ≥2 m			Extent[a] with baseline drawdown ≥5 m		
				5th	50th	95th	5th	50th	95th	5th	50th	95th
Floodplain, GAB GDE	Area (km^2)	290	0.8	0	0.8	0.8	0	0	0	0	0	0
Floodplain, GAB GDE, near-permanent wetland	Area (km^2)	0.3	0	0	0	0	0	0	0	0	0	0
Floodplain, GAB GDE, temporary wetland	Area (km^2)	8.7	0	0	0	0	0	0	0	0	0	0
Non-floodplain, GAB GDE	Area (km^2)	1446	75.3	5.1	75.3	75.3	3.4	3.4	3.4	0.0	0.0	0.5
Non-floodplain, GAB GDE, near-permanent wetland	Area (km^2)	0.0	0	0	0	0	0	0	0	0	0	0
Non-floodplain, GAB GDE, temporary wetland	Area (km^2)	1.6	0	0	0	0	0	0	0	0	0	0
Subtotal	**Area (km^2)**	**1746**	**76.1**	**5.1**	**76.1**	**76.1**	**3.4**	**3.4**	**3.4**	**0.0**	**0.0**	**0.5**
Temporary, lowland GAB GDE stream	Length (km)	3585	64.7	6.4	58.8	62.1	3.0	3.0	3.0	0	0	0.8
Temporary, upland GAB GDE stream	Length (km)	4183	254	17.6	247	251	2.5	2.5	3.2	0	0	0.6
Subtotal	**Length (km)**	**7768**	**319**	**24.0**	**305**	**313**	**5.5**	**5.5**	**6.2**	**0**	**0**	**1.4**
GAB springs	Number	153	0	0	0	0	0	0	0	0	0	0
Subtotal	**Number**	**153**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

[a]Extent could be number, length or area and excludes modelled open-cut mine pits.
Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Landscape classes within modelled open-cut mine pits are not included in this analysis. Due to rounding, some totals may not correspond with the sum of the separate numbers.
GAB = Great Artesian Basin, GDE = groundwater-dependent ecosystem
Data: Bioregional Assessment Programme (Dataset 7)

Table 14 'GAB GDEs (riverine, springs, floodplain or non-floodplain)' landscape group area (km^2), stream network length (km) and number of springs (number) that exceed the 5th, 50th and 95th percentile estimates of drawdown due to additional coal resource development in the zone of potential hydrological change

Landscape class	Length, area or number	Extent in assessment extent	Extent in zone of potential hydrological change (excluding modelled open-cut mine pits)	Extent[a] with additional drawdown >0.2 m			Extent[a] with additional drawdown >2 m			Extent[a] with additional drawdown >5 m		
				5th	50th	95th	5th	50th	95th	5th	50th	95th
Floodplain GAB GDE	Area (km^2)	290	0.8	0	0	0.8	0	0	0	0	0	0
Floodplain GAB GDE, near-permanent wetland	Area (km^2)	0.3	0	0	0	0	0	0	0	0	0	0
Floodplain GAB GDE, temporary wetland	Area (km^2)	8.7	0	0	0	0	0	0	0	0	0	0
Non-floodplain GAB GDE	Area (km^2)	1446	75.3	0	0.1	75.3	0	0	0	0	0	0
Non-floodplain GAB GDE, near-permanent wetland	Area (km^2)	0.0	0	0	0	0	0	0	0	0	0	0
Non-floodplain GAB GDE, temporary wetland	Area (km^2)	1.6	0	0	0	0	0	0	0	0	0	0
Subtotal	**Area (km^2)**	**1746**	**76.1**	**0**	**0.1**	**76.1**	**0**	**0**	**0**	**0**	**0**	**0**
Temporary lowland GAB GDE stream	Length (km)	3585	64.7	0	0.7	64.7	0	0	1.5	0	0	1.5
Temporary upland GAB GDE stream	Length (km)	4183	254	0	2.0	254	0	0	0.8	0	0	0.8
Subtotal	**Length (km)**	**7768**	**319**	**0**	**2.6**	**319**	**0**	**0**	**2.3**	**0**	**0**	**2.3**
GAB springs	Number	153	0	0	0	0	0	0	0	0	0	0
Subtotal	**Number**	**153**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

[a]Extent could be a number, length or area and excludes modelled open-cut mine pits.
Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. Landscape classes within modelled open-cut mine pits are not included in this analysis. Due to rounding, some totals may not correspond with the sum of the separate numbers.
GAB = Great Artesian Basin, GDE = groundwater-dependent ecosystem
Data: Bioregional Assessment Programme (Dataset 7)

3.4.4.2.2 Surface water

No surface water numerical modelling was undertaken for the Maranoa-Balonne-Condamine subregion. Some potential hydrological changes may, however, be specified conceptually based on scientific logic as described in Section 3.3.

3.4.4.3 Potential ecosystem impacts

The zone of potential hydrological change in the vicinity of New Acland Coal Mine includes temporary streams and remnant vegetation associated with GAB aquifer outcrop areas. These temporary streams are likely to have fringing riverine vegetation communities that have some degree of groundwater dependence (Table 14). However, the regional groundwater model predictions indicate that median drawdown in the regional watertable under the baseline and due to additional coal resource development near New Acland Coal Mine is less than 0.2 m, with the exception of areas adjacent to New Acland Coal Mine Stage 2 operations (Figure 28). This suggests that these temporary streams, which flow through human-modified landscapes toward Lagoon and Oakey creeks and then into the Condamine River, are *very unlikely* to be impacted.

The north-eastern part of the zone of potential hydrological change near The Range coal mine overlies an area of Hutton Sandstone aquifer outcrop, which is predominantly remnant vegetation classified as ‘Non-floodplain, GAB GDE’ and watercourses classified as ‘Temporary, upland GAB GDE stream’. Median drawdown under the baseline in this area is less than 0.5 m and drawdown due to additional coal resource development is less than 0.2 m. Drawdown of this magnitude is in addition to and of a similar magnitude to natural watertable fluctuation (<2 m) (Table 12) for remnant vegetation in this area.

Temporary streams that are identified as GAB GDEs may include unidentified watercourse springs that access GAB aquifers. Median additional drawdown in excess of 0.2 m is predicted to affect up to 3 km of these streams, with most watercourses in this landscape group predicted to experience up to 0.5 m of baseline drawdown (Figure 29). Local impact assessment and modelling is required to provide more detail to supplement results from the regional model for communities where the critical thresholds identified in Table 12 for this landscape group are exceeded.

3.4.5 'Non-floodplain or upland riverine (including non-GAB GDEs)' landscape group

3.4.5.1 Description

The 'Non-floodplain or upland riverine (including non-GAB GDEs)' landscape group includes ecosystems that are dependent on upland streams and wetlands that are not associated with alluvial systems, and non-GAB GDEs that are associated with perched watertables, such as inland sand ridges, and permeable rock types, such as the basalt aquifers of the Main Range Volcanics. 'Non-GAB springs' are associated with local flow systems in the basalt aquifers and are disconnected from the underlying GAB aquifers. Upland streams and wetlands are characterised by a highly temporary surface water regime, characterised by surface water pulses following rainfall. Localised groundwater discharge in upland areas at the surface, into wetland systems and streams supports non-floodplain, non-GAB GDE remnant vegetation and aquatic communities.

Inland sand ridges occur outside the most elevated portion of the floodplain or alluvial land zones and are more common in the western part of the assessment extent. Inland sand ridges support *Corymbia* and *Eucalyptus* species with varying reliance on perched aquifers within the sandy profile (Holloway et al., 2013).

Ecosystems dependent on groundwater held in permeable rocks such as basalts are common in the eastern portion of the assessment extent in the more elevated Main Range Volcanics of the Great Dividing Range. Groundwater is transmitted and stored through fractures, inter-granular spaces or weathered zones and is typically discharged to the surface at contact zones between two rock types (Figure 30) (DSITI, 2015). Associated plant communities tend to be open woodlands, dominated by *Eucalyptus* spp. on Cenozoic igneous rocks and with shrub and grass (*Pennisetum* spp.) layers. Small stands of brigalow and semi-evergreen vine thickets are also supported by these permeable landforms with subsurface expression of groundwater. Aquifers in permeable rocks may also support ecosystems within the aquifer itself, which is sometimes indicated by the presence of stygofauna (DEHP, 2015). These non-floodplain, non-GAB GDEs are characterised by localised flow systems that have intermittent/aseasonal hydrological connectivity (Figure 30) (DSITI, 2015).

Non-floodplain, temporary wetlands on low permeability, shrink-swell cracking clays sometimes form gilgai (meaning 'small waterhole' wetlands) (DEHP, 2013c). These temporary wetlands are essentially small depressions within the Cenozoic clay deposits that are interspersed with mounds and depressions over relatively small distances (approximately 2 m; Chertkov, 2005). The timing and magnitude of wet and dry phases within these wetlands are determined by localised runoff from rainfall, which means that their dependency on the surface water network at larger scales is likely to be negligible.

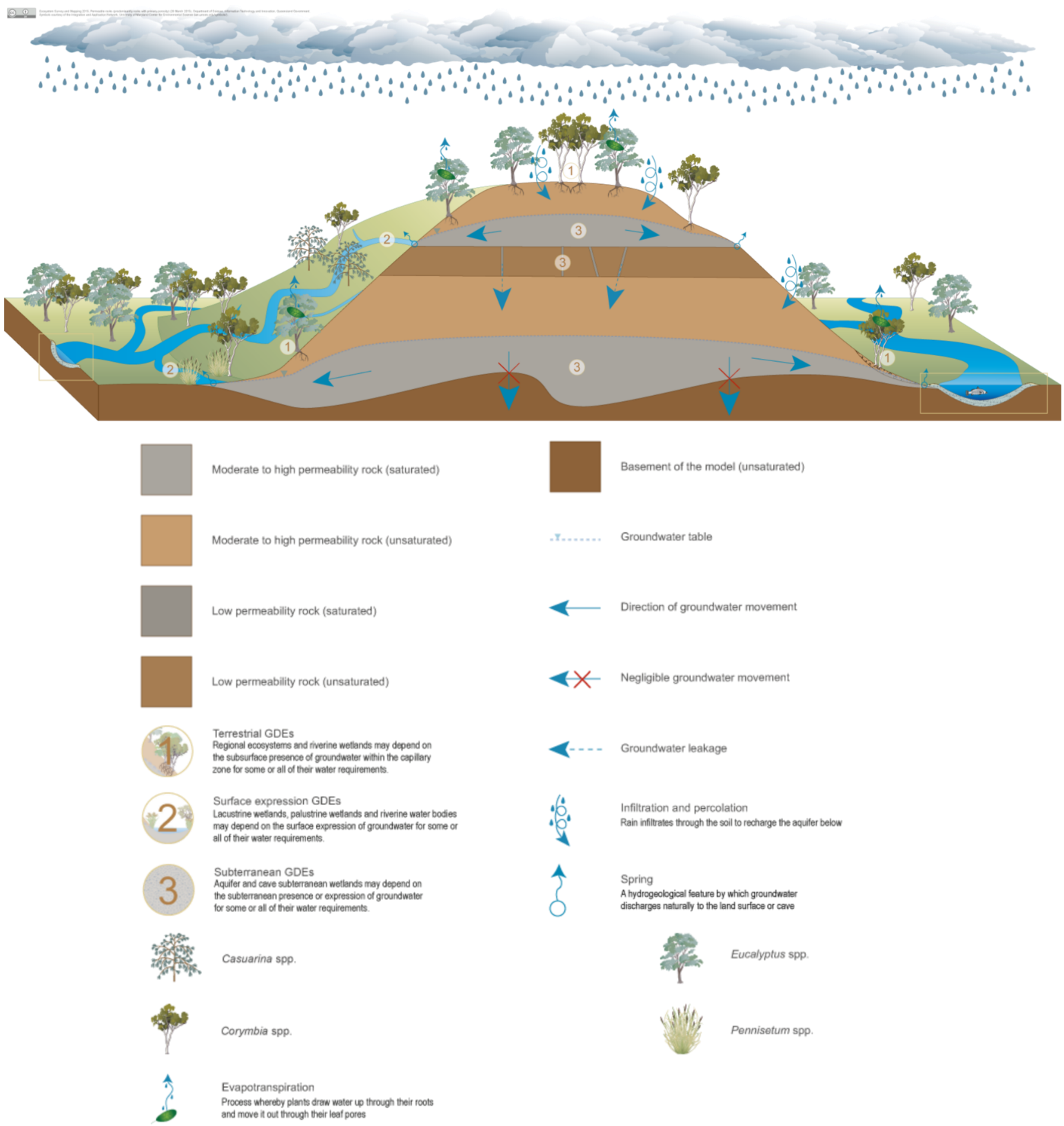

Figure 30 Pictorial conceptual model of groundwater-dependent ecosystems associated with permeable rock (basalt)

GDE = groundwater-dependent ecosystem
Source: DEHP (2015)

The zone of potential hydrological change contains six landscape classes in the 'Non-floodplain or upland riverine (including non-GAB GDEs)' landscape group. These are 'Non-floodplain non-GAB GDE', 'Non-floodplain, non-GAB GDE, near-permanent wetland', 'Non-floodplain, near-permanent wetland', 'Non-floodplain, temporary wetland', 'Temporary, upland non-GAB GDE stream' and 'Temporary, upland stream'. None of the 'Non-GAB springs' that access the aquifers associated with the Main Range Volcanics are contained within the zone of potential hydrological change. The basalt aquifers are represented in layer 1 of the OGIA groundwater model, which is used to define the zone of potential hydrological change for the regional watertable.

The temporary, upland streams intersect temporary or near-permanent non-floodplain wetlands, indicating a reliance of these wetlands on riverine or instream flow patterns. Pulse events dominate temporary, upland riverine systems in this landscape group and inundate standing water bodies including the temporary and near-permanent wetlands. Thus, pulse events improve longitudinal connectivity along the channel or drainage line. Unlike lowland riverine systems, these moderate- to high-flow events recede abruptly after rainfall, resulting in no or limited overbank flows.

Hydrological response variables identified for the 'Non-floodplain or upland riverine (including non-GAB GDEs)' landscape group are summarised in Table 15. Groundwater discharge to streams also supports the maintenance of flow regimes to support the channel habitat. The temporary nature of the upland riverine systems in this landscape group mean that changes to the magnitude and duration of high flows and the frequency and variability of flood pulses will affect water availability. Temporary upland streams that are associated with non-GAB aquifers are also potentially affected by drawdown.

Wetlands within the zone of potential hydrological change are dependent on surface water flow regimes, particularly the magnitude and duration of high flows and the frequency and variability of flood pulses. Remnant vegetation classified as 'Non-floodplain, non-GAB GDE' is dependent on access to groundwater and so is potentially affected by maximum drawdown in the regional watertable, annual amplitude of drawdown, rate of annual drawdown and change to groundwater quality.

Table 15 Ecological relevance of hydrological changes for landscape classes in the 'Non-floodplain or upland riverine (including non-GAB GDEs)' landscape group that are contained within the zone of potential hydrological change

Landscape class	Ecological relevance of hydrological changes
Non-floodplain non-GAB GDE	Groundwater-dependent *Eucalyptus* dominated woodlands, and some Brigalow and semi-evergreen vine thickets on Cenozoic igneous rocks. Potentially impacted by drawdown in addition to, but of a similar magnitude to, natural watertable fluctuation (<2 m). A 2 m drawdown threshold is used for this landscape class.
Non-floodplain non-GAB GDE, near-permanent wetland	Groundwater-dependent near-permanent wetlands in upland areas that are dependent on surface expression of groundwater from permeable rock types. Potentially impacted by drawdown in addition to, but of a similar magnitude to, natural watertable fluctuation (<2 m). A 2 m drawdown threshold is used for this landscape class.
Non-floodplain, near-permanent wetland	Near-permanent wetlands that are not groundwater dependent, but may be affected by changes to inflows from upstream GDEs. This landscape class is not potentially impacted by groundwater drawdown, but may be affected by changes to the surface water regime, which are not modelled.
Non-floodplain, temporary wetland	Temporary wetlands that are not groundwater dependent, but may be affected by changes to inflows from upstream GDEs. This landscape class is not potentially impacted by groundwater drawdown, but may be affected by changes to the surface water regime, which are not modelled.
Temporary upland non-GAB GDE stream	Temporary streams and/or watercourse springs in upland areas that are reliant on the surface expression of groundwater from permeable rock geologies. These ecosystems are sensitive to changes in groundwater flows in these aquifers. A 0.2 m drawdown threshold is used for this landscape class.
Temporary upland stream	Temporary streams in upland areas that receive water from surface runoff. This landscape class is not potentially impacted by groundwater drawdown, but may be affected by changes to the surface water regime, which are not modelled.

GAB = Great Artesian Basin, GDE = groundwater-dependent ecosystem

3.4.5.2 Potential hydrological impacts

3.4.5.2.1 Groundwater

Outside of the modelled open-cut mine pits, non-floodplain or upland riverine landscapes that are potentially impacted cover 12 km^2 (which is 0.4% of the landscape group in the assessment extent) of remnant vegetation and 477 km (2.0%) of streams, which are predominantly not groundwater dependent (Figure 31 and Table 8). Most of the remnant vegetation in the zone (11 km^2) is dependent on local groundwater flow systems in the alluvium or Main Range Volcanics aquifers or is associated with non-floodplain wetlands. Most streams in the zone are not groundwater dependent (469 km) and so are unlikely to be affected by groundwater drawdown. None of the 'Non-GAB springs' associated with the Main Range Volcanics basalt aquifers are contained within the zone of potential hydrological change.

The median (50th percentile) estimate of exceeding 0.2 m drawdown due to additional coal resource development includes 5 km^2 of remnant vegetation and 256 km of stream network (Table 17). Median drawdown due to additional coal resource development is less than 2 m, with the exception of 1 km^2 of remnant vegetation adjacent to the modelled open-cut mine pits (Figure 31).

Drawdown under the baseline is less than 2 m for most remnant vegetation and streams in this landscape group (Figure 32). Median baseline drawdown in excess of 2 m covers 3 km^2 of remnant vegetation and 182 km of stream network in this landscape group (Table 16).

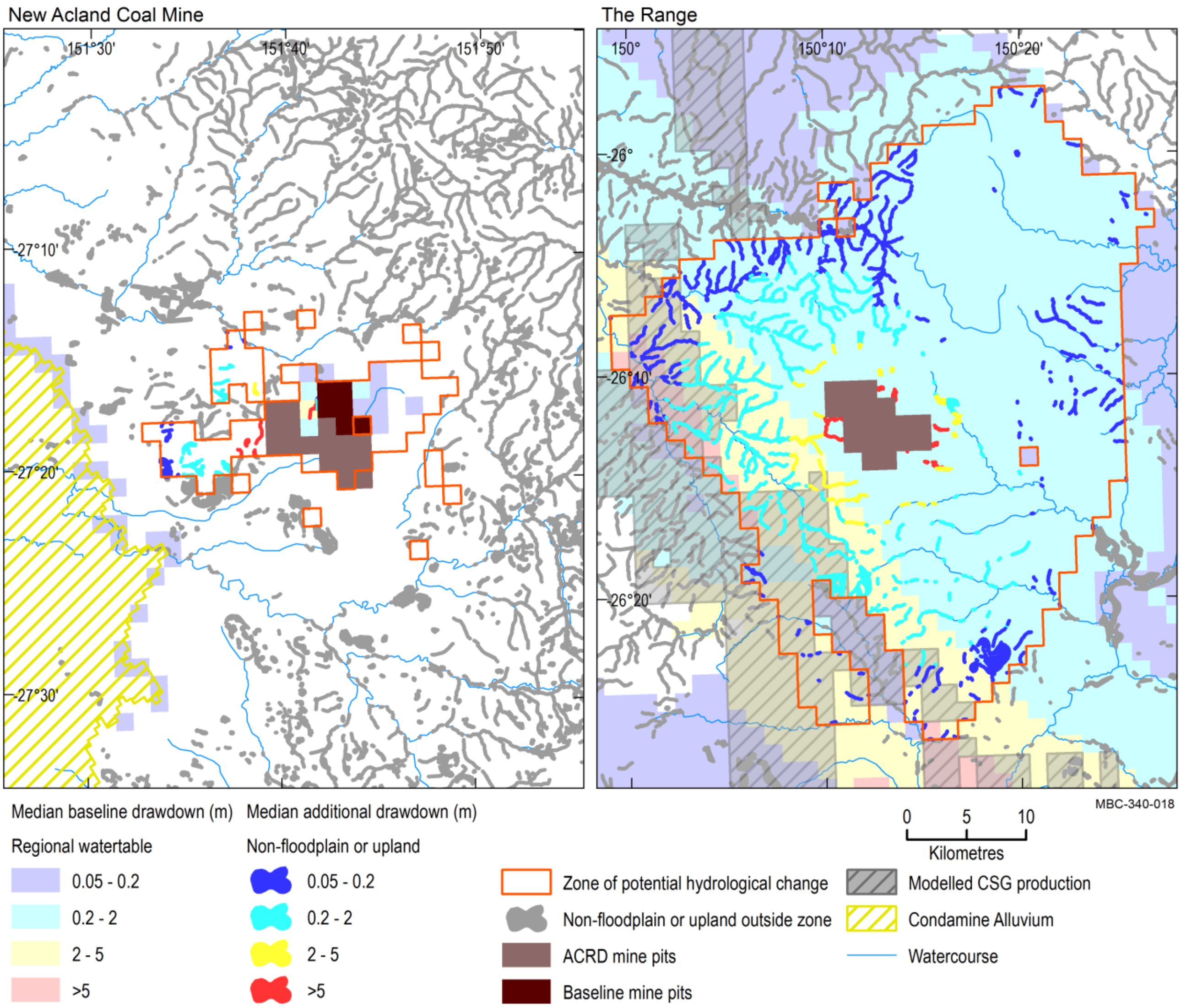

Figure 31 'Non-floodplain or upland riverine (including non-GAB GDEs)' landscape group: location of remnant vegetation and stream network contained within the zone of potential hydrological change in the Maranoa-Balonne-Condamine subregion

Median is the 50th percentile. Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. The mine pits in the CRDP are the sum of those in the baseline and the additional coal resource development (ACRD). Landscape classes within modelled open-cut mine pits are not included in this analysis.

ACRD = additional coal resource development, CSG = coal seam gas, GAB = Great Artesian Basin, GDE = groundwater-dependent ecosystem

Data: Bioregional Assessment Programme (Dataset 1, Dataset 2, Dataset 3, Dataset 4, Dataset 8, Dataset 9)

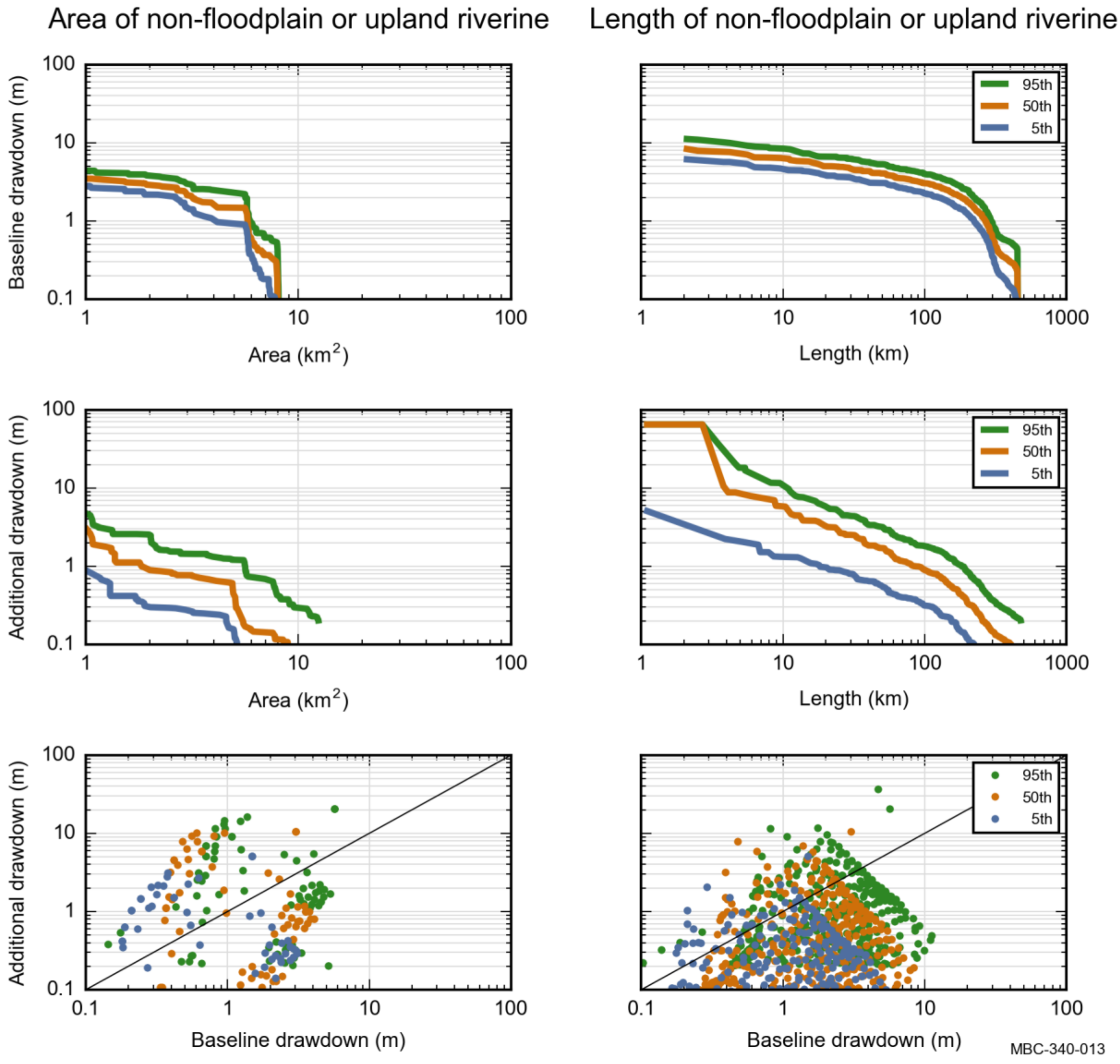

Figure 32 'Non-floodplain or upland riverine (including non-GAB GDEs)' landscape group: the top two rows show area (km^2) or stream length (km) within the zone that exceeds the 5th, 50th and 95th percentile estimates of baseline drawdown and additional drawdown, and the bottom row shows baseline drawdown (m) compared to additional drawdown (m) in each assessment unit

Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. Landscape classes within modelled open-cut mine pits are not included in this analysis. GAB = Great Artesian Basin, GDE = groundwater-dependent ecosystem
Data: Bioregional Assessment Programme (Dataset 7)

Table 16 'Non-floodplain or upland riverine (including non-GAB GDEs)' landscape group: area (km²), stream network length (km) and number of springs (number) that exceed the 5th, 50th and 95th percentile estimates of baseline drawdown in the zone of potential hydrological change

Landscape class	Length, area or number	Extent in assessment extent	Extent in zone of potential hydrological change (excluding modelled open-cut mine pits)	Extent[a] with baseline drawdown ≥0.2 m			Extent[a] with baseline drawdown ≥2 m			Extent[a] with baseline drawdown ≥5 m		
				5th	50th	95th	5th	50th	95th	5th	50th	95th
Non-floodplain, non-GAB GDE	Area (km²)	2,551	11.1	6.0	6.6	6.7	2.4	2.7	5.1	0	0	0
Non-floodplain, non-GAB GDE, near-permanent wetland	Area (km²)	2.9	0	0	0	0	0	0	0	0	0	0
Non-floodplain, non-GAB GDE, temporary wetland	Area (km²)	32.8	0	0	0	0	0	0	0	0	0	0
Non-floodplain, near-permanent wetland	Area (km²)	46.6	0.5	0.3	0.4	0.4	0.1	0.2	0.2	0	0	0.04
Non-floodplain, temporary wetland	Area (km²)	195	0.9	0.4	0.9	0.9	0.2	0.2	0.4	0	0	0.01
Subtotal	**Area (km2)**	**2,829**	**12.5**	**6.7**	**7.9**	**8.0**	**2.6**	**3.2**	**5.6**	**0**	**0**	**0.1**
Near-permanent, upland stream	Length (km)	159	0	0	0	0	0	0	0	0	0	0
Temporary, upland non-GAB GDE stream	Length (km)	2,119	7.7	0	0	0	0	0	0	0	0	0
Temporary, upland stream	Length (km)	21,757	469	346	452	453	124	182	221	5.6	22.1	54.9
Subtotal	**Length (km)**	**24,035**	**477**	**346**	**452**	**453**	**124**	**182**	**221**	**5.6**	**22.1**	**54.9**
Non-GAB springs	Number	24	0	0	0	0	0	0	0	0	0	0
Subtotal	**Number**	**24**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

[a]Extent could be a number, length or area and excludes modelled open-cut mine pits.
Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Landscape classes within modelled open-cut pits are not included in this analysis. Due to rounding, some totals may not correspond with the sum of the separate numbers.
GAB = Great Artesian Basin, GDE = groundwater-dependent ecosystem
Data: Bioregional Assessment Programme (Dataset 7)

Table 17 'Non-floodplain or upland riverine (including non-GAB GDEs)' landscape group: area (km^2), stream network length (km) and number of springs (number) that exceed the 5th, 50th and 95th percentile estimates of additional drawdown in the zone of potential hydrological change

Landscape class	Length, area or number	Extent in assessment extent	Extent in zone of potential hydrological change (excluding modelled mine open-cut pits)	Extent[a] with additional drawdown ≥0.2 m			Extent[a] with additional drawdown ≥2 m			Extent[a] with additional drawdown ≥5 m		
				5th	50th	95th	5th	50th	95th	5th	50th	95th
Non-floodplain non-GAB GDE	Area (km^2)	2,551	11.1	4.0	4.5	11.1	0.3	0.9	1.7	0.0	0.3	0.8
Non-floodplain non-GAB GDE, near-permanent wetland	Area (km^2)	2.9	0	0	0	0	0	0	0	0	0	0
Non-floodplain non-GAB GDE, temporary wetland	Area (km^2)	32.8	0	0	0	0	0	0	0	0	0	0
Non-floodplain, near-permanent wetland	Area (km^2)	46.6	0.5	0.3	0.4	0.5	0	0.1	0.2	0	0.1	0.1
Non-floodplain, temporary wetland	Area (km^2)	195	0.9	0.3	0.3	0.9	0	0.1	0.2	0	0	0.1
Subtotal	Area (km^2)	**2,829**	**12.5**	**4.6**	**5.3**	**12.5**	**0.3**	**1.1**	**2.1**	**0**	**0.4**	**1.0**
Near-permanent upland stream	Length (km)	159	0	0	0	0	0	0	0	0	0	0
Temporary upland non-GAB GDE stream	Length (km)	2,119	7.7	0	4.8	7.7	0	3.2	3.2	0	3.2	3.2
Temporary upland stream	Length (km)	21,757	469	154	251	469	5.1	33.6	78.2	1.1	7.1	20.9
Subtotal	Length (km)	**24,035**	**477**	**154**	**256**	**477**	**5.1**	**36.8**	**81.4**	**1.1**	**10.3**	**24.2**
Non-GAB springs	Number	24	0	0	0	0	0	0	0	0	0	0
Subtotal	Number	**24**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

[a]Extent could be a number, length or area and excludes modelled open-cut pits.
Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. Landscape classes within modelled open-cut mine pits are not included in this analysis. Due to rounding, some totals may not correspond with the sum of the separate numbers.
GAB = Great Artesian Basin, GDE = groundwater-dependent ecosystem
Data: Bioregional Assessment Programme (Dataset 7)

3.4.5.2.2 Surface water

No surface water numerical modelling was undertaken for the Maranoa-Balonne-Condamine subregion. Some potential hydrological changes may, however, be specified conceptually based on scientific logic as described in Section 3.3.

3.4.5.3 Potential ecosystem impacts

Non-floodplain or upland landscapes in the zone of potential hydrological change in the vicinity of New Acland Coal Mine are predominantly temporary upland streams and remnant vegetation associated with the unconfined Main Range Volcanics aquifer. Median drawdown under the baseline is less than 0.2 m and due to additional coal resource development is less than 2 m in this area, with the exception of small areas immediately adjacent to mine operations (Figure 31), which are predicted to experience localised additional drawdown (<5 m) by the regional groundwater model. Local impact assessment and modelling is required to provide more detail to supplement results from the regional model.

Groundwater drawdown of this magnitude is unlikely to affect high flows and flood pulses that drive water availability in these temporary upland streams that are groundwater dependent, but may affect low flows and channel habitat. Potential impacts to fringing riverine vegetation communities associated with these upland streams are likely to be limited in this predominantly human-modified landscape in the vicinity of New Acland Coal Mine.

The western part of the zone of potential hydrological change near The Range coal mine contains temporary upland streams that flow through human-modified landscapes. Median drawdown under the baseline in the area ranges from 0.2 m to more than 5 m and drawdown due to additional coal resource development is less than 2 m (Figure 31). However, these streams are not classified as groundwater dependent and are therefore unlikely to be affected by groundwater drawdown predicted in this area (Table 15).

Groundwater-dependent remnant vegetation (‘Non-floodplain non-GAB GDE’) is located near the proposed mine area and in the southern corner of the zone of potential hydrological change near The Range coal mine. Median drawdown under the baseline near the modelled open-cut mine pits is 0.2 to 2 m and drawdown due to additional coal resource development is 3 to 10 m, which is likely to affect these GDEs (Figure 31). Local impact assessment and modelling is required to provide more detail to supplement results from the regional model.

3.4.6 'Human-modified' landscape group

3.4.6.1 Description

Most of the assessment extent (72.2%) is dominated by human-modified landscapes used for agricultural production, forestry, mining and urban development (Table 8). This landscape group represents the areas not included in the remnant vegetation mapping (Queensland Herbarium, Department of Science, Information Technology, Innovation and the Arts, Dataset 10) and is predominantly dryland areas that have been cleared or highly modified. As such, it is likely that important natural ecosystems are not represented in this landscape group.

The water dependency of this landscape group ranges from a heavy dependence on groundwater and surface water extracted from nearby aquifers and streams (e.g. intensive uses and production from irrigated agriculture and plantations), through to dryland cropping and grazing that are reliant on incident rainfall and local surface water runoff (e.g. production from dryland agriculture and plantations). Deeper-rooted vegetation, including remnant vegetation and plantations may tap into groundwater within certain landscapes. Intensive areas, such as townships and extractive industries, often have a strong reliance on groundwater and surface water via bores and river offtakes.

Much of the area in the vicinity of New Acland Coal Mine is classified as 'Human-modified', indicating the fragmented nature of this landscape. There are large areas classified as 'Conservation and natural environments', 'Production from dryland agriculture and plantations' and 'Production from relatively natural environments'. There are smaller areas classified as 'Intensive uses' and 'Production from irrigated agriculture and plantations'.

The western parts of the zone of potential hydrological change in the vicinity of The Range coal mine are predominantly human-modified landscapes, including 'Production from relatively natural environments' and smaller areas of 'Production from dryland agriculture and plantations'. This landscape is drained by temporary upland streams that flow into Juandah Creek on the western edge, which leads to the Dawson River in the north. Small areas are classified as 'Conservation and natural environments', 'Intensive uses', 'Production from irrigated agriculture and plantations', 'Production from relatively natural environments' and 'Water'.

Hydrological response variables identified for the 'Human-modified' landscape group are summarised in Table 18. Areas with a heavy dependence on groundwater and surface water (e.g. 'Intensive uses' and 'Production from irrigated agriculture and plantations') may be affected by groundwater drawdown. 'Make good' obligations apply for groundwater bores affected by CSG extraction under Queensland's *Water Act 2000*, where water pressure is predicted to fall by more than 5 m for consolidated aquifers, such as sandstone, and 2 m for unconsolidated aquifers, such as sand.

Areas classified as 'Water' may include temporary water bodies or artificial dams that will be affected by changes to the magnitude and duration of high flows and frequency of flood pulses. Other landscape classes are not considered to be water dependent for this Assessment (Table 18).

Table 18 Ecological relevance of hydrological changes for landscape classes in the 'Human-modified' landscape group that are contained within the zone of potential hydrological change

Landscape class	Ecological relevance of hydrological changes
Conservation and natural environments	Non-remnant vegetation that is not groundwater dependent and is not included in Queensland's remnant vegetation mapping. This landscape class is not considered to be water dependent for this Assessment.
Intensive uses	Intensive areas, such as townships and extractive industries, often have a strong reliance on groundwater and surface water. Drawdown thresholds of 5 m for consolidated aquifers, such as sandstone, and 2 m for unconsolidated aquifers, such as sand, are used for this landscape class.
Production from dryland agriculture and plantations	Non-remnant vegetation used for dryland cropping and grazing that is not considered to be water dependent for this Assessment.
Production from irrigated agriculture and plantations	Irrigated agriculture and plantations often have a strong reliance on groundwater and surface water. Drawdown thresholds of 5 m for consolidated aquifers, such as sandstone, and 2 m for unconsolidated aquifers, such as sand, are used for this landscape class.
Production from relatively natural environments	Non-remnant vegetation used for dryland grazing that is not considered to be water dependent for this Assessment.
Water	Water bodies that are not included in the Queensland wetland and GDE mapping, but may include temporary water bodies and artificial dams. This landscape class is not considered to be groundwater dependent, but may be affected by changes to the surface water regime.

GDE = groundwater-dependent ecosystem

3.4.6.2 Potential hydrological impacts

3.4.6.2.1 Groundwater

There is 685 km^2 of non-remnant vegetation in the 'Human-modified' landscape group contained within the zone of potential hydrological change (Figure 33 and Table 8). Non-remnant vegetation in the zone of potential hydrological change (excluding open-cut mine pits) is predominantly classified as 'Production from relatively natural environments' (541 km^2) or 'Production from dryland agriculture and plantations' (140 km^2).

The median (50th percentile) estimate of exceeding 0.2 m drawdown due to additional coal resource development includes 371 km^2 of human-modified landscapes (Table 20). The area potentially affected by median additional drawdown in excess of 2 m is 92 km^2. Median additional drawdown is less than 5 m, with the exception of 32 km^2 of human-modified landscapes in the immediate vicinity of the operational areas (Figure 33).

Median drawdown under the baseline is predominantly less than 2 m, covering 223 km^2 of the 685 km^2 of human-modified landscapes in the zone of potential hydrological change (Figure 34 and Table 19). Median drawdown under the baseline in excess of 5 m, associated with CSG development to the west of The Range proposed coal mine, covers 36 km^2 of human-modified landscapes located along the south-western edge of the zone of potential hydrological change (Figure 33).

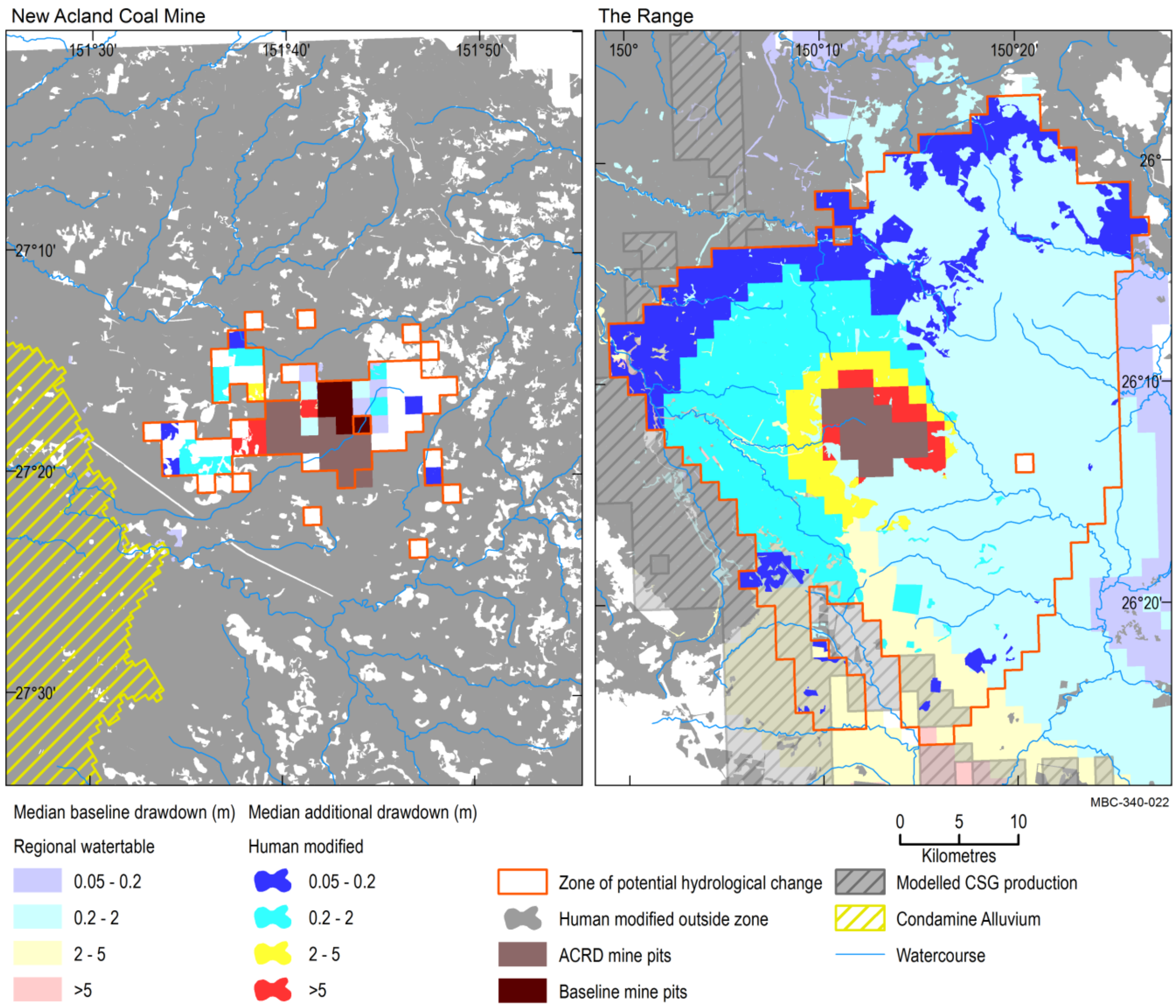

Figure 33 'Human-modified' landscape group: location of non-remnant vegetation areas contained within the zone of potential hydrological change in the Maranoa-Balonne-Condamine subregion

Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. The mine pits in the CRDP are the sum of those in the baseline the additional coal resource development. Landscape classes within modelled open-cut mine pits are not included in this analysis.
ACRD = additional coal resource development, CSG = coal seam gas
Data: Bioregional Assessment Programme (Dataset 1, Dataset 2, Dataset 3, Dataset 4, Dataset 8, Dataset 9)

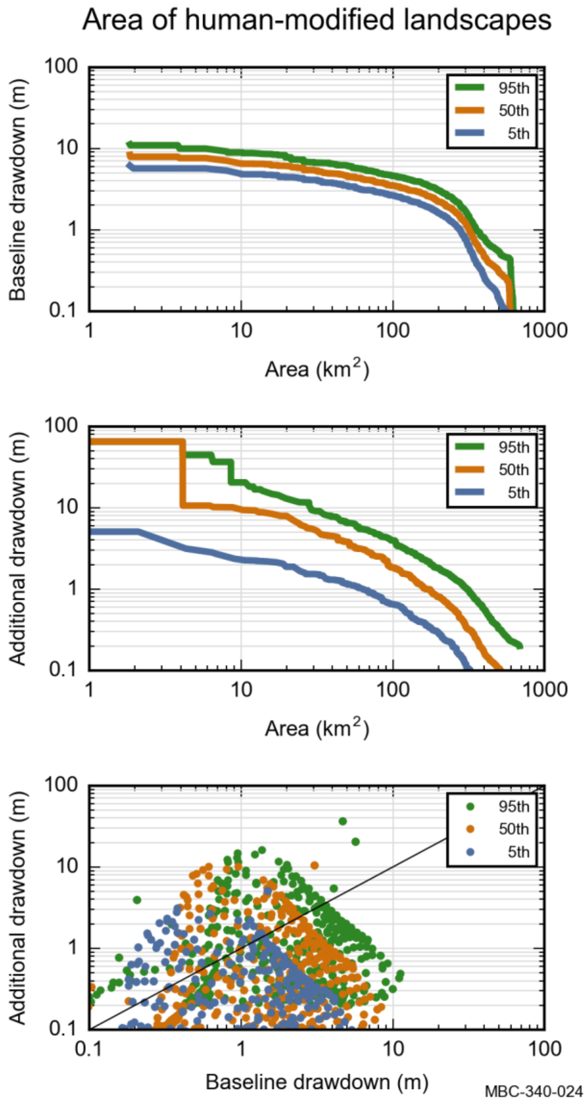

Figure 34 ‘Human-modified’ landscape group: the top two rows show area (km²) within the zone that exceeds the 5th, 50th and 95th percentile estimates of baseline drawdown and additional drawdown, and the bottom row shows baseline drawdown (m) compared to additional drawdown (m) in each assessment unit

Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. Landscape classes within modelled open-cut mine pits are not included in this analysis.
Data: Bioregional Assessment Programme (Dataset 7)

Table 19 'Human-modified' landscape group: area (km^2) that exceeds the 5th, 50th and 95th percentile estimates of baseline drawdown in the zone of potential hydrological change

Landscape class	Area in assessment extent	Area in zone of potential hydrological change (excluding modelled open-cut mine pits)	Area[a] with baseline drawdown ≥0.2 m			Area[a] with baseline drawdown ≥2 m			Area[a] with baseline drawdown ≥5 m		
			5th	50th	95th	5th	50th	95th	5th	50th	95th
Conservation and natural environments	554	1.8	1.3	1.3	1.3	0.9	0.9	0.9	0	0.1	0.7
Intensive uses	788	0.8	0.2	0.4	0.4	0	0.1	0.4	0	0	0
Production from dryland agriculture and plantations	18,992	140	72.8	84.9	100	35.9	51.8	58.2	0.1	7.2	19.5
Production from irrigated agriculture and plantations	3,476	0.8	0.2	0.2	0.2	0.1	0.2	0.2	0	0	0
Production from relatively natural environments	69,833	541	369	497	503	122	169	216	8.0	28.7	58.6
Water	164	0.8	0.7	0.8	0.8	0.3	0.4	0.6	0	0	0.1
Total	**93,807**	**685**	**444**	**584**	**606**	**159**	**223**	**276**	**8.1**	**36.1**	**78.9**

[a]Numbers exclude the modelled open-cut mine pits.
Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Landscape classes within modelled open-cut mine pits are not included in this analysis. Due to rounding, some totals may not correspond with the sum of the separate numbers.
Data: Bioregional Assessment Programme (Dataset 7)

Table 20 'Human-modified' landscape group: area (km²) that exceeds the 5th, 50th and 95th percentile estimates of additional drawdown in the zone of potential hydrological change

Landscape class	Area in assessment extent	Area in zone of potential hydrological change (excluding modelled open-cut mine pits)	Area[a] with additional drawdown ≥0.2 m			Area[a] with additional drawdown ≥2 m			Area[a] with additional drawdown ≥5 m		
			5th	50th	95th	5th	50th	95th	5th	50th	95th
Conservation and natural environments	554	1.8	0.8	1.3	1.8	0	0	0.1	0	0	0
Intensive uses	788	0.8	0.2	0.2	0.8	0	0.1	0.4	0	0	0.3
Production from dryland agriculture and plantations	18,992	140	42.8	79.8	140	1.3	14.0	37.7	1.3	4.4	11.8
Production from irrigated agriculture and plantations	3,476	0.8	0.2	0.2	0.8	0	0.1	0.4	0	0	0
Production from relatively natural environments	69,833	541	203	289	541	17.6	78.0	140	0.8	27.1	61.0
Water	164	0.8	0.4	0.6	0.8	0	0.1	0.2	0	0	0.1
Total	**93,807**	**685**	**247**	**371**	**685**	**18.9**	**92.4**	**179**	**2.1**	**31.6**	**73.2**

[a]Numbers exclude the modelled open-cut mine pits.
Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. Landscape classes within modelled open-cut mine pits are not included in this analysis. Due to rounding, some totals may not correspond with the sum of the separate numbers.
Data: Bioregional Assessment Programme (Dataset 7)

3.4.6.2.2 Surface water

No surface water numerical modelling was undertaken for the Maranoa-Balonne-Condamine subregion. Some potential hydrological changes may, however, be specified conceptually based on scientific logic as described in Section 3.3 (Potential hydrological impacts).

3.4.6.3 Potential ecosystem impacts

The New Acland Coal Mine Stage 3 zone of potential hydrological change includes small areas of human-modified landscapes that are likely to have a heavy dependence on groundwater and surface water extracted from nearby aquifers and streams (e.g. intensive uses and production from irrigated agriculture and plantations) (Figure 33 and Table 8). Most of the remaining areas of non-remnant vegetation are classified as 'Conservation and natural environments', 'Production from dryland agriculture and plantations' and 'Production from relatively natural environments'. These landscape classes are reliant on incident rainfall and local surface water runoff, with limited groundwater dependency.

The zone of potential hydrological change near The Range proposed coal mine contains large areas of non-remnant vegetation classified as 'Production from relatively natural environments', with smaller areas classified as 'Conservation and natural environments' and 'Production from dryland agriculture and plantations'. These landscapes are reliant on incident rainfall and local surface water runoff, with limited groundwater dependency. Small areas are classified as 'Intensive uses' and 'Production from irrigated agriculture and plantations', which are likely to have some dependence on groundwater and surface water extracted from nearby aquifers and streams.

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3.5 Impacts on and risks to water-dependent assets

Summary

Potential impacts on and risks to water-dependent assets due to additional coal resource development were analysed by intersecting assets with the zone of potential hydrological change. Water-dependent assets that occur within or across the zone need to be considered further, while assets that do not occur in the zone are considered *very unlikely* (less than 5% chance) to experience potential impacts and are 'ruled out' from further consideration. Of the 2660 water-dependent assets nominated by the community for the subregion, 2495 are *very unlikely* to be impacted because they experience less than 0.2 m drawdown due to additional coal resource development.

The 115 ecological water-dependent assets in the zone of potential hydrological change include 12 assets classified in the 'Groundwater feature (subsurface)' subgroup and 29 assets in the 'Surface water feature' subgroup. None of the 882 water-dependent assets in the 'Floodplain', 'Lake, reservoir, lagoon or estuary', 'Marsh, sedgeland, bog, spring or soak' or 'Waterhole, pool, rock pool or billabong' classes are in the zone of potential hydrological change. This includes the 177 springs assessed in Section 3.4.

There are 74 water-dependent assets in the 'Vegetation' subgroup in the zone of potential hydrological change, including 33 assets in the 'Groundwater-dependent ecosystem' class, 39 assets in the 'Habitat (potential species distribution)' class and 2 riparian vegetation assets. This includes the potential habitats of 4 threatened ecological communities and 18 species listed under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* and an additional 11 species and 6 endangered regional ecosystems listed under Queensland's *Nature Conservation Act 1992*. Water-dependent assets listed as protected reserves, parks or bird habitats are not found within the zone.

There is at least a 5% chance that 163 bores experience greater than 0.2 m drawdown in the source aquifer due to additional coal resource development. The 163 bores are part of 13 economic water-dependent assets comprising 7 water access rights and 6 basic water rights (stock and domestic). Of these 163 bores, it is *very likely* (greater than 95% chance) that additional drawdown exceeds 5 m in 17 bores located near the proposed New Acland Stage 3 coal mine pits, including 5 bores that access water from the near-surface aquifer and 12 bores that access water from the deeper Walloon Coal Measures.

The Barakula State Forest, near Miles in Queensland, is the sole sociocultural water-dependent asset located in the zone of potential hydrological change. It is *very likely* that 21 km^2 or 0.7% of the 3092 km^2 forest experiences more than 0.2 m of drawdown due to additional coal resource development.

3.5.1 Overview

This section describes the ecological, economic and sociocultural assets that are potentially impacted by hydrological changes due to additional coal resource development. Assets were nominated by the community for the Bioregional Assessment Programme, where each asset is an entity having value or many values associated with it. A water-dependent asset is an asset that is potentially impacted, either positively or negatively, by changes to the groundwater and/or surface water regime due to coal resource development. The water-dependent asset register is a list of assets associated with a bioregion or subregion.

The water dependence of each asset was assessed individually. In many cases, assets were clearly water dependent, such as groundwater bores, rivers and wetlands. In other cases, the water dependency of assets – such as the potential habitat of threatened species, ecological communities and regional ecosystems – was less clear. The Assessment team reviewed the available ecological knowledge and used spatial overlay to determine their water dependency. The water dependency of other assets – such as national parks, nature reserves or historical buildings – was assessed based on the presence of floodplains, wetlands or surface water features, shallow groundwater or other water-dependent assets within their spatial boundaries.

The water-dependent asset register for the Maranoa-Balonne-Condamine subregion (dated 26 June 2015; Mitchell et al., 2015a; Bioregional Assessment Programme, Dataset 1) described in companion product 1.3 (Mitchell et al., 2015b) was updated after product 1.3 was finalised. A review of the ecological knowledge used to determine the nature of the water dependency of the potential habitat of threatened species and communities identified an additional 17 ecological assets that were added to the water-dependent asset register for the Maranoa-Balonne-Condamine subregion. Consultation with Traditional Owners in the Maranoa-Balonne-Condamine subregion identified an additional 56 Indigenous assets that were considered to be water dependent. These additional assets have been added to an updated version of the water-dependent asset register (Bioregional Assessment Programme, Dataset 2; Bioregional Assessment Programme, 2017).

The impact and risk analysis used this updated water-dependent asset register (Bioregional Assessment Programme, Dataset 2; Bioregional Assessment Programme, 2017), which contains a total of 2660 water-dependent assets that comprise 2215 ecological assets, 310 economic assets and 135 sociocultural assets.

Users can explore further details about assets, including their spatial extents, using a map-based interface on the BA Explorer at www.bioregionalassessments.gov.au/explorer/MBC/assets.

3.5.2 Ecological assets

3.5.2.1 Description

The water-dependent asset register for the Maranoa-Balonne-Condamine subregion (Bioregional Assessment Programme, 2017) contains 2215 ecological assets (Table 21). This includes:

- 23 assets in the 'Groundwater feature (subsurface)' subgroup, including alluvial aquifers, geological formations, recharge areas and groundwater management areas

- 1688 assets in the ‘Surface water feature’ subgroup, including several spring complexes, wetlands and lagoons. The spring complexes are part of the 177 springs assessed in Section 3.4
- 504 assets in the ‘Vegetation’ subgroup, comprising:
  - 313 assets in the ‘Groundwater-dependent ecosystem’ class that rely on either the surface or subsurface expression of groundwater described in the *National atlas of groundwater dependent ecosystems* (GDE Atlas) (Bureau of Meteorology, 2012) and the Queensland Government GDE mapping (DSITIA, 2012)
  - 171 assets in the ‘Habitat (potential species distribution)’ class that are listed threatened ecological communities, species or regional ecosystems under the Commonwealth’s *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) or Queensland’s *Nature Conservation Act 1992* (Nature Conservation Act)
  - 20 assets in the ‘Riparian vegetation’ class that include protected reserves, parks, bird habitats and key environmental assets.

Table 21 Number of ecological water-dependent assets in the assessment extent, outside of the zone of potential hydrological change and in the zone of potential hydrological change associated with the two additional coal resource developments: New Acland Coal Mine Stage 3 and The Range coal mine

Asset subgroup	Asset class	Number of water-dependent assets in assessment extent	Number of water-dependent assets outside zone of potential hydrological change	Number of water-dependent assets in zone of potential hydrological change (including modelled open-cut mine pits)
Groundwater feature (subsurface)	Aquifer, geological feature, alluvium or stratum	23	11	12
	Subtotal	**23**	**11**	**12**
Surface water feature	Floodplain	6	6	0
	Lake, reservoir, lagoon or estuary	55	55	0
	Marsh, sedgeland, bog, spring or soak	267	267	0
	River or stream reach, tributary, anabranch or bend	695	677	18
	Waterhole, pool, rock pool or billabong	554	554	0
	Wetland, wetland complex or swamp	111	100	11
	Subtotal	**1688**	**1659**	**29**
Vegetation	Groundwater-dependent ecosystem	313	280	33
	Habitat (potential species distribution)	171	132	39
	Riparian vegetation	20	18	2
	Subtotal	**504**	**430**	**74**
Total		**2215**	**2100**	**115**

Data: Bioregional Assessment Programme (Dataset 2, Dataset 3)

3.5.2.2 'Groundwater feature (subsurface)' subgroup

Twelve of the 23 assets in the 'Groundwater feature (subsurface)' subgroup are potentially impacted by drawdown due to additional coal resource development (Table 21). This includes:

- 11 assets that overlap most of the zone of potential hydrological change (Table 22 and Table 23) and so cannot be shown individually in this product. This includes the spatial extent of 11 aquifers or geological features, including Great Artesian Basin (GAB) recharge areas, Condamine Alluvium, Main Range Volcanics, Hutton/Marburg and Springbok sandstone aquifers, and the Walloon Coal Measures
- 1 multi-point asset that includes 252 of 13,249 groundwater production bores in the vicinity of the Condamine Alluvium. The bores included in this asset are only located near New Acland Coal Mine (Figure 35).

The area of aquifer or geological feature where the median (50th percentile) estimate of drawdown due to additional coal resource development exceeds 0.2 m includes 618 km^2 and in excess of 2 m covers 144 km^2. Median additional drawdown is less than 5 m, with the exception of 49 km^2 in the immediate vicinity of the operational areas (Table 23).

Median drawdown under the baseline is predominantly less than 2 m, covering 373 km^2 of the 1532 km^2 of aquifer or geological feature in the zone of potential hydrological change. Median drawdown under the baseline in excess of 5 m, associated with coal seam gas (CSG) development to the west of The Range proposed coal mine, covers 43 km^2 located along the south-western edge of the zone of potential hydrological change (Figure 35 and Table 22).

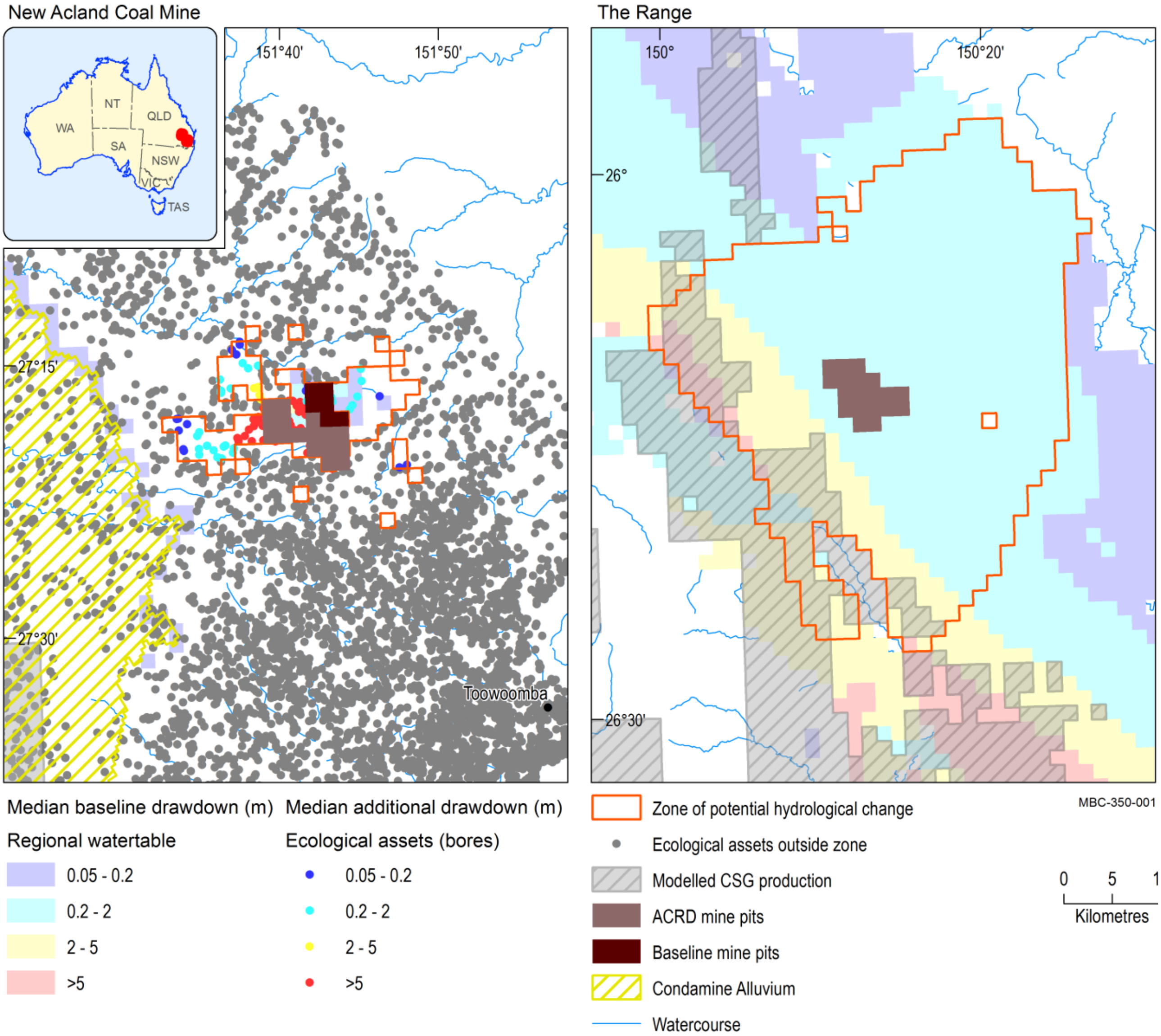

Figure 35 Median baseline drawdown and additional drawdown for ecological assets in the 'Groundwater feature (subsurface)' subgroup in the zone of potential hydrological change in the vicinity of New Acland Coal Mine and The Range coal mine

Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. The mine pits in the CRDP are the sum of those in the baseline and the additional coal resource development. Areas within modelled open-cut pits (Table 4) are not included in this analysis.
ACRD = additional coal resource development, CSG = coal seam gas
This figure shows the location of bores contained in multi-point asset 9490 - 'Groundwater production bores (13249 Bores mostly in Condamine)', which is classified as an ecological asset in the water-dependent asset register in the 'Groundwater feature (subsurface)' subgroup and 'Aquifer, geological feature, alluvium or stratum' class.
Data: Bioregional Assessment Programme (Dataset 2, Dataset 4, Dataset 5, Dataset 6, Dataset 7, Dataset 8)

Table 22 Number and area of ecological water-dependent assets in the 'Groundwater feature (subsurface)' subgroup that exceed the 5th, 50th and 95th percentile estimates of baseline drawdown (m) in the zone of potential hydrological change

Asset subgroup	Asset class	Number[a] or area	Assets in assessment extent		Assets in zone of potential hydrological change		Extent[bc] of assets with baseline drawdown ≥0.2 m			Extent[bc] of assets with baseline drawdown ≥2 m			Extent[bc] of assets with baseline drawdown ≥5 m		
			Number[a]	Area	Number[a]	Area[b]	5th	50th	95th	5th	50th	95th	5th	50th	95th
Groundwater feature (subsurface)	Aquifer, geological feature, alluvium or stratum	Area (km^2)	*21*	129,956	*11*	1532	869	1418	1441	236	373	476	9.0	42.7	106
	Aquifer, geological feature, alluvium or stratum	*Number*	*2*	–	*1*	–	*1*	*1*	*1*	*0*	*1*	*1*	*0*	*0*	*1*

[a]Numbers in table are italicised, to distinguish from areas. Numbers within the whole zone are included in this analysis.
[b]Areas within modelled open-cut mine pits (Table 4) are not included in this analysis.
[c]Extent could be number or area.
'–' means 'not applicable'. The extent potentially exposed to ≥0.2, ≥2 and ≥5 m baseline drawdown is shown for the 5th, 50th and 95th percentile estimates of the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Areas within modelled open-cut mine pits (Table 4) are not included in this analysis. The zone of potential hydrological change is defined as the area with a greater than 5% chance of exceeding 0.2 m drawdown due to additional coal resource development.
Data: Bioregional Assessment Programme (Dataset 3)

Table 23 Number and extent of ecological water-dependent assets in the 'Groundwater feature (subsurface)' subgroup that exceed the 5th, 50th and 95th percentile estimates of additional drawdown (m) in the zone of potential hydrological change

Asset subgroup	Asset class	Number[a] or area	Assets in assessment extent		Assets in zone of potential hydrological change		Extent[bc] of assets with additional drawdown ≥0.2 m			Extent[bc] of assets with additional drawdown ≥2 m			Extent[bc] of assets with additional drawdown ≥5 m		
			Number[a]	Area	Number[a]	Area[b]	5th	50th	95th	5th	50th	95th	5th	50th	95th
Groundwater feature (subsurface)	Aquifer, geological feature, alluvium or stratum	Area (km^2)	*21*	129,956	*11*	1532	384	618	1532	24.7	144	272	2.2	49.4	110
	Aquifer, geological feature, alluvium or stratum	*Number*	*2*	–	*1*	–	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*

[a]Numbers in table are italicised, to distinguish from areas. Numbers within the whole zone are included in this analysis.
[b]Areas within modelled open-cut mine pits (Table 4) are not included in this analysis.
[c]Extent could be number or area.
'–' means 'not applicable'. The extent potentially exposed to ≥0.2, ≥2 and ≥5 m additional drawdown is shown for the 5th, 50th and 95th percentile estimates of the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. Areas within modelled open-cut mine pits (Table 4) are not included in this analysis. The zone of potential hydrological change is defined as the area with a greater than 5% chance of exceeding 0.2 m drawdown due to additional coal resource development.
Data: Bioregional Assessment Programme (Dataset 3)

3.5.2.3 'Surface water feature' subgroup

Twenty-nine ecological assets classified in the 'Surface water feature' subgroup overlap the zone of potential hydrological change (Table 21 and Figure 36). This includes:

- 18 assets classified as 'River or stream reach, tributary, anabranch or bend' that cover 18,075 km^2 of catchment area and 32,261 km of stream length, comprising
  - 1 stream on the Auburn River and tributaries in the Burnett river basin
  - 2 catchment areas, Upper Myall and Upper Oakey Creeks, in the Condamine river basin
  - 15 streams in the Fitzroy river basin, including Bungaban, Downfall, Juandah, Roche, Six Mile, Twenty Mile, Two Mile and Weringa creeks
- 11 assets classified as 'Wetland, wetland complex or swamp' that cover 1.5 km^2 of wetland area and 1429 km of streams included in Queensland's wetland mapping, comprising
  - 4 wetland areas mapped as 'Artificial/highly modified wetlands (dams, ring tanks, irrigation channel)' in the Balonne, Boyne and Auburn, Condamine and Dawson river basins
  - 3 riverine wetland areas in the Balonne and Dawson river basins
  - 2 wetland areas mapped as 'Catchment Coastal/Sub-coastal floodplain grass, sedge and herb swamps' or 'Coastal/Sub-coastal floodplain lakes' in the Dawson river basin
  - 1 asset containing streams included in Queensland's wetland mapping
  - 1 wetland regional ecosystem.

None of the 882 assets classified as 'Floodplain', 'Lake, reservoir, lagoon or estuary', 'Marsh, sedgeland, bog, spring or soak' or 'Waterhole, pool, rock pool or billabong' are located within the zone of potential hydrological change (Table 21). Potential impacts on springs and spring complexes, including watercourse springs, are assessed in Section 3.4. This includes the 177 springs previously assessed.

The extent of rivers or streams where the median (50th percentile) estimate of drawdown due to additional coal resource development exceeds 0.2 m includes 8 km^2 of catchment area and 231 km of stream length. Median additional drawdown is less than 5 m, with the exception of 5 km of streams in the immediate vicinity of the operational areas (Table 25). Median drawdown under the baseline is predominantly less than 2 m, except for 194 km of streams in the zone of potential hydrological change (Figure 37 and Table 24).

The extent of wetlands where the median (50th percentile) estimate of drawdown due to additional coal resource development exceeds 0.2 m includes less than 1 km^2 of wetland area and 532 km of wetland streams. Median additional drawdown is less than 5 m, with the exception of less than 1 km^2 of wetland area and 25 km of wetland streams in the immediate vicinity of the operational areas (Table 25). Median drawdown under the baseline is predominantly less than 5 m, except for less than 1 km^2 of wetland area and 55 km of wetland streams in the zone of potential hydrological change (Figure 37 and Table 24).

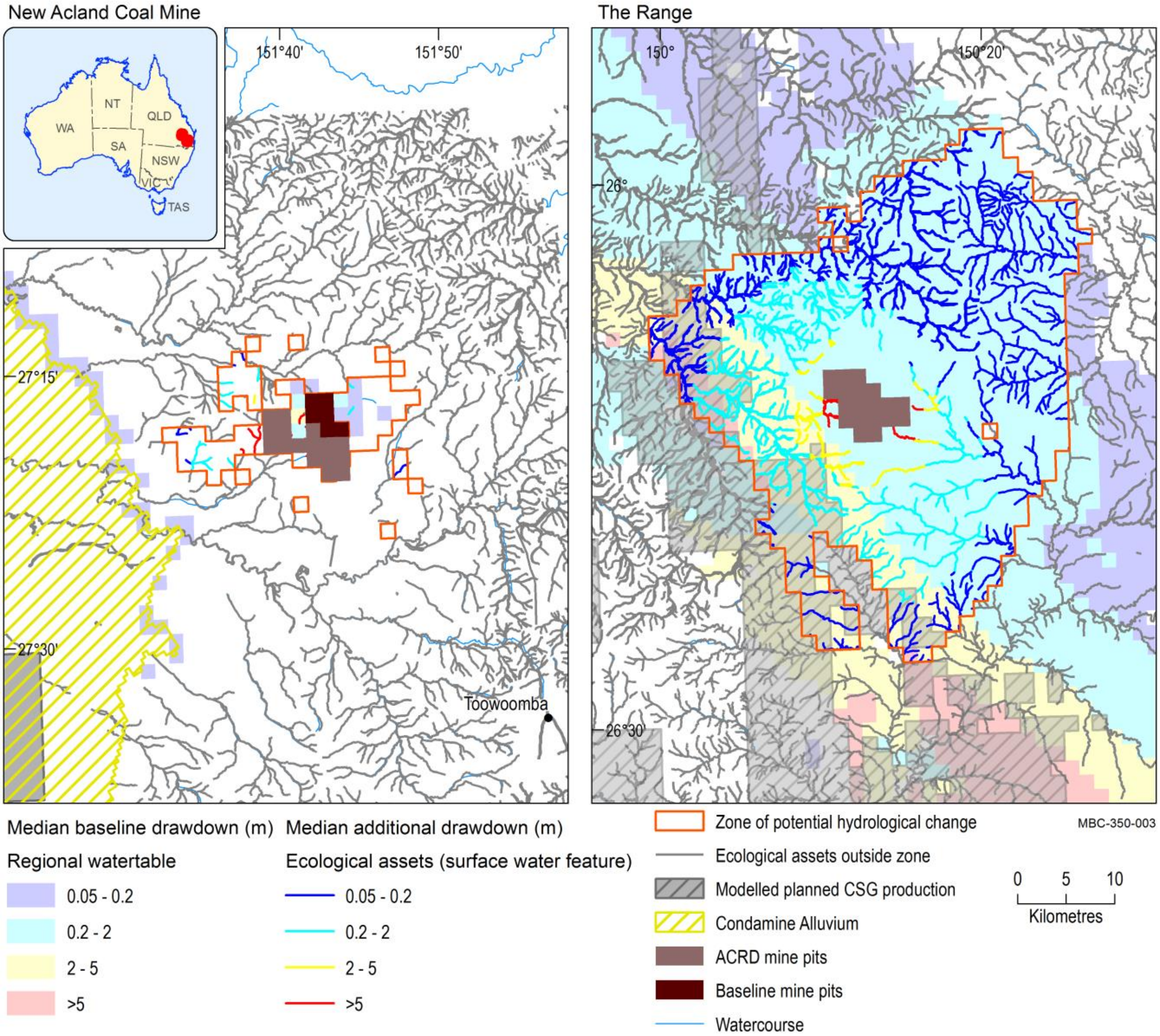

Figure 36 Median baseline drawdown and additional drawdown for ecological assets in the 'Surface water feature' subgroup in the zone of potential hydrological change in the vicinity of New Acland Coal Mine and The Range coal mine

Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. The mine pits in the CRDP are the sum of those in the baseline and the additional coal resource development. Areas within modelled open-cut mine pits (Table 4) are not included in this analysis.
CSG = coal seam gas
Data: Bioregional Assessment Programme (Dataset 2, Dataset 4, Dataset 5, Dataset 6, Dataset 7, Dataset 8)

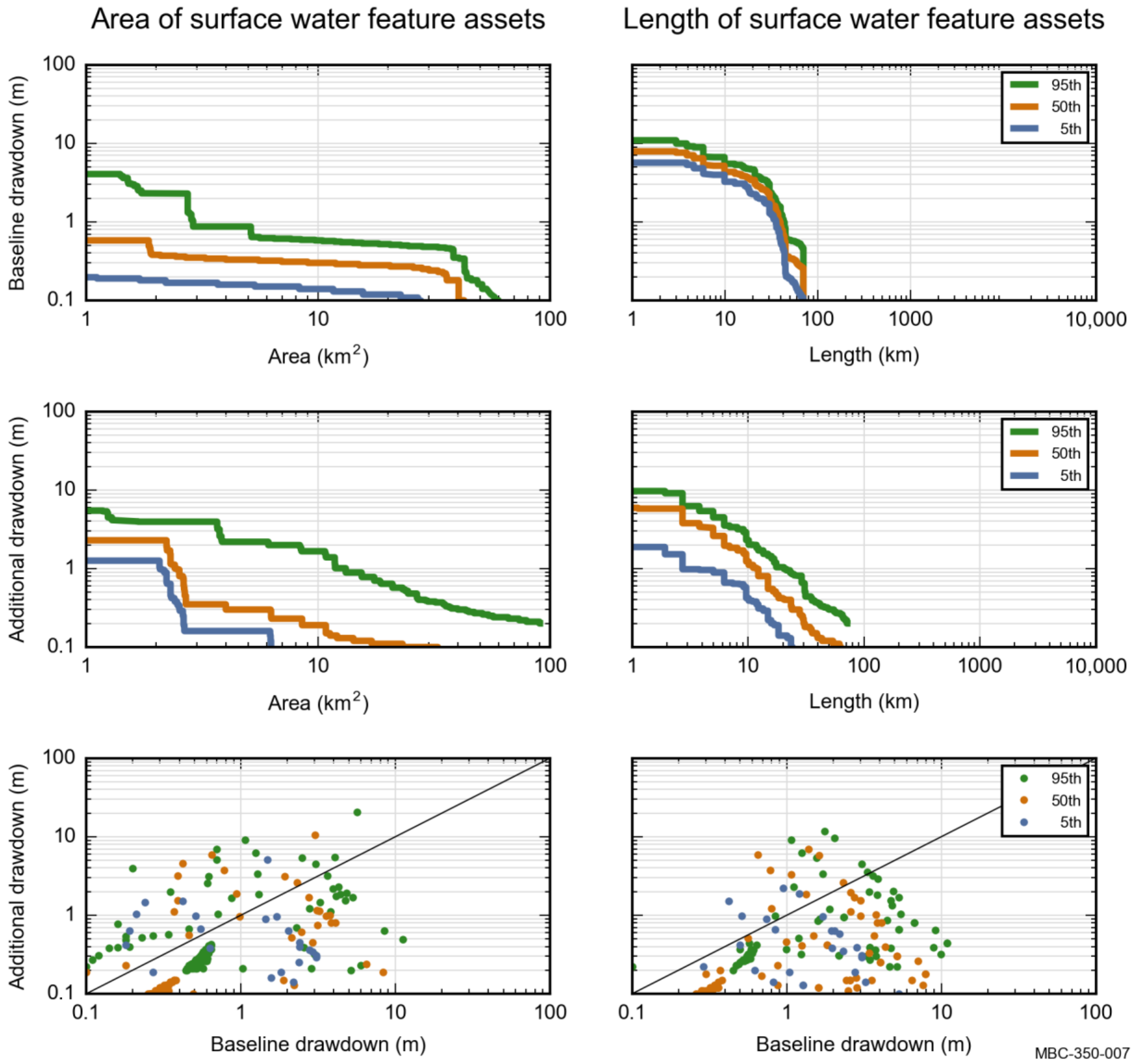

Figure 37 For ecological assets in the 'Surface water feature' subgroup in the zone of potential hydrological change: the top two rows show area (km^2) and length (km) of assets that exceed the 5th, 50th and 95th percentile estimates of baseline drawdown and additional drawdown, and the bottom row shows baseline drawdown compared to additional drawdown

Colours represent the 5th, 50th and 95th percentile. Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. Areas within modelled open-cut mine pits (Table 4) are not included in this analysis.
Data: Bioregional Assessment Programme (Dataset 3)

Table 24 Number and extent of ecological water-dependent assets in the 'Surface water feature' subgroup that exceed the 5th, 50th and 95th percentile estimates of baseline drawdown (m) in the zone of potential hydrological change

Asset class	Number[a], length or area	Assets in assessment extent		Assets in zone of potential hydrological change		Extent[bc] of assets with baseline drawdown ≥0.2 m			Extent[bc] of assets with baseline drawdown ≥2 m			Extent[bc] of assets with baseline drawdown ≥5 m		
		Number[a]	Length or area	Number[a]	Length or area[b]	5th	50th	95th	5th	50th	95th	5th	50th	95th
Floodplain	Area (km^2)	*6*	81.8	*0*	0	0	0	0	0	0	0	0	0	0
Lake, reservoir, lagoon or estuary	Length (km)	*33*	22,127	*0*	0	0	0	0	0	0	0	0	0	0
Lake, reservoir, lagoon or estuary	*Number*	*22*	–	*0*	–	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Marsh, sedgeland, bog, spring or soak	*Number*	*267*	–	*0*	–	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
River or stream reach, tributary, anabranch or bend	Area (km^2)	*26*	18,075	*3*	89.1	0.3	34.5	42.5	0	0	2.1	0	0	0
River or stream reach, tributary, anabranch or bend	Length (km)	*669*	32,261	*15*	508	337	508	508	152	194	223	11.5	38.8	78.7
Waterhole, pool, rock pool or billabong	Area (km^2)	*554*	230	*0*	0	0	0	0	0	0	0	0	0	0
Wetland, wetland complex or swamp	Area (km^2)	*110*	2,755	*10*	1.5	0.9	1.5	1.5	0.4	0.6	0.7	0	0.1	0.2
Wetland, wetland complex or swamp	Length (km)	*1*	87,742	*1*	1429	761	1312	1335	265	378	460	17.2	54.7	134

[a]Numbers in table are italicised, to distinguish from areas. Numbers within the whole zone are included in this analysis.
[b]Lengths or areas within modelled open-cut mine pits (Table 4) are not included in this analysis.
[c]Extent could be a number, length or area.
'–' means 'not applicable'. The extent potentially exposed to ≥0.2, ≥2 and ≥5 m baseline drawdown is shown for the 5th, 50th and 95th percentile estimates of the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Areas and lengths within modelled open-cut mine pits (Table 4) are not included in this analysis. The zone of potential hydrological change is defined as the area with a greater than 5% chance of exceeding 0.2 m drawdown due to additional coal resource development.
Data: Bioregional Assessment Programme (Dataset 3)

Table 25 Number and extent of ecological water-dependent assets in the 'Surface water feature' subgroup that exceed the 5th, 50th and 95th percentile estimates of additional drawdown (m) in the zone of potential hydrological change

Asset class	Number[a], length or area	Assets in assessment extent		Assets in zone of potential hydrological change		Extent[bc] of assets with additional drawdown ≥0.2 m			Extent[bc] of assets with additional drawdown ≥2 m			Extent[bc] of assets with additional drawdown ≥5 m		
		Number[a]	Length or area	Number[a]	Length or area[b]	5th	50th	95th	5th	50th	95th	5th	50th	95th
Floodplain	Area (km²)	*6*	81.8	*0*	0	0	0	0	0	0	0	0	0	0
Lake, reservoir, lagoon or estuary	Length (km)	*33*	22,127	*0*	0	0	0	0	0	0	0	0	0	0
Lake, reservoir, lagoon or estuary	*Number*	*22*	–	*0*	–	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Marsh, sedgeland, bog, spring or soak	*Number*	*267*	–	*0*	–	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
River or stream reach, tributary, anabranch or bend	Area (km²)	*26*	18,075	*3*	89.1	2.0	7.8	89.1	0	2.0	5.7	0	0	1.1
River or stream reach, tributary, anabranch or bend	Length (km)	*669*	32,261	*15*	508	146	231	508	3.0	30.6	77.7	0	4.6	17.0
Waterhole, pool, rock pool or billabong	Area (km²)	*554*	230	*0*	0	0	0	0	0	0	0	0	0	0
Wetland, wetland complex or swamp	Area (km²)	*110*	2,755	*10*	1.5	0.7	0.8	1.5	0	0.2	0.4	0	0.1	0.2
Wetland, wetland complex or swamp	Length (km)	*1*	87,742	*1*	1429	294	532	1429	10.7	79.6	191	2.7	25.7	61.6

[a]Numbers in table are italicised, to distinguish from areas. Numbers within the whole zone are included in this analysis.
[b]Lengths or areas within modelled open-cut mine pits (Table 4) are not included in this analysis.
[c]Extent could be a number, length or area.
'–' means 'not applicable'. The extent potentially exposed to ≥0.2, ≥2 and ≥5 m additional drawdown is shown for the 5th, 50th and 95th percentile estimates of the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. Areas within modelled pits (Table 4) are not included in this analysis. The zone of potential hydrological change is defined as the area with a greater than 5% chance of exceeding 0.2 m drawdown due to additional coal resource development.
Data: Bioregional Assessment Programme (Dataset 3)

3.5.2.4 'Vegetation' subgroup

3.5.2.4.1 'Groundwater-dependent ecosystem' class

Water-dependent assets classified as groundwater-dependent ecosystems (GDEs) include areas identified from previous studies, or classified as having high or medium potential for groundwater interaction in the *National atlas of groundwater dependent ecosystems* (GDE atlas) (Bureau of Meteorology, 2012; Bioregional Assessment Programme, Dataset 4). The asset register also includes all of the GDE areas, lines and points identified in the Queensland Government GDE mapping (DSITIA, 2012). GDEs are classified as either subsurface GDEs (those that rely on the subsurface presence of groundwater) or surface GDEs (those that rely on the surface expression of groundwater). Subsurface and terrestrial GDEs include vegetation communities that interact with a groundwater system beneath the surface. Surface GDEs include vegetation communities that are associated with groundwater discharged to the surface as springs or baseflow such as vegetation in fringing waterways or wetlands. Watercourse GDEs are lines or stream segments identified as groundwater dependent in the Queensland Government GDE mapping (DSITIA, 2012).

The source aquifer for all water-dependent assets in the 'Groundwater-dependent ecosystem' class is assumed to be the regional watertable. The zone of potential hydrological change includes 33 water-dependent assets in the 'Groundwater-dependent ecosystem' class (Bioregional Assessment Programme, 2017). This includes:

- 17 GDE assets sourced from the GDE atlas, comprising
  - 6 surface GDEs that cover 233 km^2
  - 11 subsurface GDEs that cover 362 km^2
- 16 assets sourced from the Queensland Government GDE mapping, comprising
  - 9 terrestrial GDEs that cover 88 km^2
  - 4 surface GDEs that cover 2 km^2
  - 3 watercourse GDEs that cover 399 km.

The extent of GDEs where the median (50th percentile) estimate of drawdown due to additional coal resource development exceeds 0.2 m in the regional watertable includes 196 km^2 of GDEs and 11 km of groundwater-dependent streams. Median drawdown for GDE areas is predominantly less than 5 m due to additional coal resource development, with the exception of 18 km^2 in the immediate vicinity of the operational areas, and less than 5 m under the baseline, with the exception of 4 km^2 to the south-west of The Range coal mine (Table 26 and Table 27).

Median drawdown for watercourse GDEs is predominantly less than 2 m, including 6 km of streams under the baseline, with 5 km of streams potentially affected by additional coal resource development in the zone of potential hydrological change (Table 26 and Table 27). Watercourse GDEs affected by additional drawdown are predicted to experience less than 1 m of drawdown in the regional watertable under the baseline (Figure 39).

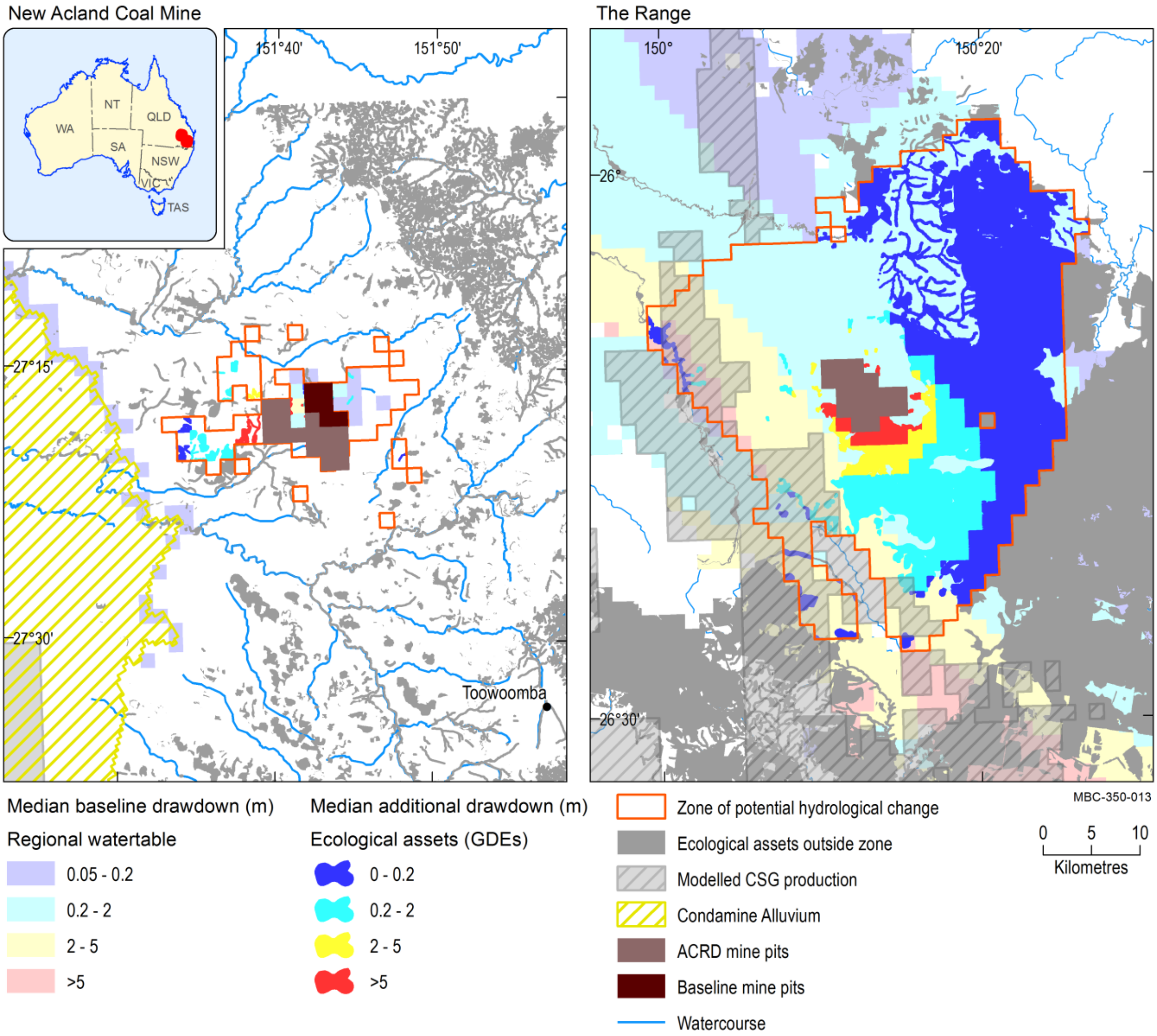

Figure 38 Median baseline drawdown and additional drawdown for ecological assets in the 'Groundwater-dependent ecosystem' class in the zone of potential hydrological change in the vicinity of New Acland Coal Mine and The Range coal mine

Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. The mine pits in the CRDP are the sum of those in the baseline and the additional coal resource development. Areas within modelled open-cut mine pits (Table 4) are not included in this analysis.
ACRD = additional coal resource development, CSG = seam coal gas, GDE = groundwater-dependent ecosystem
Data: Bioregional Assessment Programme (Dataset 2, Dataset 4, Dataset 5, Dataset 6, Dataset 7, Dataset 8)

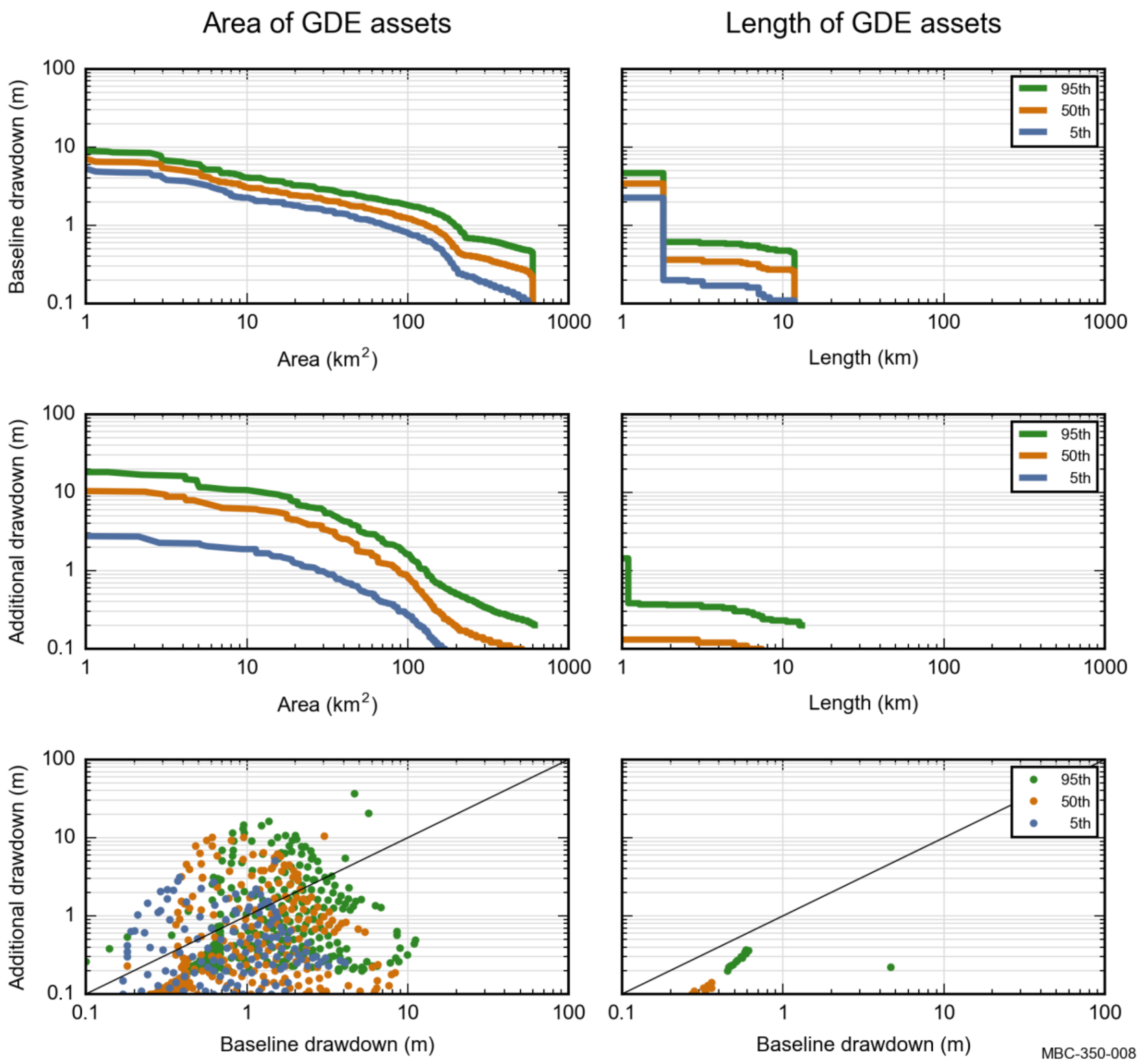

Figure 39 For ecological assets in the 'Groundwater-dependent ecosystem' class in the zone of potential hydrological change: the top two plots show area (km^2) and length (km) of assets that exceed the 5th, 50th and 95th percentile estimates of baseline drawdown and additional drawdown, and the bottom row shows baseline drawdown compared to additional drawdown for each assessment unit occupied by assets

Colours represent the 5th, 50th and 95th percentile. Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. Areas within modelled open-cut mine pits (Table 4) are not included in this analysis. GDE = groundwater-dependent ecosystem
Data: Bioregional Assessment Programme (Dataset 3)

Table 26 Number and extent of ecological water-dependent assets in the 'Vegetation' subgroup that exceed the 5th, 50th and 95th percentile estimates of baseline drawdown (m) in the zone of potential hydrological change

Asset class	Length or area	Assets in assessment extent		Assets in zone of potential hydrological change		Extent[bc] of assets with baseline drawdown ≥0.2 m			Extent[bc] of assets with baseline drawdown ≥2 m			Extent[bc] of assets with baseline drawdown ≥5 m		
		Number[a]	Length or area	Number[a]	Length or area[b]	5th	50th	95th	5th	50th	95th	5th	50th	95th
Groundwater-dependent ecosystem	Area (km^2)	*290*	33,051	*30*	613	275	597	597	13.5	37.5	74.4	0.9	4.0	6.7
Groundwater-dependent ecosystem	Length (km)	*23*	25,038	*3*	398	25.1	370	379	5.5	5.5	6.0	0	0	1.7
Habitat (potential species distribution)	Area (km^2)	*171*	886,076	*39*	1545	869	1419	1442	236	373	476	9.0	42.7	106
Riparian vegetation	Area (km^2)	*20*	7,651	*2*	17.2	14.8	17.2	17.2	3.5	6.2	7.9	0	0.2	1.1

[a]Numbers in table are italicised, to distinguish from areas. Numbers within the whole zone are included in this analysis.
[b]Lengths or areas within modelled open-cut mine pits (Table 4) are not included in this analysis.
[c]Extent could be length or area.
The extent potentially exposed to ≥0.2, ≥2 and ≥5 m baseline drawdown is shown for the 5th, 50th and 95th percentile estimates of the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Areas and lengths within modelled open-cut mine pits are not included in this analysis. The zone of potential hydrological change is defined as the area with a greater than 5% chance of exceeding 0.2 m drawdown due to additional coal resource development.
Data: Bioregional Assessment Programme (Dataset 3)

Table 27 Number and extent of ecological water-dependent assets in the 'Vegetation' subgroup that exceed the 5th, 50th and 95th percentile estimates of additional drawdown (m) in the zone of potential hydrological change

Asset class	Length or area	Assets in assessment extent		Assets in zone of potential hydrological change		Extent[bc] of assets with additional drawdown ≥0.2 m			Extent[bc] of assets with additional drawdown ≥2 m			Extent[bc] of assets with additional drawdown ≥5 m		
		Number[a]	Length or area	Number[a]	Length or area[b]	5th	50th	95th	5th	50th	95th	5th	50th	95th
Groundwater-dependent ecosystem	Area (km^2)	*290*	33,051	*30*	613	116	196	613	5.7	48.2	86.6	0.1	17.7	34.5
Groundwater-dependent ecosystem	Length (km)	*23*	25,038	*3*	398	0	11.4	398	0	5.5	7.9	0	5.3	7.4
Habitat (potential species distribution)	Area (km^2)	*171*	886,076	*39*	1545	384	618	1545	24.7	144	272	2.2	49.4	110
Riparian vegetation	Area (km^2)	*20*	7,651	*2*	17.2	4.3	8.3	17.2	0.2	1.1	2.5	0	0.3	0.8

[a]Numbers in table are italicised, to distinguish from areas. Numbers within the whole zone are included in this analysis.
[b]Lengths or areas within modelled open-cut mine pits (Table 4) are not included in this analysis.
[c]Extent could be length or area.
The extent potentially exposed to ≥0.2, ≥2 and ≥5 m additional drawdown is shown for the 5th, 50th and 95th percentile estimates of the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. Areas and lengths within modelled open-cut mine pits (Table 4) are not included in this analysis.
The zone of potential hydrological change is defined as the area with a greater than 5% chance of exceeding 0.2 m drawdown due to additional coal resource development.
Data: Bioregional Assessment Programme (Dataset 3)

3.5.2.4.2 'Habitat (potential species distribution)'and 'Riparian vegetation' classes

The water-dependent asset register for the Maranoa-Balonne-Condamine subregion includes 171 habitat (potential species distribution) assets and 20 riparian vegetation assets (Bioregional Assessment Programme, Dataset 2; Bioregional Assessment Programme, 2017), including:

- 118 threatened ecological communities, species or regional ecosystems, comprising
  - 8 threatened ecological communities and 52 species listed under the EPBC Act
  - 31 threatened species and 27 endangered regional ecosystems listed under the Nature Conservation Act
- 53 protected reserves, parks and bird habitats, comprising
  - 40 reserves and parks listed in the Collaborative Australian Protected Area Database (CAPAD)
  - 10 protected reserves, parks or habitats nominated by the community
  - 3 bird habitats identified as Important Bird Areas (Birdlife Australia, 2014)
- 20 riparian vegetation assets, comprising
  - 20 water-dependent assets identified by the community in the Water Assessment Information Tool database (WAIT) or listed in the Murray–Darling Basin Authority Key Environmental Asset (KEA) datasets.

The asset under consideration is the habitat of the species, community or ecosystem rather than the species, community or ecosystem per se, hence these assets are listed under the 'Vegetation' subgroup. Habitats were considered water dependent if there was evidence for a dependency or an association with alluvial and soakage areas, drainage lines, floodplain or riparian vegetation communities, wetlands and/or permanent open water or mound springs. The decision not to include species in the asset register was based on evidence from species profiles and other published material that show that these habitats are almost entirely restricted to grassland, woodland, dry scrub, open forest, heathlands or rainforest vegetation communities or rocky outcrops.

The zone of potential hydrological change includes 41 water-dependent assets in the 'Habitat (potential species distribution)' or 'Riparian vegetation' classes (Bioregional Assessment Programme, Dataset 3; Bioregional Assessment Programme, 2017). This includes:

- 39 threatened ecological communities, species or regional ecosystems, comprising
  - 4 threatened ecological communities and 18 species listed under the EPBC Act
  - 11 threatened species and 6 endangered regional ecosystems listed under the Nature Conservation Act
- 2 riparian vegetation assets identified by the community in WAIT that cover 17 km^2.

No protected reserves, parks, bird habitats or key environmental assets are in the zone of potential hydrological change.

The extent of habitat areas where the median (50th percentile) estimate of drawdown due to additional coal resource development exceeds 0.2 m in the regional watertable covers 618 km^2.

Median drawdown for habitat areas is predominantly less than 5 m, with the exception of 49 km^2 potentially affected by additional coal resource development in the immediate vicinity of the operational areas, and 43 km^2 to the south-west of The Range coal mine potentially affected by baseline coal resource development (Figure 41).

Median drawdown for riparian vegetation is predominantly less than 2 m, including 6 km^2 under the baseline and 1 km^2 potentially affected by additional coal resource development in the zone of potential hydrological change (Table 26 and Table 27).

The nature of water dependency of the 39 threatened ecological communities, species or regional ecosystems in the zone of potential hydrological change is described in Table 28. The potential distribution of three threatened species – fork-tailed swift (*Apus pacificus*), great egret (*Ardea alba*) and red goshawk (*Erythrotriorchis radiatus*) – covers the entire zone of potential hydrological change.

The potential distribution of a further six threatened species covers large parts of the zone of potential hydrological change, including the star finch (eastern) (*Neochmia ruficauda ruficauda*) (91%), painted honeyeater (*Grantiella picta*) (65%), brigalow scaly-foot (*Paradelma orientalis*) (48%), southern squatter pigeon (*Geophaps scripta scripta*) (42%), large-eared pied bat (*Chalinolobus dwyeri*) (35%) and satin flycatcher (*Myiagara cyanoleuca*) (17%). The potential distribution of the remaining habitat areas covers less than 10% of the zone of potential hydrological change (Table 29 and Table 30).

The potential distribution of the 'Natural grasslands on basalt and fine-textured alluvial plains of northern New South Wales and southern Queensland Threatened Ecological Community' covers 9% of the zone of potential hydrological change in the vicinity of New Acland Coal Mine (Figure 40).

Several assessment units are predicted to experience drawdown in excess of 2 m under the baseline and due to additional coal resource development (Figure 41). These assessment units are located in the immediate vicinity of the operational areas and contain parts of these widely distributed habitat areas (Figure 40).

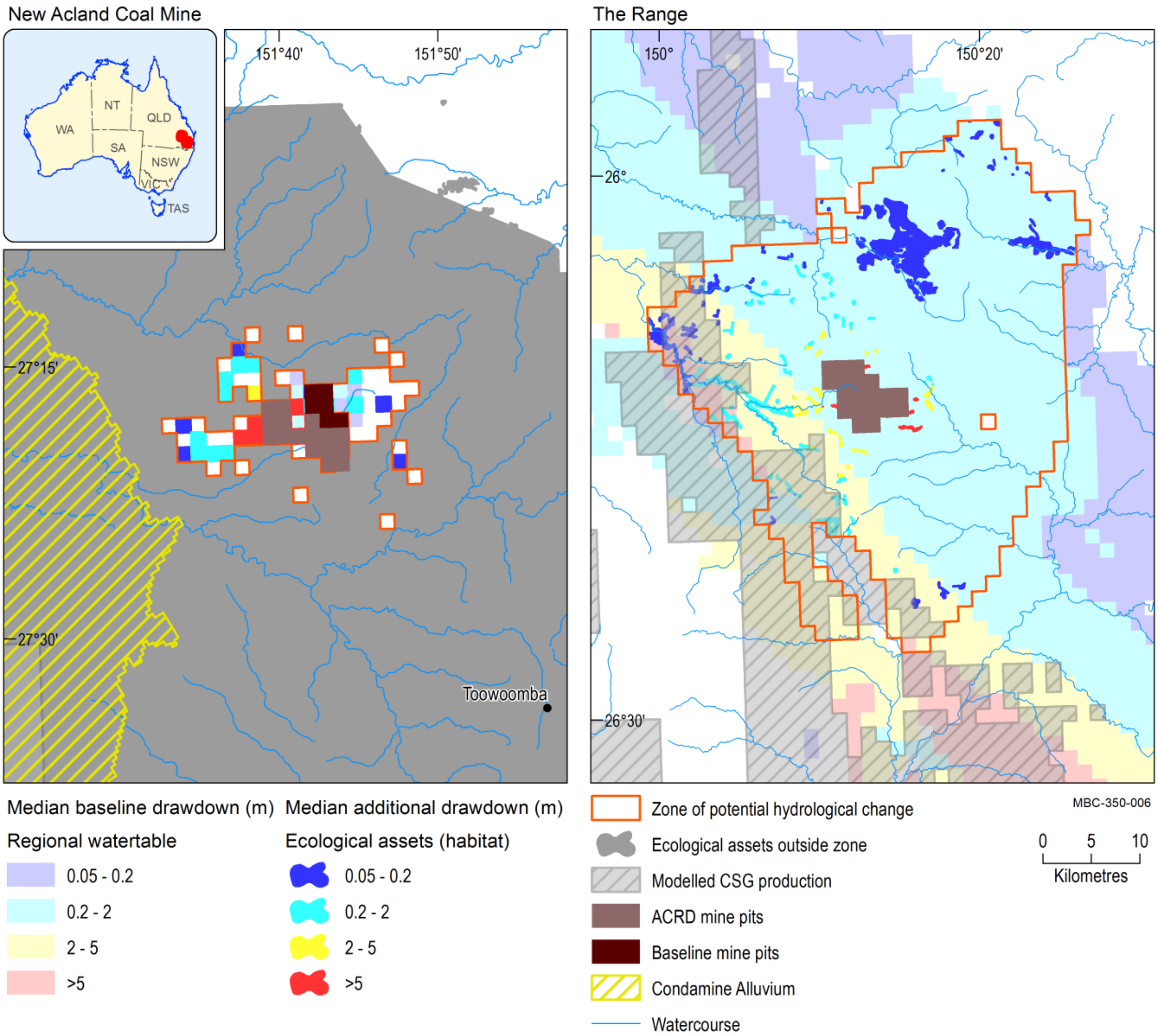

Figure 40 Median baseline drawdown and additional drawdown for threatened ecological communities listed under the Commonwealth's *Environment Protection and Biodiversity Act 1999* in the zone of potential hydrological change in the vicinity of New Acland Coal Mine and The Range coal mine

Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. The mine pits in the CRDP are the sum of those in the baseline and the additional coal resource development. Areas within modelled open-cut mine pits (Table 4) are not included in this analysis.
ACRD = additional coal resource development, CSG = coal seam gas
Data: Bioregional Assessment Programme (Dataset 2, Dataset 4, Dataset 5, Dataset 6, Dataset 7, Dataset 8)

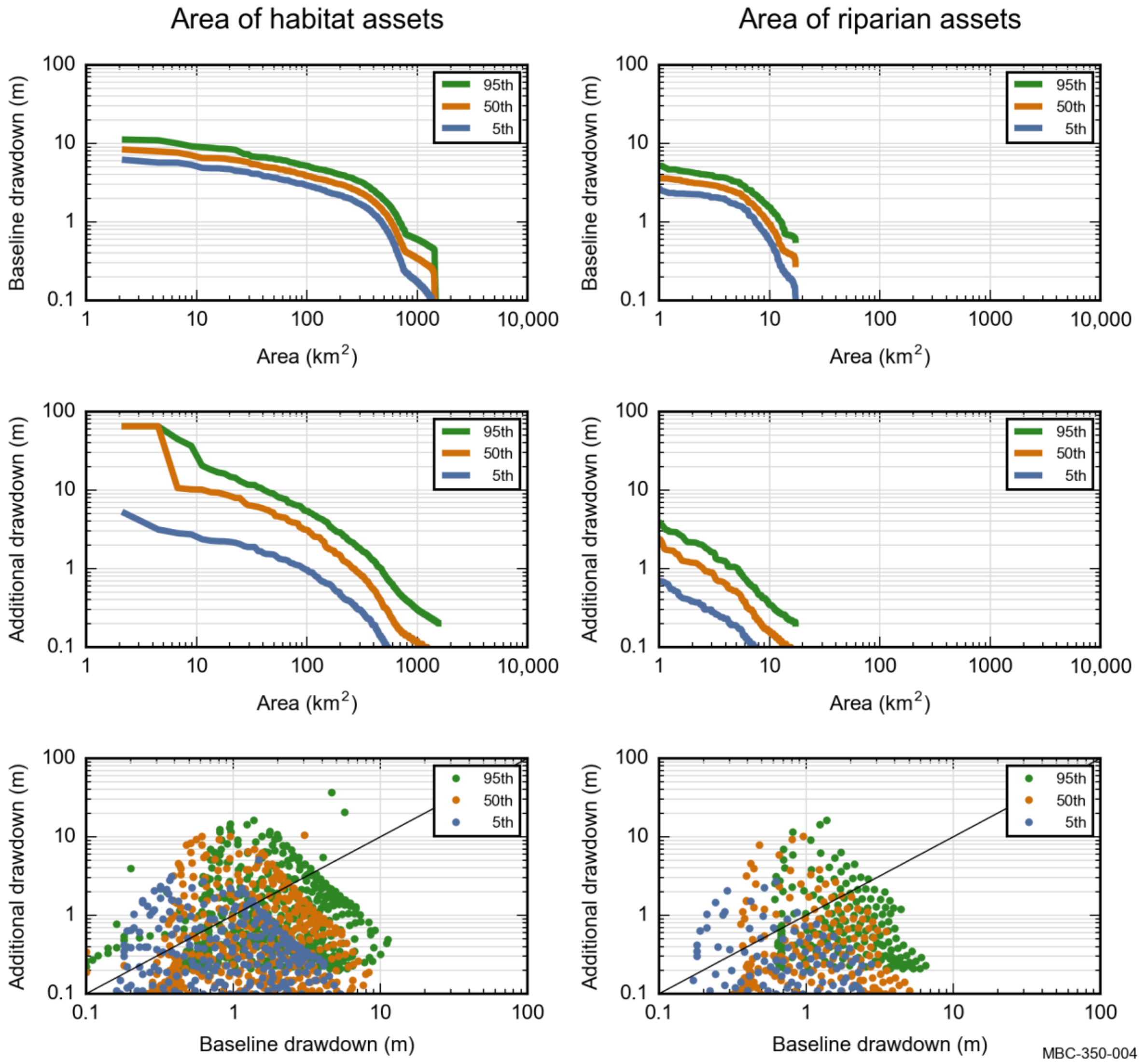

Figure 41 For ecological assets in the ‘Habitat (potential species distribution)’ and ‘Riparian vegetation’ classes in the zone of potential hydrological change: the top two rows show area (km^2) of habitat and riparian assets that exceed the 5th, 50th and 95th percentile estimates of baseline drawdown and additional drawdown, and the bottom row shows baseline drawdown compared to additional drawdown for each assessment unit occupied by assets

Colours represent the 5th, 50th and 95th percentile. Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. Areas within modelled open-cut mine pits (Table 4) are not included in this analysis.
Data: Bioregional Assessment Programme (Dataset 3)

Table 28 'Habitat (potential species distribution)' class: nature of water dependency in the class for those assets listed under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* or Queensland's *Nature Conservation Act 1992* in the zone of potential hydrological change

Asset name[a]	Legislation	Status	Nature of water dependency
Brigalow (Acacia harpophylla dominant and co-dominant)	EPBC Act	Threatened ecological community	Brigalow demonstrates water dependency, associated with alluvial aquifers (river and creek flats) and sandstone outcrops. Changes in watertable depth and/or groundwater regime could reduce water availability in this community (intersecting with 'Floodplain remnant vegetation' and 'Non-floodplain, GAB GDE' landscape classes) and diminish vegetation health.
Natural grasslands on basalt and fine-textured alluvial plains	EPBC Act	Critically endangered threatened ecological community	Potential habitat distribution of this community intersects with alluvium (river and creek flats). Changes in watertable depth and/or groundwater regime across this habitat is unlikely to have severe impacts on this community given the relatively shallow rooting depth and unlikely reliance on groundwater.
Semi-evergreen vine thickets	EPBC Act	Endangered threatened ecological community	This community is associated with permeable rock and basalt land forms and changes in watertable depth and/or groundwater regime in and around localised discharge sites ('Non-floodplain, non-GAB GDE' landscape class) could impact on vegetation health.
Weeping Myall Woodlands	EPBC Act	Endangered threatened ecological community	Community demonstrates water dependency, associated with alluvium (river and creek flats) and cracking clay soils. Changes in watertable depth and/or groundwater regime on floodplain aquifers ('Floodplain remnant vegetation' landscape class) could affect vegetation health.
Belson's Panic (Homopholis belsonii)	EPBC Act	Vulnerable threatened species	Belson's Panic is known to occur on sites that receive irregular or intermittent flooding, as well as sites on more elevated and well-drained soils. Changes in associated community structure from drawdown might affect this habitat.
Black-faced Monarch (Monarcha melanopsis)	EPBC Act	Endangered Marine; Migratory threatened species	Black-faced Monarch occurs in rainforest ecosystems, including semi-deciduous vine-thickets and complex notophyll vine-forest that may be associated with landscape classes such as 'Non-floodplain, non-GAB GDE'. Groundwater drawdown within these unique habitats could potentially impact this species.
Blotched Sarcochilus (Sarcochilus weinthalii)	EPBC Act	Vulnerable threatened species	Blotched Sarcochilus is an orchid that grows on the upper branches of rainforest trees. It occurs in dry rainforest, inland from the coast and may be occur across remnant vegetation within the 'Non-floodplain, non-GAB GDE' landscape class. Changes to watertable depth may alter ecosystem health in these habitats.
Cattle Egret (Ardea ibis)	EPBC Act	Marine; Migratory threatened species	Cattle Egret habitat includes wetlands such as off channel water bodies or 'Floodplain, temporary wetland' landscape class, for roosting, breeding and feeding. Hydrological changes to this species' habitat could affect wetland water regime by flooding or groundwater connectivity.

Asset name[a]	Legislation	Status	Nature of water dependency
Dunmall's Snake (Furina dunmalli)	EPBC Act	Vulnerable threatened species	The nature of the water dependency and ecological requirements of Dunmall's Snake are poorly known. The species is associated with forests and woodlands on alluvial cracking clays throughout the Brigalow Belt. Drawdown could impact habitat if the associated groundwater-dependent vegetation loses contact with watertable.
Finger Panic Grass (Digitaria porrecta)	EPBC Act	Restricted threatened species	Finger Panic Grass sometimes occurs on alluvial flats supporting woodlands dominated by poplar box or forest red gum (e.g. 'Floodplain remnant vegetation' landscape class). These alluvial flats receive intermittent and irregular flooding from adjacent riverine water bodies. Changes in associated community structure from drawdown might affect this habitat.
Five-clawed Worm-skink (Anomalopus mackayi)	EPBC Act	Vulnerable threatened species	Five-clawed Worm-skink habitat is associated with floodplain landscapes including woodlands dominated by *E.coolibah* (coolabah) and *E. largiflorens* (blackbox) trees (intersecting the 'Floodplain remnant vegetation' landscape class). Drawdown could impact habitat if the associated riparian groundwater-dependent vegetation loses contact with watertable.
Fork-tailed Swift (Apus pacificus)	EPBC Act	Marine; Migratory threatened species	Fork-tailed Swift habitat can include alluvial river and creek flats as well as upland sites. Drawdown could affect habitat if the associated groundwater-dependent vegetation loses contact with watertable.
Great Egret (Ardea alba)	EPBC Act	Marine; Migratory threatened species	Great Egret habitat includes wetlands such as off channel water bodies or 'Temporary, floodplain wetland' landscape class, for roosting, breeding and feeding. Impacts on this habitat is likely to result if drawdown affects wetland water regime via flooding or groundwater connectivity.
Grey-headed Flying-fox (Numbereropus poliocephalus)	EPBC Act	Vulnerable threatened species	Grey-headed Flying-fox use a broad range of vegetation types for roosting, including rainforests, open forests, closed and open woodlands, *Melaleuca* swamps and *Banksia* woodlands. Drawdown could impact habitat if the associated groundwater-dependent vegetation loses contact with watertable.
Koala (Phascolarctos cinereus (combined populations of Queensland, NSW and the ACT))	EPBC Act	Vulnerable threatened species	Koala occur in *Eucalyptus* dominated woodlands in riparian and non-riparian habitat. Species such as *E. tereticornis* are known to be preferred food trees for koala. Drawdown could impact habitat if the associated riparian groundwater-dependent vegetation loses contact with watertable or changes in flooding from adjacent riverine water body.
Red Goshawk (Erythrotriorchis radiatus)	EPBC Act	Vulnerable threatened species	Red Goshawk prefers forests and woodlands with a mosaic of forest types and permanent water. Riparian woodlands are often utilised. Red Goshawk nest in tall trees within 1 km of permanent water bodies. Impacts on this habitat is likely to result if drawdown affects riverine water regime via changes to flooding or groundwater connectivity.

Asset name[a]	Legislation	Status	Nature of water dependency
Satin Flycatcher (Myiagra cyanoleuca)	EPBC Act	Marine; Migratory threatened species	Satin Flycatchers inhabit riparian channels heavily vegetated by eucalypt-dominated forests and taller woodlands. Drawdown could impact habitat if the associated groundwater-dependent vegetation loses contact with watertable.
Squatter Pigeon (southern) (Geophaps scripta scripta)	EPBC Act	Vulnerable threatened species	Squatter Pigeon (southern) occupy habitats in open-forests and woodlands dominated by remnant, regrowth or partly modified *Eucalyptus*, *Corymbia*, *Acacia* or *Callitris* vegetation communities. These habitats are generally within 3 km of water bodies. Drawdown affecting a range of surface water habitats could potentially restrict this species' habitat availability.
Star Finch (eastern) (Neochmia ruficauda ruficauda)	EPBC Act	Endangered threatened species	Star Finch occurs mainly in grassy woodlands dominated by *Eucalyptus*, *Corymbia* and *Melaleuca*, often along watercourses, near permanent water or in areas that are frequently inundated. The species are often associated with *E. coolabah*, *E. camaldulensis*, *E. brownii* and *E. tereticornis*, all of which are extensively distributed in the floodplain landscape group.
Stream Clematis (Clematis fawcettii)	EPBC Act	Vulnerable threatened species	Stream Clematis occurs most commonly in the canopy gaps of drier rainforests near streams. Changes in associated community structure from drawdown might affect this habitat.
White-bellied Sea-Eagle (Haliaeetus leucogaster)	EPBC Act	Marine; Migratory threatened species	White-bellied Sea-Eagle inhabits large areas of open water (larger rivers, swamps, lakes, the sea) including 'Temporary lowland streams' and 'Floodplain temporary wetland' landscape classes. Drawdown could affect wetland/riverine water regime via flooding or groundwater connectivity.
Yakka Skink (Egernia rugosa)	EPBC Act	Vulnerable threatened species	Yakka Skink occurs in rocky outcrops and sand plain areas with dense ground vegetation, and is often associated with partly buried rocks, logs tree stumps and animal burrows. Drawdown that affects canopy density of groundwater-dependent vegetation may affect this species' habitat.
Acacia harpophylla and/or Casuarina cristata open forest on fine-grained sedimentary rocks	Nature Conservation Act	Endangered regional ecosystem	Community demonstrates water dependency, associated with alluvial aquifers (river and creek flats) and sandstone outcrops. Changes in watertable depth and/or groundwater regime could reduce water availability in this community (intersecting with 'Floodplain remnant vegetation' and 'Non-floodplain GAB GDE' landscape classes) and diminish vegetation health.
Acacia harpophylla and/or Casuarina cristata shrubby open forest on Cainozoic clay plains	Nature Conservation Act	Endangered regional ecosystem	Community demonstrates water dependency, associated with alluvial aquifers (river and creek flats) and sandstone outcrops. Changes in watertable depth and/or groundwater regime could reduce water availability in this community (intersecting with 'Floodplain remnant vegetation' and 'Non-floodplain GAB GDE' landscape classes) and diminish vegetation health.
Dichanthium sericeum and/or Astrebla spp. grassland on alluvial plains with cracking clay soils	Nature Conservation Act	Endangered regional ecosystem	Potential habitat distribution of this community intersects with alluvium (river and creek flats). Changes in watertable depth and/or groundwater regime across this habitat is unlikely to have severe impacts on this community given the relatively shallow rooting depth and unlikely reliance on groundwater.

Asset name[a]	Legislation	Status	Nature of water dependency
Eucalyptus brownii or Eucalyptus populnea woodland on Cainozoic igneous rocks	Nature Conservation Act	Endangered regional ecosystem	Community is associated with permeable rock and basalt land forms. Changes to watertable depth and/or groundwater regime in and around localised groundwater discharge sites (‘Non-floodplain non-GAB GDE’ landscape class) could impact affect vegetation health.
Eucalyptus populnea woodland with Acacia harpophylla and/or Casuarina cristata on alluvial plains	Nature Conservation Act	Endangered regional ecosystem	Community demonstrates water dependency, associated with alluvial aquifers (river and creek flats) and sandstone outcrops. Changes in watertable depth and/or groundwater regime could reduce water availability in this community (intersecting with ‘Floodplain remnant vegetation’ and ‘Non-floodplain non-GAB GDE’ landscape classes) and diminish vegetation health.
Eucalyptus populnea, Acacia harpophylla open forest on fine-grained sedimentary rocks	Nature Conservation Act	Endangered regional ecosystem	Community demonstrates water dependency, associated with sandstone outcrops. Changes in watertable depth and/or groundwater regime could reduce water availability in this community (intersecting with ‘Non-floodplain GAB GDE’ landscape class) and diminish vegetation health.
Adelotus brevis	Nature Conservation Act	Vulnerable threatened species	Tusked Frog inhabits sites associated with riparian vegetation including rainforests, wet forests and flooded grassland and pasture. These habitats are usually found near creeks, ditches and ponds. Drawdown could impact habitat if the associated riparian groundwater-dependent vegetation loses contact with watertable.
Chalinolobus dwyeri	Nature Conservation Act	Vulnerable threatened species	Large-eared Pied Bat roosts and forages in a variety of different habitats across the landscape including; box gum woodlands, river/rainforest corridors as well as sandstone cliffs and escarpments. Drawdown could impact habitat if the associated groundwater-dependent vegetation loses contact with watertable.
Dasyurus maculatus maculatus	Nature Conservation Act	Vulnerable threatened species	Spot-tailed Quoll has a preference for forest habitats at wetter sites including; riparian forests (including *E. camaldulensis*), lowland forests and eucalypt woodlands. These vegetation types typically intersect with ‘Floodplain non-GAB GDE’ and ‘Non-floodplain non-GAB GDE’ landscape classes. Drawdown could impact habitat if the associated riparian groundwater-dependent vegetation loses contact with watertable.
Grantiella picta	Nature Conservation Act	Vulnerable threatened species	Painted Honeyeater is most commonly found in dry forests and woodlands, particularly those dominated by *Acacia* or eucalypt species. Drawdown could impact habitat if the associated groundwater-dependent vegetation loses contact with watertable.
Haloragis exalata subsp velutina	Nature Conservation Act	Vulnerable threatened species	Tall Velvet Sea-berry occupies a range of habitats spanning rainforests, sclerophyll forests and grasslands. Associated tree species include *Eucalyptus tereticornis*, *Angophora subvelutina* and *Acacia irrorata* that occur on basaltic soils. Drawdown in the 'Non-floodplain or upland riverine (including non-GAB GDEs)' landscape group could affect water availability of this species.

Asset name[a]	Legislation	Status	Nature of water dependency
Hemiaspis damelii	Nature Conservation Act	Endangered threatened species	Grey Snake prefers woodlands on heavier, cracking clay soils, adjacent or near wetlands and stream channels and ditches. This habitat would include 'Floodplain remnant vegetation' and 'Floodplain GAB GDE' landscape classes. It shelters under rocks, logs and other debris as well as in soil cracks. Drawdown could affect wetland/riverine water regime via flooding or groundwater connectivity.
Paradelma orientalis	Nature Conservation Act	Least concern threatened species	Brigalow Scaly-foot occurs in a wide variety of remnant and non-remnant open forest to woodland habitats, including the Brigalow (dominant and co-dominant) ecological community. It occurs in a range of land forms with variable surface or groundwater dependencies, including alluvial ('Floodplain or lowland riverine') and sandstone ranges ('GAB GDEs'). Changes to watertable depth could reduce water availability in these habitats and diminish vegetation health.
Phascolarctos cinereus	Nature Conservation Act	Not listed threatened species	Koala habitat includes riverine riparian forests including 'Floodplain non-GAB GDEs' dominated by *E. camaldulensis.* Drawdown could impact habitat if the associated riparian groundwater-dependent vegetation loses contact with watertable.
Picris barbarorum	Nature Conservation Act	Vulnerable threatened species	Small erect herb with little published information on preferred habitat. Most likely is associated with grassland like other members of this genus.
Samadera bidwillii	Nature Conservation Act	Vulnerable threatened species	Quassia is a small shrub that commonly occurs in lowland rainforest or on rainforest margins, but can also be found in other forest types, such as open forest and woodland. It is commonly found in areas adjacent to both temporary and permanent watercourses.
Tympanocrynumberis cf tetraporophora	Nature Conservation Act	Endangered threatened species	Condamine Earless Dragon is associated with natural grasslands and highly modified cropping environments in the Condamine River floodplain ('Floodplain remnant vegetation' landscape class). It shelters in rocky outcrops and cracks in the clay rich soils in the alluvial zone. Drawdown could impact habitat if the associated groundwater-dependent vegetation loses contact with watertable.

[a]Punctuation and typography appear as used in the asset database.
Data: Bioregional Assessment Programme (Dataset 3)

Table 29 'Habitat (potential species distribution)' class: area (km²) of assets listed under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* or Queensland's *Nature Conservation Act 1992* that exceed the 5th, 50th and 95th percentile estimates of baseline drawdown in the zone of potential hydrological change

Asset name[a]	Area in assessment extent	Area in zone of potential hydrological change (excluding modelled open-cut mine pits)	Area[b] with baseline drawdown ≥0.2 m			Area[b] with baseline drawdown ≥2 m			Area[b] with baseline drawdown ≥5 m		
			5th	50th	95th	5th	50th	95th	5th	50th	95th
Brigalow (Acacia harpophylla dominant and co-dominant)	1,972	16.2	11.9	15.5	15.9	5.6	7.5	8.8	0	0.8	1.6
Natural grasslands on basalt and fine-textured alluvial plains	16,147	134	2.2	9.0	31.4	0	2.2	9.0	0	0	2.2
Semi-evergreen vine thickets	534	2.3	0	1.7	1.7	0	0	0	0	0	0
Weeping Myall Woodlands	3,212	40.8	10.2	40.5	40.5	7.3	7.8	8.5	0.8	3.4	5.9
Belson's Panic (Homopholis belsonii)	192	44.8	0	2.2	20.2	0	0	2.2	0	0	0
Black-faced Monarch (Monarcha melanopsis)	11,173	133	2.2	9.0	31.4	0	2.2	9.0	0	0	2.2
Blotched Sarcochilus (Sarcochilus weinthalii)	1,457	21.0	0	0	1.1	0	0	0	0	0	0
Cattle Egret (Ardea ibis)	63,183	134	2.2	9.0	31.4	0	2.2	9.0	0	0	2.2
Dunmall's Snake (Furina dunmalli)	3,395	104	28.1	103	103	0	0	0	0	0	0
Finger Panic Grass (Digitaria porrecta)	12,520	81.3	2.2	10.1	14.6	0	2.2	6.7	0	0	2.2
Five-clawed Worm-skink (Anomalopus mackayi)	7,221	90.1	2.2	6.7	12.5	0	2.2	6.7	0	0	2.2
Fork-tailed Swift (Apus pacificus)	129,763	1,545	869	1419	1442	236	373	476	9.0	42.7	106
Great Egret (Ardea alba)	129,763	1,545	869	1419	1442	236	373	476	9.0	42.7	106
Grey-headed Flying-fox (Numbereropus poliocephalus)	8,999	134	2.2	9.0	31.4	0	2.2	9.0	0	0	2.2
Koala (Phascolarctos cinereus (combined populations of Queensland, NSW and the ACT))	33,233	145	2.2	19.4	41.8	0	2.2	9.0	0	0	2.2
Red Goshawk (Erythrotriorchis radiatus)	49,364	1,545	869	1419	1442	236	373	476	9.0	42.7	106

Asset name[a]	Area in assessment extent	Area in zone of potential hydrological change (excluding modelled open-cut mine pits)	Area[b] with baseline drawdown ≥0.2 m			Area[b] with baseline drawdown ≥2 m			Area[b] with baseline drawdown ≥5 m		
			5th	50th	95th	5th	50th	95th	5th	50th	95th
Satin Flycatcher (Myiagra cyanoleuca)	26,030	262	129	136	159	66.7	116	132	0	0	12.6
Squatter Pigeon (southern) (Geophaps scripta scripta)	42,989	653	268	612	624	123	162	184	9.0	39.5	74.9
Star Finch (eastern) (Neochmia ruficauda ruficauda)	93,710	1,411	867	1410	1410	236	371	467	9.0	42.7	103
Stream Clematis (Clematis fawcettii)	3,356	0.5	0	0	0	0	0	0	0	0	0
White-bellied Sea-Eagle (Haliaeetus leucogaster)	17,952	20.0	0	1.2	4.0	0	0	1.2	0	0	0
Yakka Skink (Egernia rugosa)	8,096	52.0	52.0	52.0	52.0	45.4	51.0	52.0	0	2.3	18.0
Acacia harpophylla and/or Casuarina cristata open forest on fine-grained sedimentary rocks	700	15.5	11.1	15.1	15.3	5.3	6.9	8.1	0	0.8	1.6
Acacia harpophylla and/or Casuarina cristata shrubby open forest on Cainozoic clay plains	766	0.04	0	0	0	0	0	0	0	0	0
Dichanthium sericeum and/or Astrebla spp. grassland on alluvial plains. Cracking clay soils	54.0	0.1	0	0	0	0	0	0	0	0	0
Eucalyptus brownii or Eucalyptus populnea woodland on Cainozoic igneous rocks	9.7	0.1	0	0	0	0	0	0	0	0	0
Eucalyptus populnea woodland with Acacia harpophylla and/or Casuarina cristata on alluvial plains	117	0.1	0	0	0	0	0	0	0	0	0
Eucalyptus populnea, Acacia harpophylla open forest on fine-grained sedimentary rocks	267	1.0	0.2	1.0	1.0	0.2	0.2	0.2	0.1	0.2	0.2
Adelotus brevis	270	0.2	0	0.2	0.2	0	0	0	0	0	0
Chalinolobus dwyeri	10,108	543	278	530	532	42.3	83.8	111	0	1.7	11.5

Asset name[a]	Area in assessment extent	Area in zone of potential hydrological change (excluding modelled open-cut mine pits)	Area[b] with baseline drawdown ≥0.2 m			Area[b] with baseline drawdown ≥2 m			Area[b] with baseline drawdown ≥5 m		
			5th	50th	95th	5th	50th	95th	5th	50th	95th
Dasyurus maculatus maculatus	2,780	2.3	0	0.1	0.5	0	0	0.1	0	0	0
Grantiella picta	85,952	1003	596	890	913	180	268	337	9.0	37.0	84.6
Haloragis exalata subsp velutina	4,194	7.5	0	0.6	3.4	0	0	0.6	0	0	0
Hemiaspis damelii	23,187	25.3	0.6	3.8	6.3	0.3	0.6	1.3	0	0	0.4
Paradelma orientalis	47,079	738	359	701	712	43.6	94.3	160	0.2	3.2	17.1
Phascolarctos cinereus	2,643	17.0	3.4	8.0	9.7	0	0.3	3.8	0	0	0.3
Picris barbarorum	11,175	37.3	0.9	8.4	17.8	0.3	0.6	2.0	0	0	0.3
Samadera bidwillii	32.0	0.1	0	0	0	0	0	0	0	0	0
Tympanocrynumberis cf tetraporophora	970	0.7	0	0	0	0	0	0	0	0	0

[a]Punctuation and typography appear as used in the asset database.
[b]Areas exclude the modelled open-cut mine pits.
The extent potentially exposed to ≥0.2, ≥2 and ≥5 m baseline drawdown is shown for the 5th, 50th and 95th percentile estimates of the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Areas within modelled open-cut mine pits (Table 4) are not included in this analysis. The zone of potential hydrological change is defined as the area with a greater than 5% chance of exceeding 0.2 m drawdown due to additional coal resource development.
Data: Bioregional Assessment Programme (Dataset 3)

Table 30 'Habitat (potential species distribution)' class: area (km^2) of assets listed under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* or Queensland's *Nature Conservation Act 1992* that exceed the 5th, 50th and 95th percentile estimates of additional drawdown in the zone of potential hydrological change

Asset name[a]	Area in assessment extent	Area in zone of potential hydrological change (excluding modelled open-cut mine pits)	Area[b] with additional drawdown ≥0.2 m			Area[b] with additional drawdown ≥2 m			Area[b] with additional drawdown ≥5 m		
			5th	50th	95th	5th	50th	95th	5th	50th	95th
Brigalow (Acacia harpophylla dominant and co-dominant)	1,972	16.2	7.6	10.6	16.2	0.3	2.6	4.9	0	0.5	1.8
Natural grasslands on basalt and fine-textured alluvial plains	16,147	134	6.7	33.6	134	2.2	11.2	29.1	2.2	9.0	20.2
Semi-evergreen vine thickets	534	2.3	0	0	2.3	0	0	0	0	0	0
Weeping Myall Woodlands	3,212	40.8	1.0	2.6	40.8	0	0.2	0.5	0	0.2	0.2
Belson's Panic (Homopholis belsonii)	192	44.8	0	4.5	44.8	0	0	2.2	0	0	0
Black-faced Monarch (Monarcha melanopsis)	11,173	133	6.7	33.6	133	2.2	11.2	29.1	2.2	9.0	20.2
Blotched Sarcochilus (Sarcochilus weinthalii)	1,457	21.0	0	0.3	21.0	0	0	0	0	0	0
Cattle Egret (Ardea ibis)	63,183	134	6.7	33.6	134	2.2	11.2	29.1	2.2	9.0	20.2
Dunmall's Snake (Furina dunmalli)	3,395	104	3.7	18.8	104	0	0	0	0	0	0
Finger Panic Grass (Digitaria porrecta)	12,520	81.3	6.7	29.1	81.3	2.2	11.2	24.7	2.2	9.0	18.0
Five-clawed Worm-skink (Anomalopus mackayi)	7,221	90.1	6.7	30.4	90.1	2.2	11.2	26.9	2.2	9.0	20.2
Fork-tailed Swift (Apus pacificus)	129,763	1545	384	618	1545	24.7	144	272	2.2	49.4	110
Great Egret (Ardea alba)	129,763	1545	384	618	1545	24.7	144	272	2.2	49.4	110
Grey-headed Flying-fox (Numbereropus poliocephalus)	8,999	134	6.7	33.6	134	2.2	11.2	29.1	2.2	9.0	20.2
Koala (Phascolarctos cinereus (combined populations of Queensland, NSW and the ACT))	33,233	145	6.7	33.6	145	2.2	11.2	29.1	2.2	9.0	20.2
Red Goshawk (Erythrotriorchis radiatus)	49,364	1545	384	618	1545	24.7	144	272	2.2	49.4	110

Asset name[a]	Area in assessment extent	Area in zone of potential hydrological change (excluding modelled open-cut mine pits)	Area[b] with additional drawdown ≥0.2 m			Area[b] with additional drawdown ≥2 m			Area[b] with additional drawdown ≥5 m		
			5th	50th	95th	5th	50th	95th	5th	50th	95th
Satin Flycatcher (Myiagra cyanoleuca)	26,030	262	43.9	87.2	262	2.2	11.2	32.8	2.2	9.0	20.2
Squatter Pigeon (southern) (Geophaps scripta scripta)	42,989	653	68.1	168	653	0	3.0	28.1	0	0	0.9
Star Finch (eastern) (Neochmia ruficauda ruficauda)	93,710	1411	377	584	1411	22.5	133	243	0	40.4	89.8
Stream Clematis (Clematis fawcettii)	3,356	0.5	0	0	0.5	0	0	0	0	0	0
White-bellied Sea-Eagle (Haliaeetus leucogaster)	17,952	20.0	0	1.5	20.0	0	0.2	4.0	0	0.2	3.6
Yakka Skink (Egernia rugosa)	8,096	52.0	0	0	52.0	0	0	0	0	0	0
Acacia harpophylla and/or Casuarina cristata open forest on fine-grained sedimentary rocks	700	15.5	7.4	10.0	15.5	0.3	2.5	4.8	0	0.5	1.7
Acacia harpophylla and/or Casuarina cristata shrubby open forest on Cainozoic clay plains	766	0.04	0	0	0.04	0	0	0	0	0	0
Dichanthium sericeum and/or Astrebla spp. grassland on alluvial plains. Cracking clay soils	54.0	0.1	0	0	0.1	0	0	0	0	0	0
Eucalyptus brownii or Eucalyptus populnea woodland on Cainozoic igneous rocks	9.7	0.1	0	0	0.1	0	0	0	0	0	0
Eucalyptus populnea woodland with Acacia harpophylla and/or Casuarina cristata on alluvial plains	117	0.1	0	0	0.1	0	0	0	0	0	0
Eucalyptus populnea, Acacia harpophylla open forest on fine-grained sedimentary rocks	267	1.0	0	0	1.0	0	0	0	0	0	0
Adelotus brevis	270	0.2	0	0	0.2	0	0	0	0	0	0
Chalinolobus dwyeri	10,108	543	91.0	159	543	8.8	43.3	63.5	0	20.3	36.0
Dasyurus maculatus maculatus	2,780	2.3	0	0	2.3	0	0	0.3	0	0	0

Asset name[a]	Area in assessment extent	Area in zone of potential hydrological change (excluding modelled open-cut mine pits)	Area[b] with additional drawdown ≥0.2 m			Area[b] with additional drawdown ≥2 m			Area[b] with additional drawdown ≥5 m		
			5th	50th	95th	5th	50th	95th	5th	50th	95th
Grantiella picta	85,952	1003	286	469	1003	16.3	99.4	206	2.2	29.5	75.2
Haloragis exalata subsp velutina	4,194	7.5	0	0.6	7.5	0	0	1.1	0	0	0
Hemiaspis damelii	23,187	25.3	0.6	5.1	25.3	0.3	1.1	4.3	0.3	1.0	3.7
Paradelma orientalis	47,079	738	262	738	9.6	75.4	129	0.3	24.2	57.4	262
Phascolarctos cinereus	2,643	17.0	8.2	17.0	0.3	5.1	11.2	0.3	2.9	7.5	8.2
Picris barbarorum	11,175	37.3	6.7	37.3	0.3	1.4	5.0	0.3	1.3	4.1	6.7
Samadera bidwillii	32.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tympanocrynumberis cf tetraporophora	970	0.7	0.1	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.1

[a]Punctuation and typography appear as used in the asset database.
[b]Areas exclude the modelled open-cut mine pits.
The extent potentially exposed to ≥0.2, ≥2 and ≥5 m additional drawdown is shown for the 5th, 50th and 95th percentile estimates of the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. The zone of potential hydrological change is defined as the area with a greater than 5% chance of exceeding 0.2 m drawdown due to additional coal resource development.
Data: Bioregional Assessment Programme (Dataset 3)

3.5.3 Economic assets

The water-dependent asset register for the Maranoa-Balonne-Condamine subregion (Bioregional Assessment Programme, 2017) contains 310 economic assets comprising 10,825 elements (Table 31). This includes:

- 183 assets in the 'Surface water management zone or area' subgroup, comprising
  - 145 water access rights, comprising 781 elements, including the spatial location of surface water licenses and extraction works, such as from the Dawson River or Dogwood Creek water sources
  - 32 basic water rights (stock and domestic), comprising 48 elements, including the spatial location of approved extraction works, such as from the Moonie River or Myall Creek water sources
  - 6 water supply and monitoring infrastructure assets that include dams and weirs, such as the Clarendon Dam and Buckinbah Weir
- 127 assets in the 'Groundwater management zone or area' subgroup, comprising
  - 76 water access rights, containing 5567 elements or individual bores in a groundwater management zone or area, such as Oakey Creek or Surat East groundwater management areas
  - 38 basic water access rights (stock and domestic), containing 4410 elements, including 4401 individual bores that do not require a licence for the extraction of groundwater and 9 groundwater management plan areas in NSW
  - 13 water supply and monitoring infrastructure assets, such as Crows Nest and Toowoomba borefields.

Potential impacts due to additional coal resource development are contained in the zone of potential hydrological change, where there is a greater than 5% chance of exceeding 0.2 m drawdown due to additional coal resource development in the source aquifer (Figure 42). For economic assets in the 'Surface water management zone or area' subgroup, the zone is represented at the surface and for assets in the 'Groundwater management zone or area' subgroup, the zone is represented in the relevant geological layer from which assets source water. Water-dependent assets outside of this zone are *very unlikely* to be impacted by hydrological changes due to additional coal resource development.

Potential impacts to groundwater economic assets in the Maranoa-Balonne-Condamine subregion are assessed and reported for two separate datasets:

- 9,990 individual bores included in the water-dependent asset register (Bioregional Assessment Programme, Dataset 2; Bioregional Assessment Programme, 2017)
- 21,192 individual bores reported in the *Underground water impact report for the Surat Cumulative Management Area* (QWC, 2012) (Bioregional Assessment Programme, Dataset 9). This dataset includes the assigned aquifer and formation, estimated usage, depth and purpose of each bore. Estimates of groundwater extraction from these bores is described in companion product 1.5 for the Maranoa-Balonne-Condamine subregion (Cassel

et al., 2015). Potential impacts to these bores are reported in companion product 2.6.2 (Janardhanan et al., 2016).

Table 31 Number of economic water-dependent elements and assets in the assessment extent and zone of potential hydrological change

Asset subgroup	Asset class	Number in assessment extent		Number in zone of potential hydrological change (including modelled open-cut mine pits)	
		Assets	Elements	Assets	Elements
Groundwater management zone or area (surface area)	A groundwater feature used for water supply	0	0	0	0
	Water supply and monitoring infrastructure	13	13	0	0
	Water access right	76	5,567	7	117
	Basic water right (stock and domestic)	38	4,410	6	46
	Subtotal	**127**	**9,990**	**13**	**163**
Surface water management zone or area (surface area)	A surface water feature used for water supply	0	0	0	0
	Water supply and monitoring infrastructure	6	6	0	0
	Water access right	145	781	1	1
	Basic water right (stock and domestic)	32	48	0	0
	Subtotal	**183**	**835**	**1**	**1**
Total		**310**	**10,825**	**14**	**164**

Data: Bioregional Assessment Programme (Dataset 2)

One of the 183 assets in the 'Surface water management zone or area' subgroup potentially experiences hydrological change due to additional coal resource development. This asset is the surface water extraction point for a licensed water access right in the headwaters of Downfall Creek in the vicinity of The Range coal mine. As surface water modelling was not carried out in this Assessment, the potential impacts to this water access right were not further assessed.

The zone of potential hydrological change in the relevant geological layer includes 13 of the 127 assets in the 'Groundwater management zone or area' subgroup (Table 31 and Figure 42). This includes 163 individual bores contained in:

- 7 water access rights, including 117 individual bores and associated licences that are managed by Queensland's 'Condamine and Balonne' and 'Great Artesian Basin' water resource management plans
- 6 basic water access rights (stock and domestic), including 46 individual bores that do not require a licence for the extraction of groundwater.

No water supply and monitoring infrastructure assets associated with either a surface water or groundwater management zone or area are located in the relevant zone of potential hydrological change and are therefore unlikely to be affected by hydrological changes associated with coal resource development in the Maranoa-Balonne-Condamine subregion.

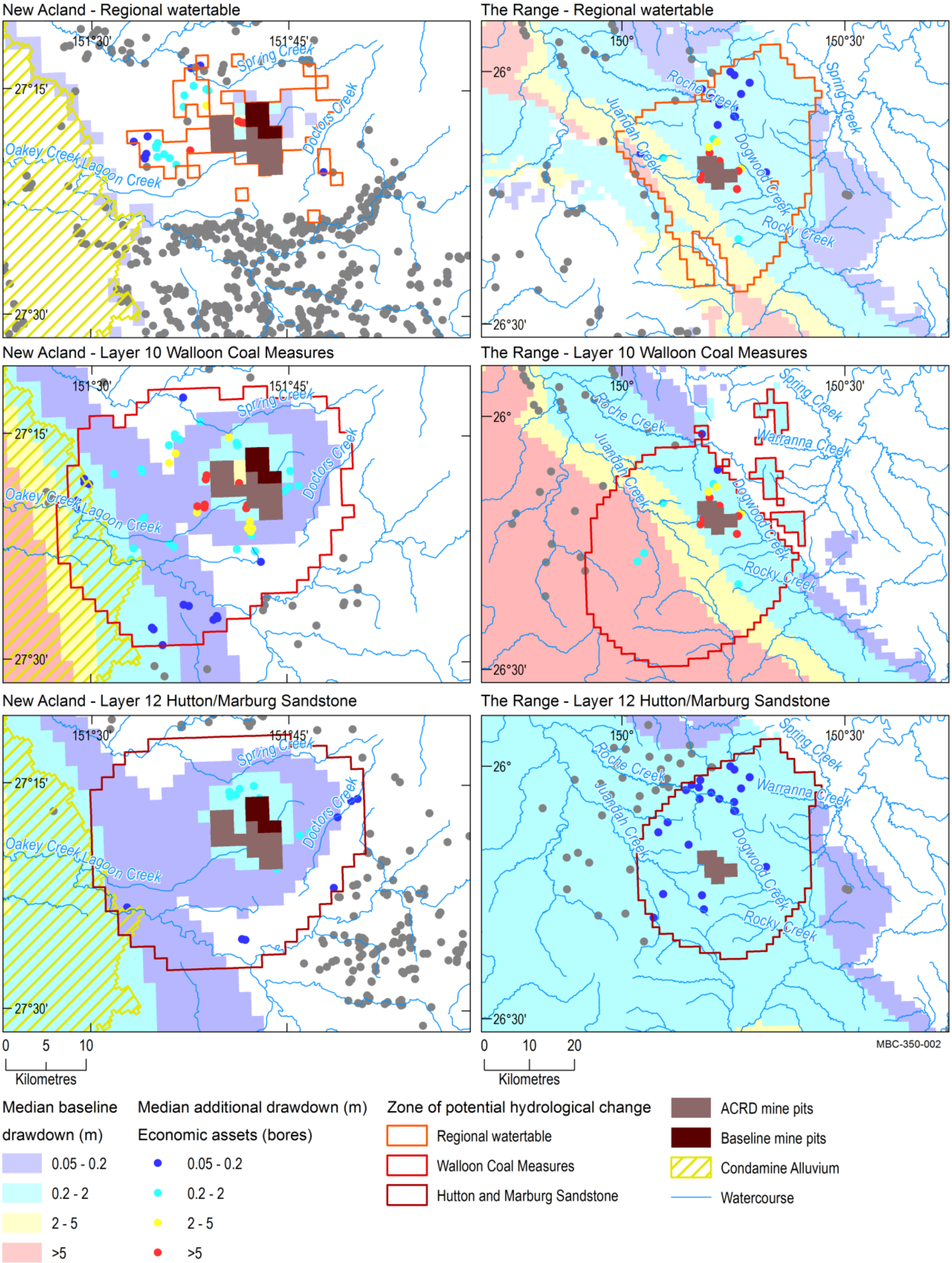

Figure 42 Median baseline drawdown and additional drawdown for economic bores in the zone of potential hydrological change in the relevant aquifer in the vicinity of New Acland Coal Mine and The Range coal mine

Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. The extent of the mine pits in the CRDP is the union of those in the baseline and the additional coal resource development (ACRD). Bores within modelled open-cut mine pits are not included in this analysis.
Data: Bioregional Assessment Programme (Dataset 2, Dataset 4, Dataset 5, Dataset 6, Dataset 7, Dataset 8, Dataset 10)

In Queensland, water resource plans (WRPs) are subordinate legislation under Queensland's *Water Act 2000*. Surface water catchments define the areal extent of the WRPs except for the GAB WRP, which is defined by geological formations. Two WRPs partially or fully overlap the zone of potential hydrological change in the Maranoa-Balonne-Condamine subregion: the Condamine and Balonne, and the GAB plan areas. Groundwater systems managed by the Condamine and Balonne WRP include alluvial and fractured rock aquifers. The GAB WRP manages the GAB water resources by formation, described as groundwater management units.

The range of model predictions indicates that the number of bores predicted to experience additional drawdown in excess of 0.2 m ranges between 72 and 163 bores (Figure 43 and Table 32), including:

- 11 to 34 bores in the Condamine and Balonne WRP
- 61 to 129 bores in the GAB WRP, including
  - 49 to 80 bores in the Eastern Downs Groundwater Management Area
  - 6 to 36 bores in the Surat North Groundwater Management Area
  - 6 to 13 bores in the Surat and Surat East Groundwater Management Area.

The number of bores predicted to experience additional drawdown in excess of 5 m ranges between 17 and 30 bores (Figure 43 and Table 32), including:

- 5 to 6 bores in the Condamine and Balonne WRP
- 12 to 24 bores in the GAB WRP, including
  - 12 to 16 bores in the Eastern Downs Groundwater Management Area
  - 0 to 5 bores in the Surat North Groundwater Management Area
  - 0 to 3 bores in the Surat and Surat East Groundwater Management Area.

Nine of the 163 bores in the zone of potential hydrological change are located within the modelled open-cut mine pits (Figure 42). This includes one basic water right (stock and domestic) in the Surat East and eight water access rights in the Eastern Downs groundwater management areas in the GAB WRP.

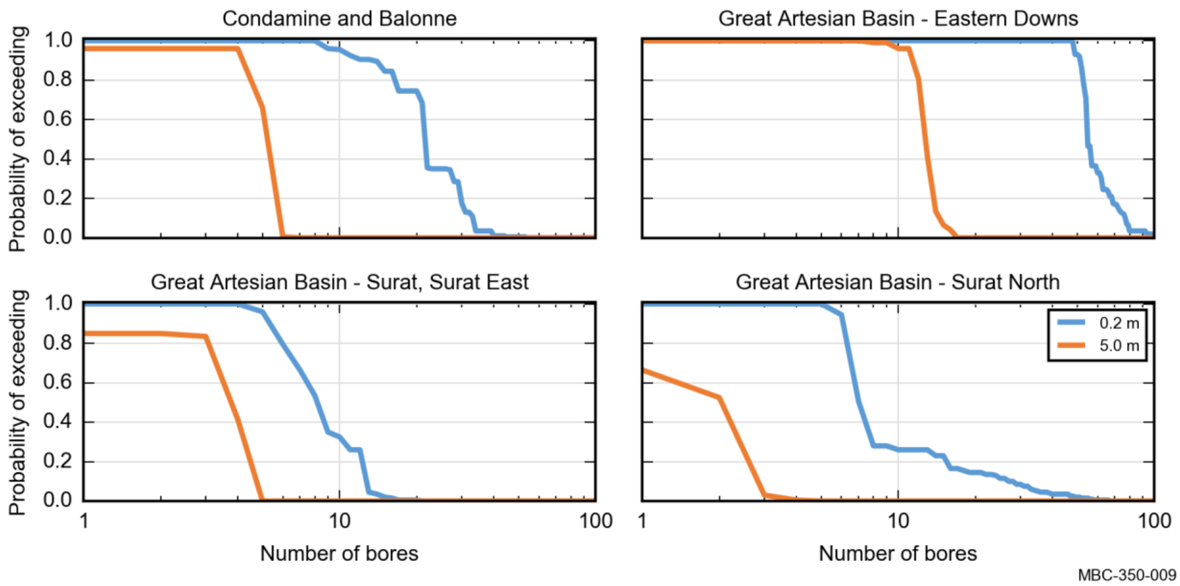

Figure 43 Probability of exceeding 0.2 and 5 m additional drawdown in the relevant aquifer for economic bores in each groundwater management area in the Condamine and Balonne and Great Artesian Basin water resource plans

Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development.
Data: Bioregional Assessment Programme (Dataset 10)

Table 32 Number of economic bores potentially exposed to additional drawdown in the relevant aquifer in the zone of potential hydrological change

Water resource plan	Groundwater management area	Number[a] with additional drawdown ≥0.2 m			Number[a] with additional drawdown ≥5 m		
		5th	50th	95th	5th	50th	95th
Condamine and Balonne		11	22	34	5	6	6
Great Artesian Basin	Eastern Downs	49	55	80	12	13	16
Great Artesian Basin	Surat, Surat East	6	9	13	0	4	5
Great Artesian Basin	Surat North	6	8	36	0	3	3
Total		**72**	**94**	**163**	**17**	**26**	**30**

[a]Numbers exclude the modelled open-cut mine pits.
The number of economic bores potentially exposed to ≥0.2 and ≥5 m additional drawdown is shown for the 5th, 50th and 95th percentile estimates. Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. The zone of potential hydrological change is defined as the area with a greater than 5% chance of exceeding 0.2 m drawdown due to additional coal resource development.
Data: Bioregional Assessment Programme (Dataset 10)

Not all bores in the assessment extent were included in the water-dependent asset register. Therefore, potential impacts to all non-petroleum and gas production bores identified for the Surat Cumulative Management Area (CMA) were assessed separately (Bioregional Assessment Programme, Dataset 9). Groundwater is extracted for and used for stock and domestic, agriculture, industrial and urban water use in the Surat CMA. 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. 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). Around 66% of the groundwater extraction from the aquifers overlying GAB is used for agriculture. The second major use of groundwater in the alluvial 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 zone of potential hydrological change in the relevant geological layer includes 501 non-petroleum and gas production bores that are located outside of the modelled mine pit cells (Table 33). The range of model predictions indicates that the number of bores predicted to experience additional drawdown in excess of 0.2 m is between 187 and 501 bores, including:

- 17 to 98 bores that access the aquifers overlying the GAB, including
  - 1 to 6 bores that access the Condamine Alluvium aquifer
  - 16 to 92 bores that access the Main Range Volcanics and Tertiary Volcanics aquifers
- 170 to 403 bores that access the deeper GAB aquifers, including
  - 141 to 266 bores that access the Walloon Coal Measures
  - 29 to 137 bores that access the Hutton and Marburg sandstone aquifer.

The number of bores predicted to experience additional drawdown in excess of 5 m ranges between 36 and 86 bores, including:

- 11 to 30 bores that access the aquifers overlying the GAB, including
  - 1 to 2 bores that access the Condamine Alluvium aquifer
  - 10 to 28 bores that access the Main Range Volcanics and Tertiary Volcanics aquifers
- 25 to 56 bores that access the deeper GAB aquifers, including
  - 25 to 56 bores that access the Walloon Coal Measures
  - 0 bores that access the Hutton and Marburg sandstone aquifer.

No bores access groundwater in the deeper Bowen Basin aquifers underlying the GAB.

Table 33 Number of non-petroleum and gas production bores in Surat Cumulative Management Area that exceed the 5th, 50th and 95th percentile estimates of additional drawdown (m) in the zone of potential hydrological change in the relevant aquifer

Group of aquifers	Aquifer	Total number (excluding modelled open-cut mine pits)	Number[a] of bores with additional drawdown ≥0.2 m			Number[a] of bores with additional drawdown ≥5 m		
			5th	50th	95th	5th	50th	95th
Aquifers overlying Great Artesian Basin	Condamine Alluvium aquifer	3,948	1	2	6	1	1	2
	Other alluvial aquifers	757	0	0	0	0	0	0
	Main Range Volcanics and Tertiary Volcanics aquifer	7,638	16	42	92	10	17	28
	Rolling Downs Group	210	0	0	0	0	0	0
	Subtotal	**12,553**	**17**	**44**	**98**	**11**	**18**	**30**
Great Artesian Basin	Bungil Formation and Mooga Sandstone	1,099	0	0	0	0	0	0
	Orallo Formation	60	0	0	0	0	0	0
	Gubberamunda Sandstone aquifer	908	0	0	0	0	0	0
	Westbourne Formation	3	0	0	0	0	0	0
	Springbok Sandstone aquifer	223	0	0	0	0	0	0
	Walloon Coal Measures	2,054	141	168	266	25	43	56
	Eurombah Formation	18	0	0	0	0	0	0
	Hutton and Marburg sandstone aquifer	2,828	29	48	137	0	0	0
	Evergreen Formation	302	0	0	0	0	0	0
	Precipice and Helidon sandstone aquifer	292	0	0	0	0	0	0
	Moolayember Formation	86	0	0	0	0	0	0
	Clematis Sandstone aquifer	195	0	0	0	0	0	0
	Subtotal	**8,068**	**170**	**216**	**403**	**25**	**43**	**56**
Aquifers underlying Great Artesian Basin	Rewan Group	37	0	0	0	0	0	0
	Bandanna Formation	43	0	0	0	0	0	0
	Undifferentiated Permian aquifers of the Bowen Basin	366	0	0	0	0	0	0
	Fractured rock aquifers in the basement	125	0	0	0	0	0	0
	Subtotal	**571**	**0**	**0**	**0**	**0**	**0**	**0**
Total		**21,192**	**187**	**260**	**501**	**36**	**61**	**86**

[a]Numbers exclude modelled open-cut mine pits.
This table is modified from Table 5-1 in QWC (2012). The number of bores potentially exposed to ≥0.2 and ≥5 m additional drawdown in the relevant aquifer is shown for the 5th, 50th and 95th percentile estimates. Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. Bores within modelled open-cut pits (Table 4) are not included in this analysis.
Data: Bioregional Assessment Programme (Dataset 8)

3.5.4 Sociocultural assets

The water-dependent asset register for the Maranoa-Balonne-Condamine subregion (Bioregional Assessment Programme, 2017) contains 135 sociocultural assets that are included in the water-dependent asset register that was used for the impact and risk analysis (updated 5 February 2016; Bioregional Assessment Programme, Dataset 2; Bioregional Assessment Programme, 2017). Of these 135 sociocultural assets, 79 were considered to be water dependent based on the presence of floodplain and wetland areas and shallow groundwater within their spatial extent as described in companion product 1.3 (Mitchell et al., 2015b). These 79 sociocultural assets include 39 built heritage assets, 11 war memorials, 3 Indigenous sites and 26 recreation areas, including national parks and areas of remnant vegetation (Table 34).

Separate reports are available on Indigenous water assets in the Queensland and NSW parts of the Maranoa-Balonne-Condamine subregion, which contributed to this Assessment. Following consultation with Traditional Owners in the Maranoa-Balonne-Condamine subregion, an additional 56 Indigenous assets were included in the water-dependent asset register used for the impact and risk analysis (updated 5 February 2016; Bioregional Assessment Programme, Dataset 2; Bioregional Assessment Programme, 2017). Of these, 35 Indigenous assets are cultural values associated with animals and plants that do not have geographic location information. This means they could not be specifically assessed for hydrological impact due to additional coal resource development using spatial overlay. None of the 35 cultural values associated with animals and plants are listed separately as ecological assets for the subregion. The cultural values and nature of the water dependency of these 35 Indigenous assets are described in Table 35.

The zone of potential hydrological change includes part of one sociocultural asset – the 3092 km^2 Barakula State Forest Area, near Miles in Queensland – which is classified as a recreation area (Table 34). It is considered to be water dependent based on the presence of floodplain and wetland areas and shallow groundwater within its spatial extent. The Barakula State Forest is located along the eastern edge of the zone of potential hydrological change in the vicinity of The Range coal mine (Figure 44).

Table 34 Number of sociocultural water-dependent assets in the assessment extent and zone of potential hydrological change

Asset subgroup	Asset class	Number of assets in assessment extent	Number of assets in zone of potential hydrological change (including modelled open-cut mine pits)
Cultural	Heritage site	50	0
Cultural	Indigenous site	59[a]	–
Social	Recreation area	26	1
Total		**135**	**1**

[a]Out of the total 59 Indigenous sites, 35 are Indigenous cultural values associated with animals and plants that do not have geographic location information, which means they cannot be specifically assessed for hydrological impact due to additional coal resource development. Therefore '–' (not applicable) is indicated for whether these assets are in the zone, because it is unknown whether the aspatial assets are in the zone.
Data: Bioregional Assessment Programme (Dataset 2, Dataset 3)

Table 35 Description of cultural values and nature of water dependency for Indigenous assets

Asset name[a]	Description of cultural values and nature of water dependency
Araucaria bidwilli (bunya)	Water dependency based on cultural considerations, requires moist conditions for germination
Xanthorrhoea	Water dependency based on cultural considerations
Callistemon viminalis (bottlebrush)	Water dependency based on cultural considerations, grows along watercourses in sandstone or granite derived geologies
Capparis mitchelli (wild orange)	Water dependency based on cultural considerations
Brachychiton populneus (kurrajong)	Water dependency based on cultural considerations
Pittosporum angustifolium (umbie umbie)	Water dependency based on cultural considerations
Eremophila longifolia (emu bush)	Water dependency based on cultural considerations
Psydrax oleifolia (lemon myrtle)	Water dependency based on cultural considerations
Santalum lanceolatum (sandalwood)	Water dependency based on cultural considerations
Capparis lasiantha (maypan)	Water dependency based on cultural considerations
Eucalyptus camaldulensis (river red gum)	Water dependency based on cultural considerations, known to have surface water and groundwater dependence
Petalostigma pubescens (quinine tree)	Water dependency based on cultural considerations
Carissa ovata (blackcurrant bush)	Water dependency based on cultural considerations
Grevillea striata (beefwood)	Water dependency based on cultural considerations, may occur along water courses
Owenia acidula (emu apple)	Water dependency based on cultural considerations
Callitris glaucophylla (white cypress pine)	Water dependency based on cultural considerations
Xylomelum cunninghamianum (native pear)	Water dependency based on cultural considerations
Santalum lanceolatum (commercial sandalwood)	Water dependency based on cultural considerations
Apophyllum anomalum (broom bush)	Water dependency based on cultural considerations
Dodonaea viscosa (sticky hopbush)	Water dependency based on cultural considerations
Ficus opposita (sandpaper fig)	Water dependency based on cultural considerations
Alphitonia excelsa (red ash)	Water dependency based on cultural considerations
Clerodendrum floribundum (lolly bush)	Water dependency based on cultural considerations, often associated with coastal rainforests and sometimes with creek lines and alluvium
Ventilago viminalis (vine tree)	Water dependency based on cultural considerations
Exocarpos cupressiformis (native cherry)	Water dependency based on cultural considerations

Asset name[a]	Description of cultural values and nature of water dependency
Dendrophthoe glabrescens (mistletoe)	Water dependency based on cultural considerations
Eremophila dutonii (red poverty bush)	Water dependency based on cultural considerations
Eremophila freelingii (rock fuschia bush)	Water dependency based on cultural considerations
Eremophila latrobei (crimson turkey bush)	Water dependency based on cultural considerations
Typha domingensis (bulrush)	Water dependency based on cultural considerations, emergent aquatic perennial
Marsdenia australis (maypan/bush banana)	Water dependency based on cultural considerations
Cherax destructor (bugili (crayfish))	Water dependency based on cultural considerations, aquatic crustacean
Macquaria sp. (yellow belly)	Water dependency based on cultural considerations, native fish species
Morelia spilota metcalfei (bumbari (carpet snake))	Water dependency based on cultural considerations, often associated with riparian vegetation
Dromaius novaehollandise (nuriyn (emu))	Water dependency based on cultural considerations, often associated with riparian vegetation

[a]Punctuation and typography appear as used in the asset database.
Data: Bioregional Assessment Programme (Dataset 2)

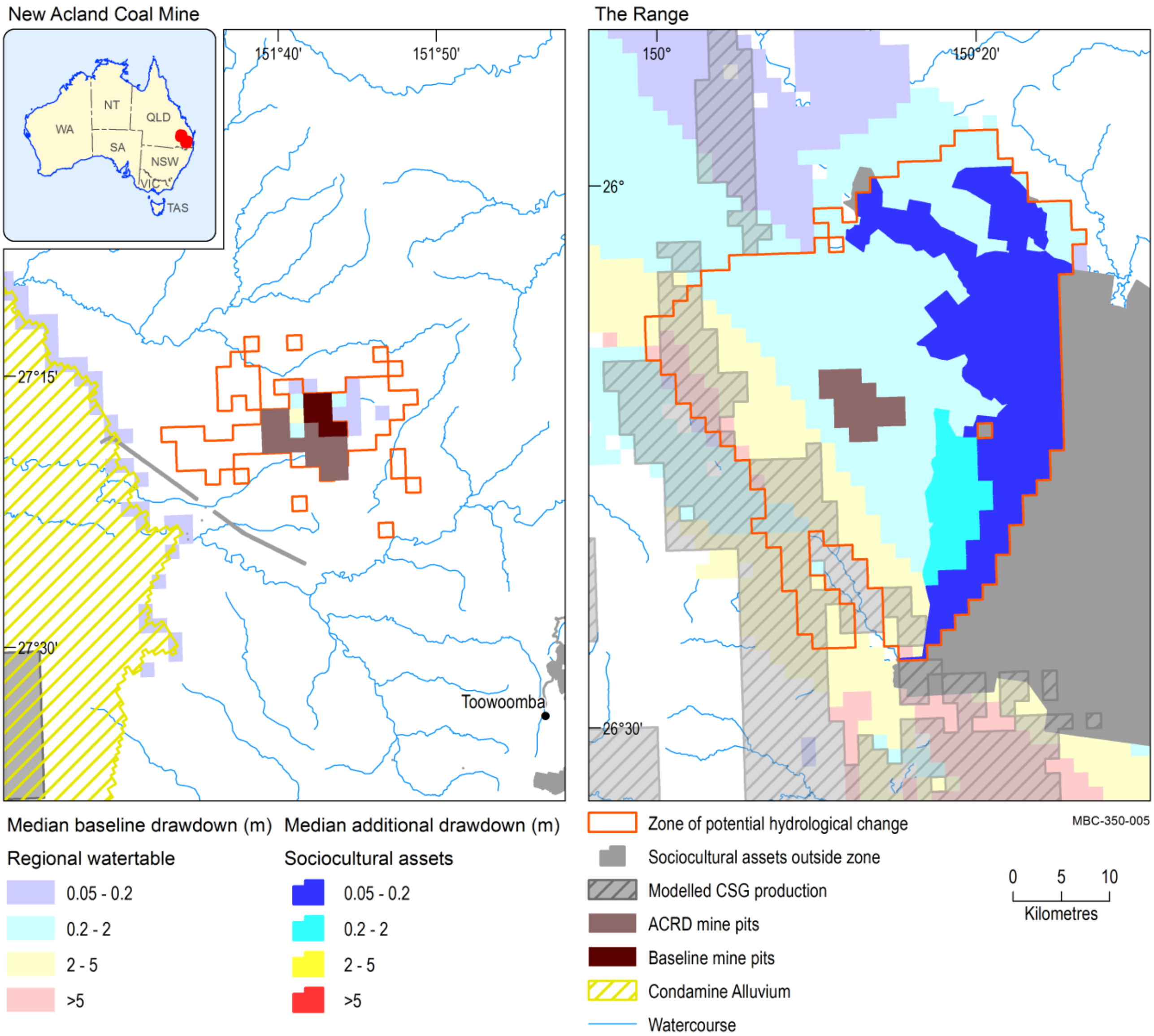

Figure 44 Median baseline drawdown and additional drawdown for sociocultural assets in the zone of potential hydrological change in the vicinity of New Acland Coal Mine and The Range coal mine

Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. The mine pits in the CRDP are the sum of those in the baseline and the additional coal resource development. Areas within modelled open-cut mine pits (Table 4) are not included in this analysis.
ACRD = additional coal resource development, CSG = coal seam gas
Data: Bioregional Assessment Programme (Dataset 2, Dataset 4, Dataset 5, Dataset 6, Dataset 7, Dataset 8)

The zone of potential hydrological change, where there is a greater than 5% chance of exceeding 0.2 m drawdown due to additional coal resource development, includes 465 km^2 of the Barakula State Forest (Table 36 and Figure 45). Median drawdown due to additional coal resource development is less than 2 m, and predominantly less than 2 m under the baseline, with the exception of 13 km^2 to the south-west of The Range coal mine (Table 36 and Table 37).

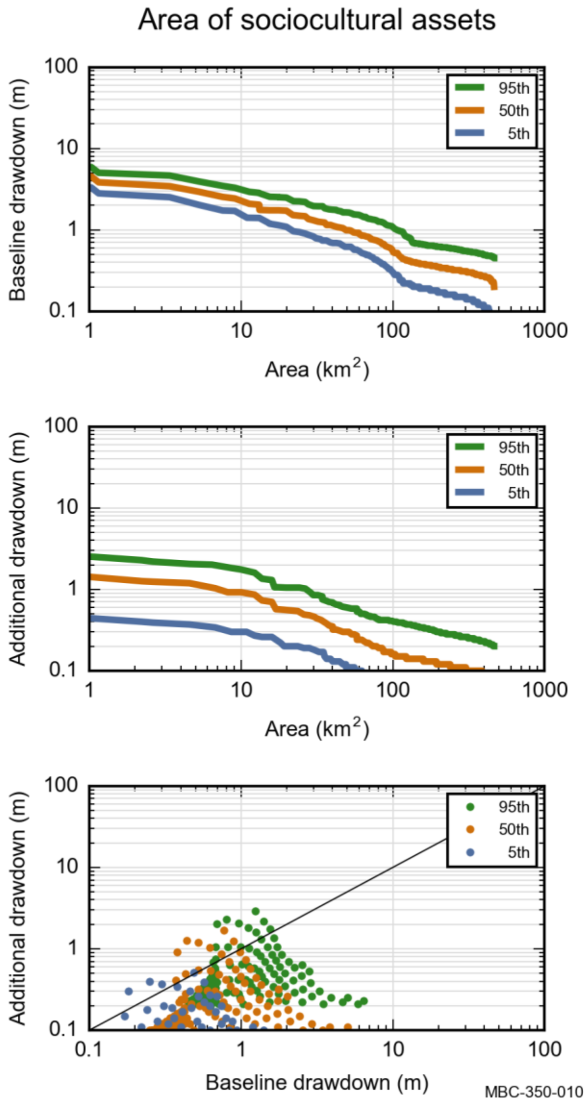

Figure 45 Area (km^2) of sociocultural assets that exceeds the 5th, 50th and 95th percentile estimates of baseline drawdown and additional drawdown in the zone of potential hydrological change

Colours represent the 5th, 50th and 95th percentile. Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. Additional drawdown is the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. Areas within modelled open-cut mine pits (Table 4) are not included in this analysis.
Data: Bioregional Assessment Programme (Dataset 3)

Table 36 Number and extent of sociocultural assets that exceed the 5th, 50th and 95th percentile estimates of baseline drawdown (m) in the zone of potential hydrological change

Asset subgroup	Asset class	Number[a], length or area	Assets in assessment extent		Assets in zone of potential hydrological change		Extent[bd] of assets with baseline drawdown ≥0.2 m			Extent[bd] of assets with baseline drawdown ≥2 m			Extent[bd] of assets with baseline drawdown ≥5 m		
			Number[a]	Length or area	Number[a]	Length or area[b]	5th	50th	95th	5th	50th	95th	5th	50th	95th
Cultural	Heritage site	Area (km²)	*50*	131	*0*	0	0	0	0	0	0	0	0	0	0
	Indigenous site	Area (km²)	*3*	26.8	*0*	0	0	0	0	0	0	0	0	0	0
	Indigenous site	Length (km)	*8*	1493	*0*	0	0	0	0	0	0	0	0	0	0
	Indigenous site	*Point (number)*	*13*	–	*0*	–	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
	Indigenous site	*Aspatial (number)*	*35*[c]	–	–	–	–	–	–	–	–	–	–	–	–
Social	Recreation area	Area (km²)	*26*	3472	*1*	465	141	465	465	5.3	13.2	27.8	0	0.3	1.2

[a]Numbers in table are italicised, to distinguish from areas. Numbers within the whole zone are included in this analysis.
[b]Lengths or areas within modelled open-cut mine pits (Table 4) are not included in this analysis.
[c]Out of the total 59 Indigenous sites, these 35 are Indigenous cultural values associated with animals and plants that do not have geographic location information, which means they cannot be specifically assessed for hydrological impact due to additional coal resource development.
[d]Extent could be a number, length or area.
'–' means 'not applicable'. The extent potentially exposed to ≥0.2, ≥2 and ≥5 m baseline drawdown is shown for the 5th, 50th and 95th percentile estimates. Baseline drawdown is the maximum difference in drawdown (*dmax*) under the baseline relative to no coal resource development. The zone of potential hydrological change is defined as the area with a greater than 5% chance of exceeding 0.2 m drawdown due to additional coal resource development.
Data: Bioregional Assessment Programme (Dataset 3)

Table 37 Number and extent of sociocultural assets that exceed the 5th, 50th and 95th percentile estimates of additional drawdown (m) in the zone of potential hydrological change

Asset subgroup	Asset class	Number[a], length or area	Assets in assessment extent		Assets in zone of potential hydrological change		Extent[bd] of assets with additional drawdown ≥0.2 m			Extent[bd] of assets with additional drawdown ≥2 m			Extent[bd] of assets with additional drawdown ≥5 m		
			Number[a]	Length or area	Number[a]	Length or area[b]	5th	50th	95th	5th	50th	95th	5th	50th	95th
Cultural	Heritage site	Area (km2)	*50*	131	*0*	0	0	0	0	0	0	0	0	0	0
	Indigenous site	Area (km2)	*3*	26.8	*0*	0	0	0	0	0	0	0	0	0	0
	Indigenous site	Length (km)	*8*	1493	*0*	0	0	0	0	0	0	0	0	0	0
	Indigenous site	*Point (number)*	*13*	–	*0*	–	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
	Indigenous site	*Aspatial (number)*	*35*[c]	–	–	–	–	–	–	–	–	–	–	–	–
Social	Recreation area	Area (km2)	*26*	3472	*0*	465	20.5	75.9	465	0	0	6.4	0	0	0

[a]Numbers in table are italicised, to distinguish from areas. Numbers within the whole zone are included in this analysis.
[b]Lengths or areas within modelled open-cut mine pits (Table 4) are not included in this analysis.
[c]Out of the total 59 Indigenous sites, these 35 are Indigenous cultural values associated with animals and plants that do not have geographic location information, which means they could not be specifically assessed for hydrological impact due to additional coal resource development.
[d]Extent could be a number, length or area.
'–' means 'not applicable'. The extent potentially exposed to ≥0.2, ≥2 and ≥5 m additional drawdown is shown for the 5th, 50th and 95th percentile estimates of the maximum difference in drawdown (*dmax*) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development. The zone of potential hydrological change is defined as the area with a greater than 5% chance of exceeding 0.2 m drawdown due to additional coal resource development.
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3.6 Commentary for coal resource developments that are not modelled

Summary

Section 3.6 describes potential impacts for those coal resource developments that were not modelled. All coal mines and gas fields included in the coal resource development pathway (CRDP) for the Maranoa-Balonne-Condamine subregion were modelled; therefore nothing is reported in this section. A summary of coal resource developments not included in the CRDP is available in Table 12 in companion product 2.3 for the Maranoa-Balonne-Condamine subregion (Holland et al., 2016).

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3.7 Conclusion

Summary

The impact and risk analysis used Queensland's Office of Groundwater Impact Assessment (OGIA) groundwater model, which was adapted for bioregional assessments (BAs), to identify where water resources and water-dependent assets are *very unlikely* to be impacted (less than 5% chance), or are potentially impacted. Water-dependent landscapes and assets, such as rivers, wetlands and groundwater systems, were ruled out using a threshold of at least a 5% chance of greater than 0.2 m drawdown due to additional coal resource development. This threshold is consistent with the most conservative minimal impact thresholds in NSW and Queensland state regulations, and is close to the practical resolution limits of modelled and measured drawdown.

The impact and risk analysis allows governments, industry and the community to focus on areas that are potentially impacted and apply local-scale modelling when making regulatory, water management and planning decisions. BAs have been developed so that they can be updated. The data, information, analytical results and models from this Assessment provide a comprehensive basis for subregion-scale re-assessment of potential impacts under an updated coal resource development pathway (CRDP). It may also be applicable for other types of resource development.

Further work should focus on identified knowledge gaps, limitations and opportunities to improve confidence in predictions of impacts to ecosystems. This includes: (i) hydrological modelling – incorporating surface water modelling and better representation of surface water – groundwater interactions; (ii) assessing impacts in the landscape – developing receptor impact models to assess potential changes to ecosystems; (iii) model resolution – developing finer resolution models to improve local-scale analysis; and (iv) climate change and land use – including additional stressors to better predict cumulative impacts.

3.7.1 Key findings

The impact and risk analysis identified where water resources and water-dependent assets are *very unlikely* to be impacted (less than 5% chance), or are potentially impacted by coal seam gas (CSG) and coal mining developments in the Maranoa-Balonne-Condamine subregion. To rule out potential impacts to water-dependent landscapes and assets, such as rivers, wetlands and groundwater systems, the impact and risk analysis used a threshold of at least a 5% chance of greater than 0.2 m drawdown due to additional coal resource development. This threshold is consistent with the most conservative minimal impact thresholds in NSW and Queensland state regulations, and is close to the practical resolution limits of modelled and measured drawdown.

Queensland's Office of Groundwater Impact Assessment (OGIA) groundwater model (QWC, 2012) was adapted to predict the potential impacts of coal resource development. The coal resource development pathway (CRDP) for the subregion includes five baseline open-cut coal mines, five baseline CSG developments and two additional coal resource developments that are open-cut coal mines: New Acland Coal Mine Stage 3 south-east of Dalby and The Range coal mine in the north between Chinchilla and Taroom.

3.7.1.1 Potential hydrological changes

Numerical groundwater modelling predicted that it is *very unlikely* that drawdown due to additional coal resource development exceeds 0.2 m in the regional watertable, except within 15 km of New Acland Coal Mine Stage 3 and within 25 km of The Range coal mine. Drawdown in the regional watertable due to additional coal resource development exceeds 0.2 m in an area of 1544 km^2 (1.2% of the total assessment extent of 129,956 km^2), including 1095 km of streams (1.8% of the 60,958 km of streams in the total assessment extent). In comparison, drawdown in the regional watertable under the baseline has at least a 5% chance of exceeding 0.2 m in an area of 17,132 km^2, which is 11 times larger than the equivalent area due to additional coal resource development.

The range of model predictions in the vicinity of New Acland Coal Mine Stage 3 indicates that additional drawdown in the regional watertable:

- in excess of 0.2 m is *very likely* (greater than 95% chance) to cover more than 7 km^2, which contains 4 km of streams, and *very unlikely* to cover more than 134 km^2, which includes 55 km of streams
- in excess of 5 m is *very likely* to cover more than 2 km^2, which contains 4 km of streams, and *very unlikely* to cover more than 20 km^2, which includes 9 km of streams. Median drawdown is up to 3 m under the baseline and up to 65 m due to additional coal resource development in the vicinity of New Acland Coal Mine in the regional watertable, which is up to 42 m thick in this area.

The greatest impact on water levels is in the Walloon Coal Measures, which is up to 200 m thick in this area. Near the mine, median drawdown in the Walloon Coal Measures is up to 3.6 m under the baseline and up to 24.9 m due to additional coal resource development.

The range of model predictions in the vicinity of The Range coal mine indicates that additional drawdown in the regional watertable:

- in excess of 0.2 m is *very likely* over an area of 377 km^2 (containing 231 km of streams) and *very unlikely* to extend beyond an area of 1409 km^2 (containing 1040 km of streams)
- in excess of 5 m is not *very likely* in any of the assessment units and *very unlikely* to extend beyond 90 km^2 (which includes 31 km of streams).

Median baseline drawdown is up to 8.3 m in the regional watertable and up to 82 m in the Walloon Coal Measures, the target of CSG production, which is up to 170 m thick in this area. Median additional drawdown is less than 10.2 m in the Walloon Coal Measures, which hosts the regional watertable in the vicinity of The Range coal mine.

3.7.1.2 Potential impacts on landscape classes

More than 35,000 km^2 of remnant vegetation, 59,000 km of streams, 1,600 km^2 of wetlands and 93,000 km^2 of productive landscapes within the assessment extent are *very unlikely* to be impacted because they are outside the zone of potential hydrological change, and thus experience less than 0.2 m drawdown due to additional coal resource development.

It is *very unlikely* that drawdown due to the two additional coal resource developments exceeds 0.2 m in the source aquifer of any springs in the assessment extent. This includes springs in the Springsure supergroup near Taroom, listed under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

3.7.1.3 Potential impacts on water-dependent assets

The water-dependent asset register for the Maranoa-Balonne-Condamine subregion (Bioregional Assessment Programme, 2017; Mitchell et al., 2015) contains 2660 assets, such as bores, wetlands or heritage sites. Of the 2660 water-dependent assets nominated by the community, 2495 are *very unlikely* to be impacted because they experience less than 0.2 m drawdown due to additional coal resource development.

However, 130 water-dependent assets are subject to potential hydrological change due to additional coal resource development. This does not mean that these assets are definitely impacted – finer resolution models are required for that local-scale assessment of impact. At this stage, however, there is not compelling evidence to rule out impacts for the following water-dependent assets:

- 115 of the 2215 *ecological assets*, including 41 ecosystems. This includes potential habitats of 4 threatened ecological communities and 18 species listed under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act); an additional 6 endangered regional ecosystems and potential habitats of 11 species listed under Queensland's *Nature Conservation Act 1992*; and 2 riparian vegetation assets.
- 14 of the 310 *economic assets*, including one licensed surface water access right and 13 groundwater economic assets comprising 163 bores (7 water access rights and 6 basic water rights (stock and domestic)). Of these 163 bores, 17 to 30 are predicted to experience additional drawdown in excess of 5 m
- 1 of the 135 *sociocultural assets*, the Barakula State Forest, near Miles in Queensland, is located where drawdown in the regional watertable due to additional coal resource development exceeds 0.2 m with greater than 5% chance. It is *very likely* that 21 km^2 (0.7% of the 3092 km^2 forest) experiences more than 0.2 m of drawdown due to additional coal resource development.

Consultation with Traditional Owners in the Maranoa-Balonne-Condamine subregion identified an additional 56 Indigenous assets, which were included in the water-dependent asset register and used for the impact and risk analysis (Bioregional Assessment Programme, 2017). Of these, 35 are cultural values associated with animals and plants that do not have geographic location information, which means they cannot be specifically assessed for impacts due to additional coal resource development.

3.7.2 How to use this impact and risk analysis

Findings from BAs can help governments, industry and the community provide better-informed regulatory, water management and planning decisions.

Assessment results flag where future efforts of regulators and proponents can be directed, and where further attention is not necessary. This is emphasised through the 'rule-out' process, which focuses on areas where hydrological changes are predicted. In doing so it has identified areas, and consequently water resources and water-dependent assets, that are *very unlikely* to experience hydrological change or impact due to additional coal resource development.

This Assessment predicts the likelihood of exceeding levels of potential hydrological change at a *regional level*. It also provides important context to identify potential issues that may need to be addressed in local-scale environmental impact assessments of new coal resource developments. It should help project proponents to meet legislative requirements to describe the environmental values that may be affected by the exercise of underground water rights, and to adopt strategies to avoid, mitigate or manage the predicted impacts. This Assessment does not investigate the broader social, economic or human health impacts of coal resource development, nor does it consider risks of fugitive gases and non-water-related impacts.

BAs are not a substitute for careful assessment of proposed coal mine or CSG extraction projects under Australian or state environmental law. Such assessments may use finer-scale groundwater and surface water models and consider impacts on matters other than water resources. However, the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (a federal government statutory authority established in 2012 under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999*) can use these Assessment results to formulate their advice.

BAs have been developed with the ability to be updated, for example, to incorporate new coal resource developments in the groundwater model. Existing datasets such as the water-dependent asset register remain relevant for future assessments. If new coal resource developments emerge in the future, the data, information, analytical results and models from this Assessment would provide a comprehensive basis for subregion-scale re-assessment of potential impacts under an updated CRDP. It may also be applicable for other types of resource development.

The full suite of information is provided at www.bioregionalassessments.gov.au with more detailed results available for:

- potential hydrological changes at www.bioregionalassessments.gov.au/explorer/MBC/potentialhydrologicalchanges
- potential impacts on landscapes at www.bioregionalassessments.gov.au/explorer/MBC/landscapes
- potential impacts on water-dependent assets at www.bioregionalassessments.gov.au/explorer/MBC/assets.

Access to underpinning datasets, including shapefiles of geographic data and modelling results, can assist decision makers at all levels to review the work undertaken to date; to explore the results using different thresholds; and to extend or update the assessment if new models or data become available. Additional guidance about how to apply the Programme's methodology is also documented in detailed scientific submethodologies (Table 1).

The Programme's rigorous commitment to data access is consistent with the Australian Government's principles of providing publicly accessible, transparent and responsibly managed public sector information.

3.7.3 Gaps, limitations and opportunities

The impact and risk analysis allows governments, industry and the community to focus on areas that are potentially impacted when making regulatory, water management and planning decisions. Due to the conservative nature of the modelling, the greatest confidence in results is for those areas that are *very unlikely* to be impacted. Where potential impacts have been identified, further work is required to determine the presence and magnitude of impacts to ecosystems.

Extending this Assessment should focus on incorporating surface water modelling and representing surface water – groundwater interactions. Key knowledge gaps identified in the following sections detail where confidence in this Assessment can be improved through further work.

3.7.3.1 Hydrological modelling

Queensland's OGIA regional groundwater model (QWC, 2012) played a central role in the hydrological analysis. The specific implementation of the model used was extended during this BA to include open-cut coal mines under both the baseline and the CRDP, compared to previous versions that only included CSG developments. The quantitative uncertainty analysis accounts for parameter uncertainty, but not conceptual model uncertainty. However, the combination of formal quantitative and qualitative uncertainty analysis techniques builds confidence in model predictions. Further, the model conceptualisation and parameterisation are conservative with respect to drawdown estimates.

The revised OGIA 2016 model addressed many of the limitations identified in the qualitative uncertainty analysis. Improvements include representation of regional geology, hydrostratigraphy and faults, as well as model discretisation, parameterisation and calibration. The patterns of long-term drawdown impacts are broadly consistent between the OGIA 2012 model used for BAs and the revised OGIA 2016 model. While this lends confidence to the BA model predictions, it is important to be aware of the difference in OGIA model versions given the proximity in timing of the completion of the hydrological modelling for the Maranoa-Balonne-Condamine subregion and the release of the latest underground water impact report (UWIR) for the Surat Cumulative Management Area (OGIA, 2016). The revised representation of hydrological changes in surficial aquifers that affect surface water – groundwater interactions and groundwater-dependent ecosystems (GDEs) are noted in particular as providing the greatest opportunities to reduce predictive uncertainty in the regional model.

The representation of near-surface geological layers in the OGIA model affects the propagation, through space and time, of drawdown that follows extraction of groundwater to enable CSG production and dewatering of open-cut mine pits. For example, the simplified regional hydrostratigraphy in the vicinity of the New Acland Coal Mine includes alluvium and Main Range Volcanics, but does not include the localised subcrop area of Walloon Coal Measures targeted by the mine. This leads to a smaller and less contiguous zone of potential hydrological change in the regional watertable near New Acland Coal Mine. In contrast, drawdown predicted near The Range coal mine is larger and spatially contiguous, where the regional watertable is represented by outcropping Walloon Coal Measures in the model.

The greatest opportunities to improve model predictions in this Assessment involve incorporation of surface water modelling and surface water – groundwater interactions to quantify changes in streams and the regional watertable that may occur as a result of coal resource development. Any assessment of changes in surface water that may occur as a result of coal resource development was limited to conceptual analysis and would need to be modelled numerically for changes to be quantified. Water quality models and data would allow related hazards to be addressed.

3.7.3.2 Assessing impacts in the landscape

As surface water modelling was not undertaken, the assessment of ecological and ecosystem impacts was limited to an overlay analysis, a summary of the hydrological changes and a conceptual understanding of the ecosystems, using landscape classes. While this is valuable, receptor impact models, used to understand the potential impacts of hydrological changes on an ecosystem or landscape, would provide better indicators of potential changes in ecosystems. These models use indicators in the ecosystem, such as the condition of the breeding habitat for a given species, or canopy cover of river red gums, to assess the potential impact of hydrological changes.

Ecological knowledge about the nature of a species’ or community’s water dependency is not available in all cases. This Assessment has relied on review of habitat requirements for each species and the presence of floodplain and wetland areas and shallow groundwater within its spatial extent. For assets that do not have geographic location information, such as cultural values identified through consultation with Traditional Owners, resources such as the *Atlas of living Australia* (ALA, 2017) could be used to identify the spatial occurrence of animals and plants associated with these cultural values in a future Assessment.

3.7.3.3 Model resolution

There is a high level of confidence in the ability of the Assessment to rule out areas that are not subject to hydrological change. This is due to the ability of the OGIA model to reflect broad-scale hydrological changes related to impacts that may accumulate from multiple sites and types of coal resource development. Where changes are predicted, and particularly close to the mine or CSG operations, the Assessment team is confident in asserting that hydrological changes may occur, but less confident in the precise magnitude or extent of propagation of those changes from depth to the surface. The underlying spatial resolution for the impact and risk analysis in this Assessment is 2.25 km^2. Although fit for purpose, a finer-resolution model would be more suitable for local-scale analysis.

3.7.3.4 Climate change and land use

In comparing results under two different futures, factors such as climate change or land use are held constant in this Assessment. Future assessments could look to include these and other stressors to more fully predict cumulative impacts at a regional level.

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Glossary

The register of terms and definitions used in the Bioregional Assessment Programme is available online at http://environment.data.gov.au/def/ba/glossary (note that terms and definitions are respectively listed under the 'Name' and 'Description' columns in this register). This register is a list of terms, which are the preferred descriptors for concepts. Other properties are included for each term, including licence information, source of definition and date of approval. Semantic relationships (such as hierarchical relationships) are formalised for some terms, as well as linkages to other terms in related vocabularies.

activity: for the purposes of Impact Modes and Effects Analysis (IMEA), a planned event associated with a coal seam gas (CSG) operation or coal mine. For example, activities during the production life-cycle stage in a CSG operation include drilling and coring, ground-based geophysics and surface core testing. Activities are grouped into components, which are grouped into life-cycle stages.

additional coal resource development: all coal mines and coal seam gas (CSG) fields, including expansions of baseline operations, that are expected to begin commercial production after December 2012

additional drawdown: the maximum difference in drawdown (dmax) between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development

aquifer: rock or sediment in a formation, group of formations, or part of a formation that is saturated and sufficiently permeable to transmit quantities of water to bores and springs

aquitard: a saturated geological unit that is less permeable than an aquifer, and incapable of transmitting useful quantities of water. Aquitards often form a confining layer over an artesian aquifer.

assessment extent: the geographic area associated with a subregion or bioregion in which the potential water-related impact of coal resource development on assets is assessed. The assessment extent is created by revising the preliminary assessment extent on the basis of information from Component 1: Contextual information and Component 2: Model-data analysis.

assessment unit: for the purposes of impact analysis, a geographic area that is used to partition the entire assessment extent into square polygons that do not overlap. The spatial resolution of the assessment units is closely related to that of the bioregional assessment groundwater modelling and is, typically, 1 x 1 km. Each assessment unit has a unique identifier. The partitioned data can be combined and recombined into any aggregation supported by the conceptual modelling, causal pathways and model data.

asset: an entity that has value to the community and, for bioregional assessment purposes, is associated with a subregion or bioregion. Technically, an asset is a store of value and may be managed and/or used to maintain and/or produce further value. Each asset will have many values associated with it and they can be measured from a range of perspectives; for example, the values of a wetland can be measured from ecological, sociocultural and economic perspectives.

baseline coal resource development: a future that includes all coal mines and coal seam gas (CSG) fields that are commercially producing as of December 2012

baseline drawdown: the maximum difference in drawdown (dmax) under the baseline relative to no coal resource development

bioregion: a geographic land area within which coal seam gas (CSG) and/or coal mining developments are taking place, or could take place, and for which bioregional assessments (BAs) are conducted

bioregional assessment: 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 coal mining development on water resources. The central purpose of bioregional assessments is to analyse the impacts and risks associated with changes to water-dependent assets that arise in response to current and future pathways of coal seam gas and coal mining development.

bore: a narrow, artificially constructed hole or cavity used to intercept, collect or store water from an aquifer, or to passively observe or collect groundwater information. Also known as a borehole or piezometer.

causal pathway: for the purposes of bioregional assessments, the logical chain of events – either planned or unplanned – that link coal resource development and potential impacts on water resources and water-dependent assets

coal resource development pathway: a future that includes all coal mines and coal seam gas (CSG) fields that are in the baseline as well as those that are expected to begin commercial production after December 2012

component: for the purposes of Impact Modes and Effects Analysis (IMEA), a group of activities associated with a coal seam gas (CSG) operation or coal mine. For example, components during the development life-cycle stage of a coal mine include developing the mine infrastructure, the open pit, surface facilities and underground facilities. Components are grouped into life-cycle stages.

conceptual model: abstraction or simplification of reality

connectivity: a descriptive measure of the interaction between water bodies (groundwater and/or surface water)

consequence: synonym of impact

context: the circumstances that form the setting for an event, statement or idea

cumulative impact: for the purposes of bioregional assessments, the total change in water resources and water-dependent assets resulting from coal seam gas and coal mining developments when all past, present and reasonably foreseeable actions that are likely to impact on water resources are considered dataset: a collection of data in files, in databases or delivered by services that comprise a related set of information. Datasets may be spatial (e.g. a shape file or geodatabase or a Web Feature Service) or aspatial (e.g. an Access database, a list of people or a model configuration file).

depressurisation: in the context of coal seam gas operations, depressurisation is the process whereby the hydrostatic (water) pressure within a coal seam is reduced (through pumping) such that natural gas desorbs from within the coal matrix, enabling the gas (and associated water) to flow to surface

dewatering: the process of controlling groundwater flow within and around mining operations that occur below the watertable. In such operations, mine dewatering plans are important to provide more efficient work conditions, improve stability and safety, and enhance economic viability of operations. There are various dewatering methods, such as direct pumping of water from within a mine, installation of dewatering wells around the mine perimeter, and pit slope drains.

direct impact: for the purposes of bioregional assessments, a change in water resources and water-dependent assets resulting from coal seam gas and coal mining developments without intervening agents or pathways

discharge: water that moves from a groundwater body to the ground surface or surface water body (e.g. a river or lake)

diversion: see extraction

drawdown: a lowering of the groundwater level (caused, for example, by pumping). In the bioregional assessment (BA) context this is reported as the difference in groundwater level between two potential futures considered in BAs: baseline coal resource development (baseline) and the coal resource development pathway (CRDP). The difference in drawdown between CRDP and baseline is due to the additional coal resource development (ACRD). Drawdown under the baseline is relative to drawdown with no coal resource development; likewise, drawdown under the CRDP is relative to drawdown with no coal resource development.

ecosystem: a dynamic complex of plant, animal, and micro-organism communities and their non-living environment interacting as a functional unit. Note: ecosystems include those that are human-influenced such as rural and urban ecosystems.

effect: for the purposes of Impact Modes and Effects Analysis (IMEA), change in the quantity and/or quality of surface water or groundwater. An effect is a specific type of an impact (any change resulting from prior events).

extraction: the removal of water for use from waterways or aquifers (including storages) by pumping or gravity channels

formation: rock layers that have common physical characteristics (lithology) deposited during a specific period of geological time groundwater: water occurring naturally below ground level (whether in an aquifer or other low permeability material), or water occurring at a place below ground that has been pumped, diverted or released to that place for storage there. This does not include water held in underground tanks, pipes or other works.

groundwater-dependent ecosystem: ecosystems that rely on groundwater - typically the natural discharge of groundwater - for their existence and health

groundwater recharge: replenishment of groundwater by natural infiltration of surface water (precipitation, runoff), or artificially via infiltration lakes or injection

groundwater system: see water system

groundwater zone of potential hydrological change: outside this extent, groundwater drawdown (and hence potential impacts) is very unlikely (less than 5% chance). It is the area with a greater than 5% chance of exceeding 0.2 m of drawdown due to additional coal resource development in the relevant aquifers.

hazard: an event, or chain of events, that might result in an effect (change in the quality and/or quantity of surface water or groundwater)

hydrogeology: the study of groundwater, including flow in aquifers, groundwater resource evaluation, and the chemistry of interactions between water and rock

hydrological response variable: a hydrological characteristic of the system that potentially changes due to coal resource development (for example, drawdown or the annual streamflow volume)

impact: a change resulting from prior events, at any stage in a chain of events or a causal pathway. An impact might be equivalent to an effect (change in the quality and/or quantity of surface water or groundwater), or it might be a change resulting from those effects (for example, ecological changes that result from hydrological changes).

impact mode: the manner in which a hazardous chain of events (initiated by an impact cause) could result in an effect (change in the quality and/or quantity of surface water or groundwater). There might be multiple impact modes for each activity or chain of events.

Impact Modes and Effects Analysis: a systematic hazard identification and prioritisation technique based on Failure Modes and Effects Analysis

indirect impact: for the purposes of bioregional assessments, a change in water resources and water-dependent assets resulting from coal seam gas and coal mining developments with one or more intervening agents or pathways

landscape class: for bioregional assessment (BA) purposes, an ecosystem with characteristics that are expected to respond similarly to changes in groundwater and/or surface water due to coal resource development. Note that there is expected to be less heterogeneity in the response within a landscape class than between landscape classes. They are present on the landscape across the entire BA subregion or bioregion and their spatial coverage is exhaustive and non-overlapping. Conceptually, landscape classes can be considered as types of ecosystem assets.

landscape group: for the purposes of bioregional assessments (BAs), a set of landscape classes grouped together based on common ecohydrological characteristics that are relevant for analysis purposes

likelihood: probability that something might happen

material: pertinent or relevant

permeability: the measure of the ability of a rock, soil or sediment to yield or transmit a fluid. The magnitude of permeability depends largely on the porosity and the interconnectivity of pores and spaces in the ground.

preliminary assessment extent: the geographic area associated with a subregion or bioregion in which the potential water-related impact of coal resource development on assets is assessed. The PAE is estimated at the beginning of a bioregional assessment, and is updated to the 'assessment extent' on the basis of information from Component 1: Contextual information and Component 2: Model-data analysis.

probability distribution: the probability distribution of a random variable specifies the chance that the variable takes a value in any subset of the real numbers. It allows statements such as 'There is a probability of x that the variable is between a and b'.

receptor: a point in the landscape where water-related impacts on assets are assessed

receptor impact variable: a characteristic of the system that, according to the conceptual modelling, potentially changes due to changes in hydrological response variables (for example, condition of the breeding habitat for a given species, or biomass of river red gums)

recharge: see groundwater recharge

risk: the effect of uncertainty on objectives

runoff: rainfall that does not infiltrate the ground or evaporate to the atmosphere. This water flows down a slope and enters surface water systems.

sensitivity: the degree to which the output of a model (numerical or otherwise) responds to uncertainty in a model input

severity: magnitude of an impact

source dataset: a pre-existing dataset sourced from outside the Bioregional Assessment Programme (including from Programme partner organisations) or a dataset created by the Programme based on analyses conducted by the Programme for use in the bioregional assessments (BAs)

spring: a naturally occurring discharge of groundwater flowing out of the ground, often forming a small stream or pool of water. Typically, it represents the point at which the watertable intersects ground level.

stratigraphy: stratified (layered) rocks stressor: chemical or biological agent, environmental condition or external stimulus that might contribute to an impact mode

subcrop: 1 - A subsurface outcrop, e.g. where a formation intersects a subsurface plane such as an unconformity. 2 - In mining, any near-surface development of a rock or orebody, usually beneath superficial material.

subregion: an identified area wholly contained within a bioregion that enables convenient presentation of outputs of a bioregional assessment (BA)

subsidence: localised lowering of the land surface. It occurs when underground voids or cavities collapse, or when soil or geological formations (including coal seams, sandstone and other sedimentary strata) compact due to reduction in moisture content and pressure within the ground.

surface water: water that flows over land and in watercourses or artificial channels and can be captured, stored and supplemented from dams and reservoirs

tenement: a defined area of land granted by a relevant government authority under prescribed legislative conditions to permit various activities associated with the exploration, development and mining of a specific mineral or energy resource, such as coal. Administration and granting of tenements is usually undertaken by state and territory governments, with various types related to the expected level and style of exploration and mining. Tenements are important mechanisms to maintain standards and safeguards relating to environmental factors and other land uses, including native title.

uncertainty: the state, even partial, of deficiency of information related to understanding or knowledge of an event, its consequence, or likelihood. For the purposes of bioregional assessments, uncertainty includes: the variation caused by natural fluctuations or heterogeneity; the incomplete knowledge or understanding of the system under consideration; and the simplification or abstraction of the system in the conceptual and numerical models.

very likely: greater than 95% chance

very unlikely: less than 5% chance

water-dependent asset: an asset potentially impacted, either positively or negatively, by changes in the groundwater and/or surface water regime due to coal resource development

water-dependent asset register: a simple and authoritative listing of the assets within the preliminary assessment extent (PAE) that are potentially subject to water-related impacts

water system: a system that is hydrologically connected and described at the level desired for management purposes (e.g. subcatchment, catchment, basin or drainage division, or groundwater management unit, subaquifer, aquifer, groundwater basin)

watertable: the upper surface of a body of groundwater occurring in an unconfined aquifer. At the watertable, pore water pressure equals atmospheric pressure.

water use: the volume of water diverted from a stream, extracted from groundwater, or transferred to another area for use. It is not representative of 'on-farm' or 'town' use; rather it represents the volume taken from the environment.

well: typically a narrow diameter hole drilled into the earth for the purposes of exploring, evaluating or recovering various natural resources, such as hydrocarbons (oil and gas) or water. As part of the drilling and construction process the well can be encased by materials such as steel and cement, or it may be uncased. Wells are sometimes known as a 'wellbore'.

zone of potential hydrological change: outside this extent, hydrological changes (and hence potential impacts) are very unlikely (less than 5% chance). Each bioregional assessment defines the zone of potential hydrological change using probabilities of exceeding thresholds for relevant hydrological response variables. The zone of potential hydrological change is the union of the groundwater zone of potential hydrological change (the area with a greater than 5% chance of exceeding 0.2 m of drawdown due to additional coal resource development in the relevant aquifers) and the surface water zone of potential hydrological change (the area with a greater than 5% chance of exceeding changes in relevant surface water hydrological response variables due to additional coal resource development).

Landscape classification

Definitions for landscape classes and landscape groups for the Maranoa-Balonne-Condamine subregion are provided below. The register of terms and definitions for the landscape classification for each bioregion and subregion in the Bioregional Assessment Programme is available online at http://environment.data.gov.au/def/ba/landscape-classification.

- 'Dryland remnant vegetation' landscape group: Ecosystems not dependent on either surface water or groundwater
  - 'Dryland remnant vegetation' landscape class: The 'Dryland remnant vegetation' landscape class is characterised by various woodland, shrubland and grassland communities that are not associated with the floodplain landscapes or other groundwater-dependent ecosystems or wetlands. Water requirements are derived from localised rainfall and runoff. These landscape classes are not considered to be water dependent in the Bioregional Assessment Programme. Vegetation in this landscape class shows no evidence of extensive mechanical or chemical disturbance and is considered 'remnant'.
- 'Floodplain or lowland riverine (including non-GAB GDEs)' landscape group: Ecosystems that are lowland alluvial plains
  - 'Floodplain remnant vegetation' landscape class: The 'Floodplain remnant vegetation' landscape class is characterised by ecosystems on recent alluvial systems and floodplains subject to periodic inundation. Vegetation is typically dominated by *Eucalyptus* or *Acacia* woodlands or open woodlands, with no evidence of groundwater dependence. This landscape class excludes floodplain palustrine and lacustrine wetlands. Vegetation in this landscape class shows no evidence of extensive mechanical or chemical disturbance and is considered 'remnant'.

- 'Floodplain, near-permanent wetland' landscape class: The 'Floodplain, near permanent wetland' landscape class is characterised by palustrine or lacustrine wetlands occurring on alluvial floodplains. These are areas of permanent or periodic/intermittent inundation (>80% of the time) with static or flowing water that is fresh. Water regimes are dominated by surface water inputs and there is no evidence of interaction with groundwater.
- 'Floodplain, non-GAB GDE' landscape class: The 'Floodplain, non-GAB GDE' landscape class is characterised by vegetation on alluvial floodplains. Vegetation may be dominated by Eucalyptus or Acacia woodlands with a dependence on groundwater. Vegetation in this landscape class shows no evidence of extensive mechanical or chemical disturbance and is considered 'remnant'.
- 'Floodplain, non-GAB GDE, near-permanent wetland' landscape class: The 'Floodplain, non-GAB GDE, near-permanent wetland' landscape class is characterised by palustrine or lacustrine wetlands occurring on alluvial floodplains. These floodplains are generally not associated with underlying bedrock of the Great Artesian Basin (GAB). These are areas of permanent or periodic/intermittent inundation (>80% of the time) with static or flowing water that is fresh. Water regimes are supported by inputs of surface water and groundwater.
- 'Floodplain, non-GAB GDE, temporary wetland' landscape class: The 'Floodplain, non-GAB GDE, temporary wetland' landscape class is characterised by palustrine or lacustrine wetlands occurring on alluvial floodplains. These are areas of periodic/intermittent inundation (<80% of the time) with static or flowing water that is fresh. Water regimes are supported by inputs of surface water and groundwater.
- 'Floodplain, temporary wetland' landscape class: The 'Floodplain, temporary wetland' landscape class is characterised by palustrine or lacustrine wetlands occurring on alluvial floodplains. These are areas of periodic/intermittent inundation (<80% of the time) with static or flowing water that is fresh. Water regimes are supported by inputs of surface water.
- 'Near-permanent, lowland stream' landscape class: The 'Near-permanent, lowland stream' landscape class is characterised by perennial or near-perennial (flow >70% of the time) streams in lowland areas. Water regimes are not supported by groundwater discharge.
- 'Temporary, lowland non-GAB GDE stream' landscape class: The 'Temporary, lowland non-GAB GDE stream' landscape class is characterised by intermittent (flow <70% of the time) streams in lowland areas. Water regimes are supported by groundwater discharge.
- 'Temporary, lowland stream' landscape class: The 'Temporary, lowland stream' landscape class is characterised by intermittent streams in lower catchment positions not dependent on groundwater. Flow regimes are intermittent to ephemeral (flow <70% of the time).

• 'GAB GDEs (riverine, springs, floodplain or non-floodplain)' landscape group: Ecosystems hydrologically connected to the Great Artesian Basin (GAB) aquifers via outcropping unweathered sandstone.

- ‘Floodplain, GAB GDE’ landscape class: The ‘Floodplain, GAB GDE’ landscape class is characterised by ecosystems that occur where recent alluvial deposits overlie outcropping unweathered sandstone of the Great Artesian Basin (GAB). Vegetation is typically groundwater-dependent Eucalyptus woodlands and forests. Vegetation in this landscape class shows no evidence of extensive mechanical or chemical disturbance and is considered ‘remnant’.
- ‘Floodplain, GAB GDE, near-permanent wetland landscape class: The ‘Floodplain, GAB GDE, near-permanent wetland’ landscape class is characterised by palustrine or lacustrine wetlands occurring on alluvial floodplains that overlie sedimentary bedrock of the Great Artesian Basin (GAB). These are areas of permanent or periodic/intermittent inundation (>80% of the time) with static or flowing water that is fresh. Water regimes are dominated by surface water inputs and there is no evidence of interaction with groundwater.
- ‘Floodplain, GAB GDE, temporary wetland’ landscape class: The ‘Floodplain, GAB GDE, temporary wetland’ landscape class is characterised by palustrine or lacustrine wetlands occurring on alluvial floodplains that overlie sedimentary bedrock of the Great Artesian Basin (GAB). These are areas of periodic/intermittent inundation (<80% of the time) with static or flowing water that is fresh. Water regimes are supported by inputs of surface water and groundwater.
- ‘Non-floodplain, GAB GDE’ landscape class: The ‘Non-floodplain, GAB GDE’ landscape class is characterised by ecosystems that occur in areas of outcropping sandstones associated with Great Artesian Basin (GAB) aquifers. Fractures, inter-granular pores and localised weathering provide localised groundwater resources that support *Eucalyptus*, *Corymbia* and *Angophora* forests and woodlands. Vegetation in this landscape class shows no evidence of extensive mechanical or chemical disturbance and is considered ‘remnant’.
- ‘Non-floodplain, GAB GDE, near-permanent wetland’ landscape class: The ‘Non-floodplain, GAB GDE, near-permanent wetland’ landscape class is characterised by near-permanent wetlands (wet >80% of the time) that occur in upland areas off floodplains on outcropping unweathered sandstone associated with the Great Artesian Basin (GAB). Water regimes are supported by localised groundwater discharge.
- ‘Non-floodplain, GAB GDE, temporary wetland’ landscape class: The ‘Non-floodplain, GAB GDE, temporary wetland’ landscape class is characterised by temporary wetlands (wet <70% of the time) that occur in upland areas off floodplains on outcropping unweathered sandstone associated with the Great Artesian Basin (GAB). Water regimes are supported by localised groundwater discharge.
- ‘Temporary, lowland GAB GDE stream’ landscape class: The ‘Temporary, lowland GAB GDE stream’ landscape class is characterised by temporary lowland streams associated with outcropping unweathered sandstone of the Great Artesian Basin (GAB). A component of baseflow or pools within the streams may be maintained by groundwater discharge.
- ‘Temporary, upland GAB GDE stream’ landscape class: The ‘Temporary, upland GAB GDE stream’ landscape class is characterised by temporary upland streams associated with

outcropping unweathered sandstone of the Great Artesian Basin (GAB). A component of baseflow or pools within the streams may be maintained by groundwater discharge.

  - 'GAB springs' landscape class: The 'GAB Springs' landscape class is characterised by springs that occur where groundwater discharges to the surface either as rejected recharge from upslope sandstone bedrock or where artesian water under pressure is discharged to the land surface.

- 'Human-modified' landscape group: Typically characterised by land with significant human modification (i.e. evidence of extensive mechanical or chemical disturbance)
  - 'Conservation and natural environments' landscape class: The 'Conservation and natural environments' landscape class is characterised by lands where the primary land use is typically natural conservation (e.g. nature reserve), managed resource protection (e.g. surface water supply) or minimal use (e.g. stock route). However, vegetation in this landscape class shows evidence of extensive mechanical or chemical disturbance and is considered 'non-remnant'.
  - 'Intensive uses' landscape class: The 'Intensive uses' landscape class is characterised by land uses that involve high levels of interference with natural processes. These land uses include transport infrastructure (roads, railways), urban infrastructure (houses, factories), intensive horticulture (glasshouses), and animal husbandry (poultry farms).
  - 'Production from dryland agriculture and plantations' landscape class: The 'Production from dryland agriculture and plantations' landscape class is characterised by land used primarily for dryland primary production including cropping, grazing and forest plantations. Native vegetation has been substantially modified and replaced by introduced species.
  - 'Production from irrigated agriculture and plantations' landscape class: The 'Production from irrigated agriculture and plantations' landscape class is characterised by land used primarily for irrigated agriculture including perennial horticulture and irrigated cropping. Native vegetation has been substantially modified and replaced by introduced species.
  - 'Production from relatively natural environments' landscape class: The 'Production from relatively natural environments' landscape class is characterised by land use that includes grazing native vegetation and production forests. Vegetation in this landscape class shows evidence of extensive mechanical or chemical disturbance and are classified as 'non-remnant'.
  - 'Water' landscape class: The 'Water' landscape class is characterised by water features important for natural resource management, agricultural production and as points of reference in the landscape. This landscape class includes both natural and artificial water bodies that are not otherwise defined in this classification.
- 'Non-floodplain or upland riverine (including non-GAB GDEs)' landscape group: Groundwater-dependent ecosystems (GDEs) not associated with floodplains or outcropping bedrock of the Great Artesian Basin (GAB)
  - 'Non-floodplain, near-permanent wetland' landscape class: The 'Non-floodplain, near-permanent wetland' landscape class is characterised by near-permanent wetlands (wet >80% of the time). These ecosystems are typically associated with basalts of the Main

Range Volcanics or other geological units not associated with the Great Artesian Basin (GAB). Landscapes in this landscape class are not considered to be groundwater dependent.

- 'Non-floodplain, non-GAB GDE' landscape class: The 'Non-floodplain, non-GAB GDE' landscape class is characterised by communities associated with inland sand ridges or permeable basalts of the Main Range Volcanics. Vegetation communities are composed of *Eucalyptus*, *Melaleuca* or *Corymbia* woodlands and forests. Vegetation in this landscape class shows no evidence of extensive mechanical or chemical disturbance and is considered 'remnant'.
- 'Non-floodplain, non-GAB GDE, near-permanent wetland' landscape class: The 'Non-floodplain, non-GAB GDE, near-permanent wetland' landscape class is characterised by near-perennial wetlands (wet >80% of the time). These ecosystems are typically associated with basalts of the Main Range Volcanics or other geological units not associated with the Great Artesian Basin (GAB). Water regimes are supported by groundwater discharge.
- 'Non-floodplain, non-GAB GDE, temporary wetland' landscape class: The 'Non-floodplain, non-GAB GDE, temporary wetland' landscape class is characterised by temporary wetlands (wet <80% of the time). These ecosystems are typically associated with basalts of the Main Range Volcanics or other geological units not associated with the Great Artesian Basin (GAB). Water regimes are supported by groundwater discharge, although to a lesser extent than the near-permanent wetlands.
- 'Non-floodplain, temporary wetland' landscape class: The 'Non-floodplain, temporary wetland' landscape class is characterised by temporary palustrine or lacustrine wetlands off floodplains and are not associated with the unweathered bedrock of the Great Artesian Basin (GAB). Water regimes are not supported by groundwater.
- 'Non-GAB springs' landscape class: The 'Non-GAB springs' landscape class is characterised by springs associated with basalt of the Main Range Volcanics.
- 'Near-permanent, upland stream' landscape class: The 'Near-permanent, upland stream' landscape class is characterised by perennial or near-perennial streams in upland areas associated with outcropping bedrock other than unweathered sandstone. The flow is more than 70% of the time and groundwater discharge contributes to the maintenance of baseflow.
- 'Temporary, upland non-GAB GDE stream' landscape class: The 'Temporary, upland non-GAB GDE stream' landscape class is characterised by intermittent or ephemeral streams (flow <70% of the time) in upland areas not associated with the outcropping Great Artesian Basin (GAB). Baseflow or pools within this landscape class may be supported by groundwater discharge.
- 'Temporary, upland stream' landscape class: The 'Temporary, upland stream' landscape class includes intermittent to ephemeral streams (flow <70% of the time) in upland areas not associated with outcropping bedrock of the Great Artesian Basin (GAB). Water regimes are dominated by surface water inputs.

4. Risk analysis for the Maranoa-Balonne-Condamine subregion

Originally the risk analysis was intended to be reported independently of the impact analysis. Instead it has been combined with the impact analysis as product 3-4 to improve readability. For risk analysis see Section 3 of this product.

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