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BIOREGIONAL ASSESSMENTS

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

Assessing impacts of coal resource development on water resources in the Maranoa-Balonne-Condamine subregion: key findings

Product 5: Outcome synthesis 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

Explore this assessment

Bioregional assessments 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. These regional-scale assessments focus on 13 areas across Queensland, NSW, Victoria and SA where coal resource development is taking place, or could take place.

The assessments identify areas 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 assessments investigate:

- the characteristics of the subregion, including water resources, assets, and coal and CSG resources (Component 1)
- how future coal resource development could affect surface water and groundwater (Component 2)
- how hydrological changes could impact on water-dependent landscapes and assets (Component 3 and Component 4).

The assessment of the **Maranoa-Balonne-Condamine subregion,** which is part of the Northern Inland Catchments Bioregional Assessment, comprises eight technical products (Box 1), which are summarised in this synthesis.

Throughout this synthesis, 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 (Box 6).

Box 1 Technical products for the Maranoa-Balonne-Condamine subregion

Component 1: Contextual information
1.1 Context statement
1.2 Coal and coal seam gas resource assessment
1.3 Description of the water-dependent asset register
1.5 Current water accounts and water quality
1.6 Data register

Component 2: Model-data analysis
2.3 Conceptual modelling
2.6.2 Groundwater numerical modelling

Component 3 and Component 4: Impact and risk analysis
3-4 Impact and risk analysis

The pages of this synthesis follow this colour guide when describing the assessment outputs. Product 2.1-2.2 (observations analysis, statistical analysis and interpolation), product 2.5 (water balance assessment), product 2.6.1 (surface water numerical modelling) and product 2.7 (receptor impact modelling) were not produced for this subregion. Product 1.4 (receptor register) and product 2.4 (two- and three-dimensional visualisations) were not produced for any bioregional assessment as evolution of the methods rendered them obsolete.

FIND MORE INFORMATION

www.bioregionalassessments.gov.au includes all technical products as well as information about all datasets used or created, most of which can be downloaded from data.gov.au. Additional resources are listed in this synthesis, and include methodologies, maps, models and lists of water-dependent assets, landscape classes and potential hazards. At www.bioregionalassessments.gov.au/explorer/MBC, users can visualise where potential impacts might occur using a map-based interface. References, further reading and datasets are listed at the end of this synthesis.

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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)

Box 2 Investigating two futures

Results are reported for two potential futures:

- **baseline coal resource development (baseline):** 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 the **additional coal resource development** (those coal mines that were expected to begin commercial production after December 2012, including expansions of baseline operations).

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

The CRDP for the Maranoa-Balonne-Condamine subregion was based on information available as of July 2015. However, coal resource developments may change over time or be withdrawn, or timing of developments may change. Factors such as climate change or land use were held constant between the two futures. Although actual climate or land use may differ, the effect on results is expected to be negligible as the assessment focused on the difference in the results between the CRDP and baseline.

Executive summary

About the subregion *see p. 2*

This synthesis presents the key findings from the bioregional assessment of the Maranoa-Balonne-Condamine subregion, part of the Northern Inland Catchments bioregion.

The Maranoa-Balonne-Condamine subregion covers 144,890 square kilometres (km^2) of the Murray–Darling Basin in Queensland and NSW (Figure 1). Land is predominantly used for agriculture, with groundwater used for stock and domestic purposes, town water supply and irrigated agriculture. The subregion contains seasonal, semi-permanent and permanent wetlands and lagoons, including some nationally significant wetlands.

Open-cut coal mines in the subregion access the relatively shallow Walloon Coal Measures of the Surat and Clarence-Moreton geological basins in the east. Coal seam gas (CSG) is extracted from the deeper resources of the Walloon Coal Measures between Roma and Millmerran (Figure 1). The groundwater model encompasses the 129,956 km^2 **assessment extent**.

Potential hydrological changes *see p. 8*

Queensland's Office of Groundwater Impact Assessment (OGIA) groundwater model (Box 3) was adapted for this assessment to predict the potential cumulative impacts of existing (baseline) and proposed (additional) coal resource development. Surface water modelling was not carried out for this assessment.

Hydrological modelling identified changes in groundwater for two futures (Box 2). The **baseline** future includes five open-cut coal mines and five CSG fields. The **coal resource development pathway** (CRDP) future includes baseline coal resource developments and two **additional coal resource developments** that are open-cut coal mines: New Acland Coal Mine Stage 3 south-east of Dalby, which is an expansion of the baseline New Acland Coal Mine, and The Range coal mine between Taroom and Chinchilla. The difference between groundwater drawdown under these two futures is due to the additional coal resource developments.

Near the proposed New Acland Coal Mine Stage 3, predicted drawdown in the **regional watertable** (which represents the upper groundwater level within the near-surface aquifer) is related to the existing and proposed New Acland Coal Mine operations. Drawdown predicted near The Range coal mine is due to the cumulative impact of the proposed mine and existing CSG development, and may require further assessment of potential cumulative impacts at a local scale.

To rule out potential impacts to water-dependent landscapes and assets, such as wetlands or bores, the impact and risk analysis used a threshold of at least a 5% chance of greater than 0.2 metres (m) drawdown due to additional coal resource development (Box 5). This conservative threshold matches state regulations (Box 9). Drawdown due to additional coal resource development exceeds this threshold in an area of 1544 km^2 (1.2% of the total area investigated, shown in Figure 1 as the **assessment extent**). This includes 1095 km of streams (1.8% of all streams in the assessment extent).

Potential impacts *see p. 15*

Potential impacts due to additional coal resource development are *very unlikely* (less than 5% chance, see Box 6) for:

- the source aquifer of any of the 177 springs in the assessment extent
- the source aquifer of 9827 of the 9990 groundwater bores (economic assets) in the assessment extent.

Additional coal resource development might affect:

- 41 ecosystems, including regional ecosystems and the potential habitats of threatened species and ecological communities
- 163 bores that are contained in 7 water access rights and 6 basic water rights (stock and domestic)
- one of the 135 sociocultural assets in the assessment extent, the Barakula State Forest, near Miles in Queensland.

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 assets. Integrating the groundwater model with a surface water model would provide further information about impacts on surface water.

About the subregion

The Maranoa-Balonne-Condamine subregion covers 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 (Figure 1). The main population centres are Chinchilla, Dalby, Goondiwindi, Roma, St George, Toowoomba and Warwick.

This assessment focused on water-dependent landscapes and assets that are potentially impacted by changes in groundwater due to additional coal resource development (Box 2). The assessment extent covers an area of 129,956 km^2.

The main natural and human-modified ecosystems in the assessment extent were categorised in a landscape classification (Box 7), which was based on the subregion's geology; the physical features of the region, known as geomorphology; hydrogeology, which describes the way water moves underground; land use; and ecology. See 'What are the potential impacts of additional coal resource development on the landscape?' (p. 15) for more information.

Assets were identified for their ecological, economic, or sociocultural values, such as a wetland providing habitat for waterbirds, river water used for agriculture, or a sacred site with cultural significance. See 'What are the potential impacts of additional coal resource development on water-dependent assets?' (p. 19) for more information.

Important groundwater systems in the subregion are alluvial aquifers associated with major rivers, including the Condamine Alluvium; basalt aquifers associated with the Main Range Volcanics geological formation; and the deeper confined aquifers of the Surat Basin, which are part of the larger Great Artesian Basin (GAB).

Coal resource development

Key finding 1: The coal resource development pathway (Box 2) is the most likely future for the subregion and includes five baseline open-cut coal mines, five baseline coal seam gas 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.

Coal is extracted from open-cut mines in the Clarence-Moreton and Surat geological basins. Although the southern part of the Bowen Basin underlies the Surat Basin in the subregion, it contains no economic coal deposits. The major coal deposits in the Walloon Coal Measures in the Surat Basin occur near Brigalow, Chinchilla and Macalister.

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) (Figure 1).

CSG is extracted from the deeper resources of the Walloon Coal Measures of the Surat Basin in the central-northern and central-eastern part of the subregion between Roma and Millmerran. No significant reserves of CSG are known in the most north-western part and the eastern part of the subregion due to the proximity to the margins of the geological basin.

CSG development in the subregion has escalated in the recent past, as illustrated by construction of three large-scale liquified natural gas (LNG) export plants on Curtis Island near Gladstone, Queensland. A large portion of the gas to be supplied to the LNG plants will be extracted from the Walloon Coal Measures in the subregion and transported to Curtis Island via pipelines. (LNG is any type of natural gas, such as CSG, that has been cooled into liquid form for storage and transport.)

For this assessment, the five CSG gas fields included in the baseline are Australia Pacific LNG Project, Santos Gladstone LNG Project, Queensland Curtis LNG Project, Surat Gas Project and Ironbark Project. To be consistent with OGIA, the CSG developments reported in Queensland's Office of Groundwater Impact Assessment (OGIA) *Annual report 2014 for the Surat underground water impact report* (OGIA, 2014) are all deemed to be in the baseline even though the Ironbark and Surat Gas projects had not commenced commercial operation as of December 2012 (which is the standard cut-off to be included in the baseline). The timeline of construction and production for each coal resource development represented in the adapted OGIA groundwater model is shown in Figure 2.

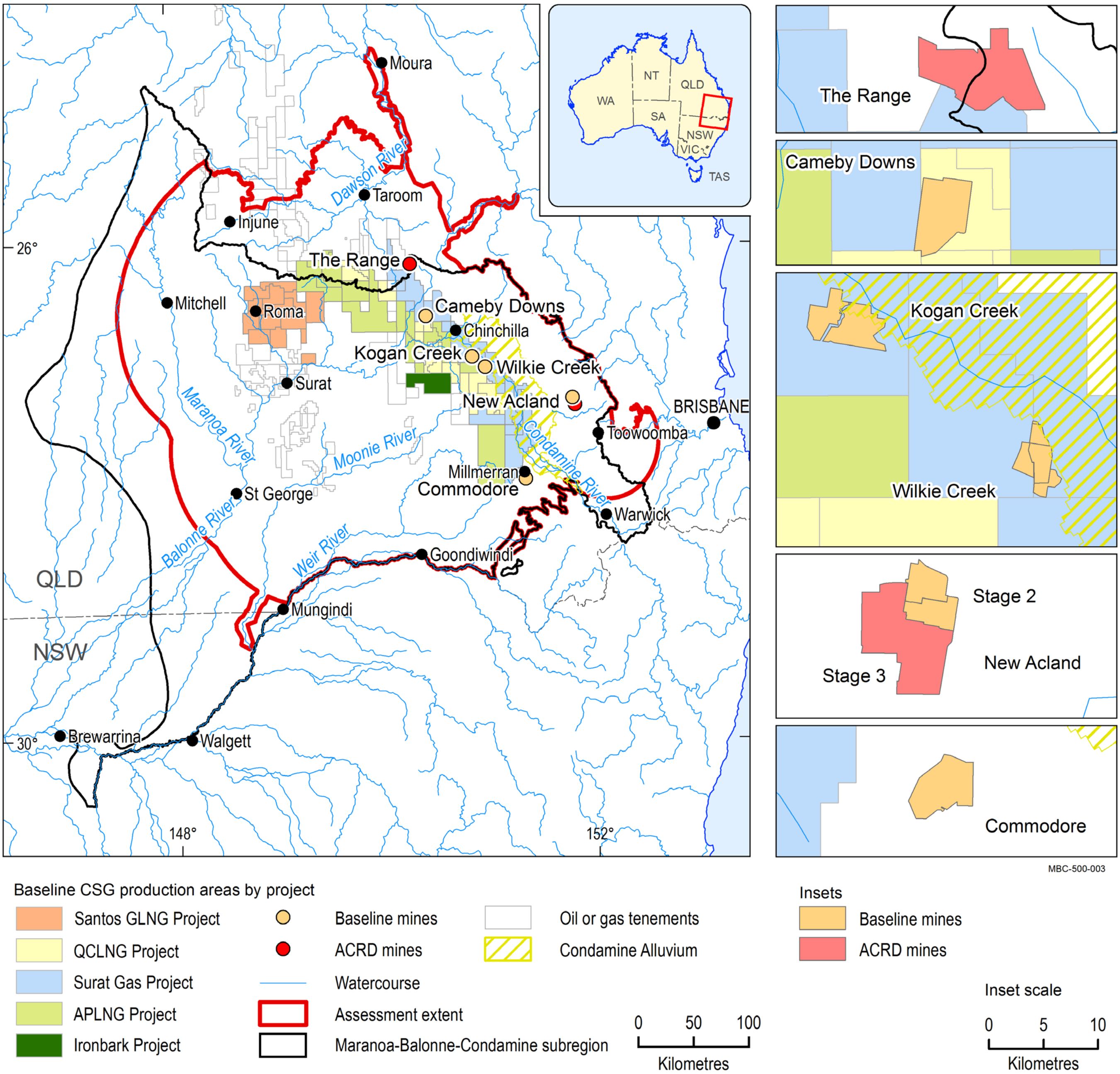


Figure 1 Baseline and additional coal resource developments included in the coal resource development pathway

Coal seam gas (CSG) production is shown by the extent of petroleum and gas tenures, which are all in the baseline. Some of these 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 coal resource developments 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), Queensland Department of Natural Resources and Mines (Dataset 2)

The CRDP for the subregion (Box 2) is based on known coal resource development proposals as of July 2015. However, proposals may have changed since then and may continue to change into the future.

This assessment focused on the potential cumulative impact of the two proposed open-cut coal mines, referred to as additional coal resource development: New Acland Coal Mine Stage 3, an extension to the existing New Acland Coal Mine in the east, and The Range, a proposed open-cut coal mine in the north of the subregion.

FIND MORE INFORMATION

Context statement, product 1.1 (Welsh et al., 2014)

Coal and coal seam gas resource assessment, product 1.2 (Sander et al., 2014)

Description of the water-dependent asset register, product 1.3 (Mitchell et al., 2015)

Water-dependent asset register (Bioregional Assessment Programme, 2017)

Conceptual modelling, product 2.3 (Holland et al., 2016)

Groundwater numerical modelling, product 2.6.2 (Janardhanan et al., 2016)

Compiling water-dependent assets, submethodology M02 (Mount et al., 2015)

Developing a coal resource development pathway, submethodology M04 (Lewis, 2014)

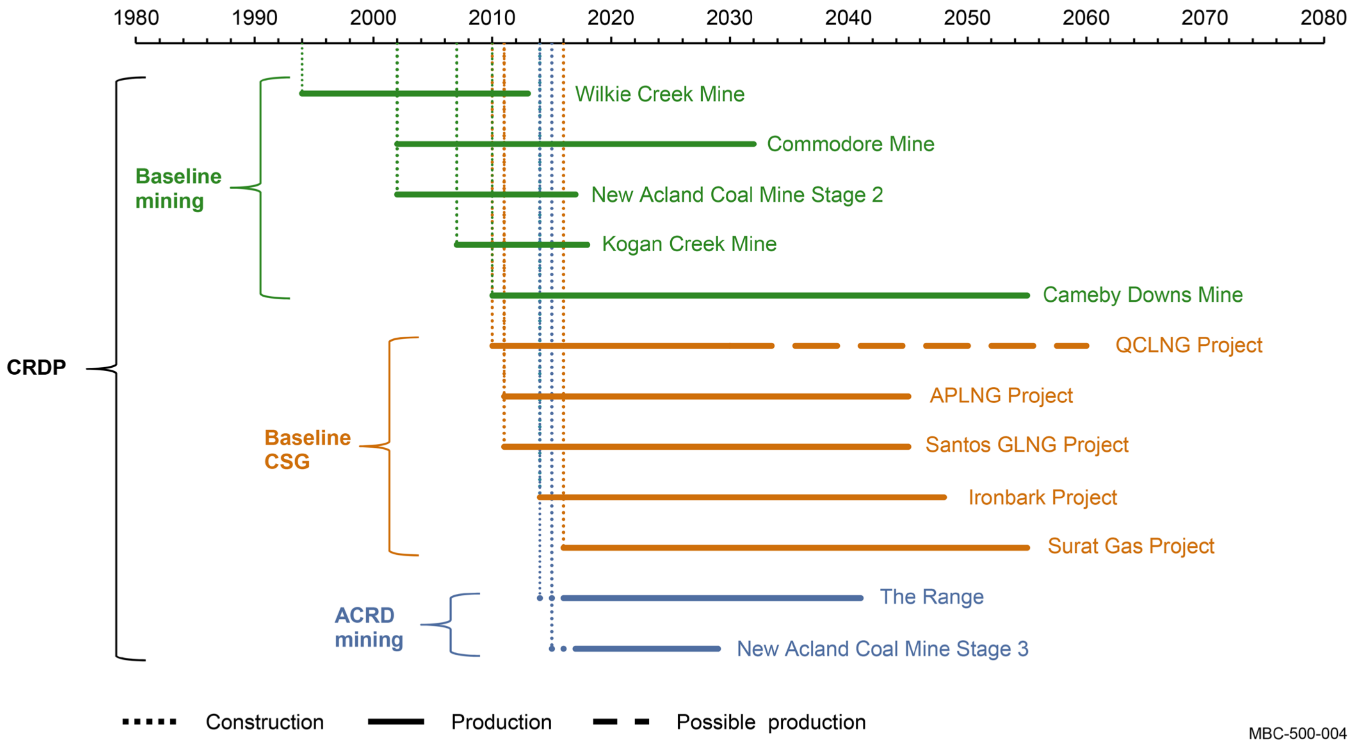


Figure 2 Timeline of baseline and additional coal resource developments for the Maranoa-Balonne-Condamine subregion

For the baseline coal seam gas (CSG) projects, construction and production occurs concurrently due to the staged development process. The coal resource developments in the CRDP are the sum of those in the baseline and the additional coal resource development (ACRD). 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

How could coal resource development result in hydrological changes?

The assessment identified potential hazards (Dataset 6) associated with coal resource development that could result in hydrological changes, such as aquifer depressurisation due to groundwater extraction. Hazards in scope were further assessed by first estimating relevant hydrological changes through groundwater modelling and then identifying potential impacts on, and risks to, water-dependent landscapes and assets (described in the following sections).

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 units or layers, as shown in Figure 3 and Figure 4. 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 consequences for surface ecosystems surrounding springs.

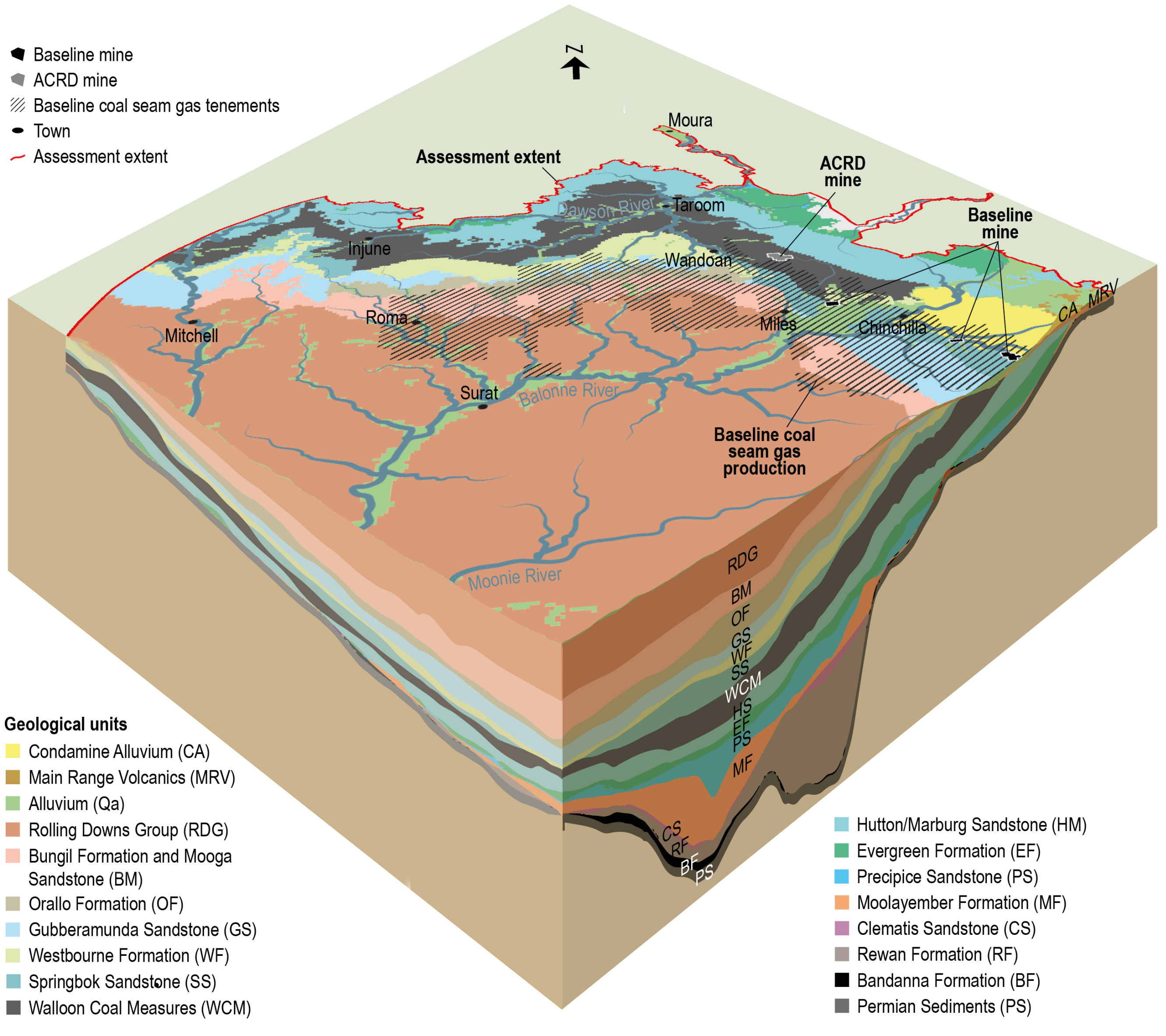


Figure 3 The cross-sections of the geological units (in the Bowen, Surat and Clarence-Moreton geological basins) that are in the regional watertable, and the locations where units outcrop at the surface towards the north and east of the subregion

ACRD = additional coal resource development

Data: Bioregional Assessment Programme (Dataset 1, Dataset 3, Dataset 4); Queensland Department of Natural Resources and Mines (Dataset 2); Queensland Office of Groundwater Impact Assessment (Dataset 5)

After the potential hazards were identified, the chain of events that commonly arise from coal resource development activities were analysed and categorised into four main causal pathway groups (Figure 4):

A. **'Subsurface depressurisation and dewatering'** includes extraction of groundwater to enable CSG extraction and dewatering of open-cut mine pits. It has the potential to directly affect the regional groundwater system, and indirectly affect surface water – groundwater interactions in aquifer outcrop areas. Potential effects are likely to be in the medium term (5 to 10 years) to long term (10 to 100 years).

B. **'Subsurface physical flow paths'** includes activities where physical changes to the rock mass or geological layers create new physical paths that water may potentially gain access to and flow along. Potential effects are in the medium to long term and are likely to be restricted to aquifer or aquifer outcrop areas, but can also affect connected watercourses within and downstream of mines.

C. **'Surface water drainage'** includes activities that physically disrupt the surface and near-surface materials (vegetation, topsoil, weathered rock). Medium- to long-term cumulative effects are possible for watercourses within and downstream of development. Activities may include construction of diversion walls and drains, interception of runoff, realignment of streams, and groundwater extraction for CSG production or underground coal mining leading to subsidence of land surface.

D. **'Operational water management'** involves modification of surface water systems to allow storage, disposal, processing and use of extracted water. Potential effects are likely to be in the medium to long term and include watercourses in aquifer outcrop areas that are within and downstream of operations.

Hazards not in scope include those that are adequately addressed by site-based risk management, such as accidents.

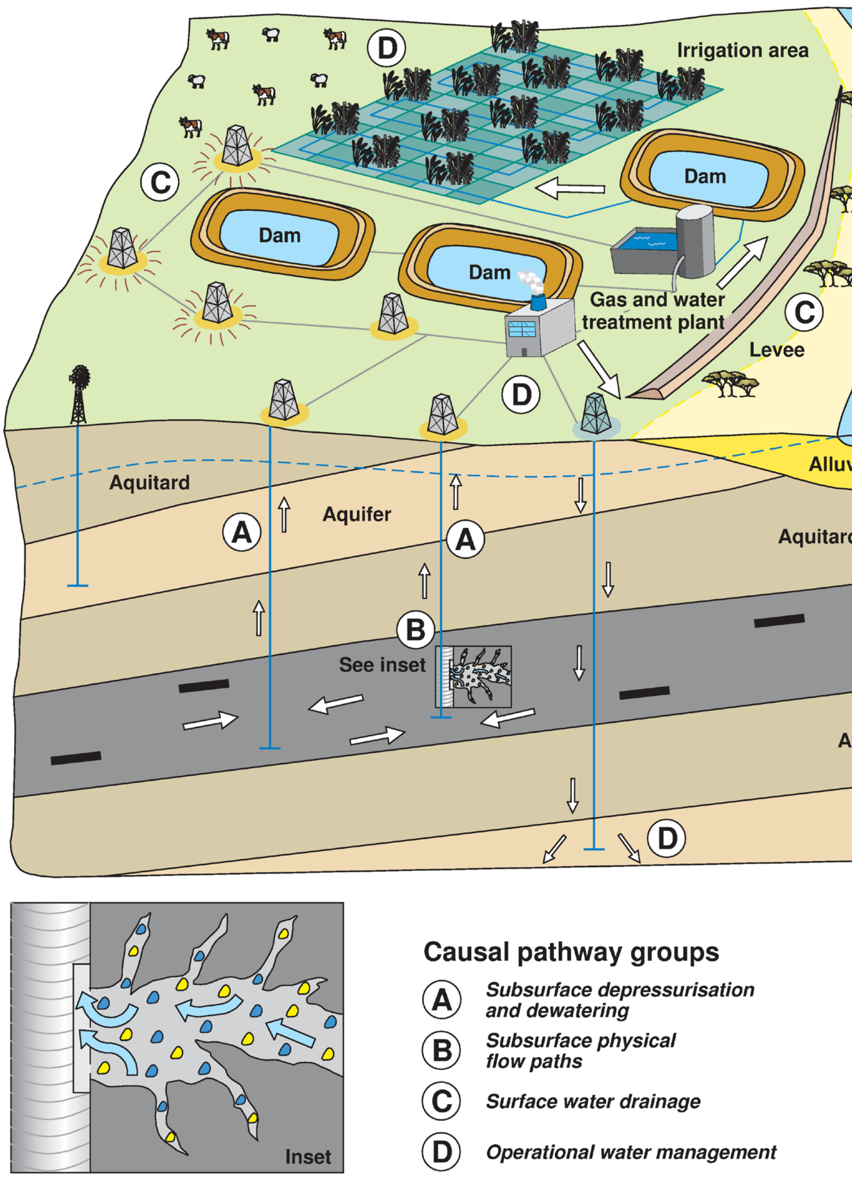


Figure 4 Conceptual diagram of the causal pathway groups associated with co

This schematic diagram is not drawn to scale. To improve clarity the potentiometric surf
predominantly composed of water (blue) and sand (yellow), with minor amounts of che
permeability of the coal seam, enabling larger volumes of gas and water to be pumped

FIND MORE INFORMATION

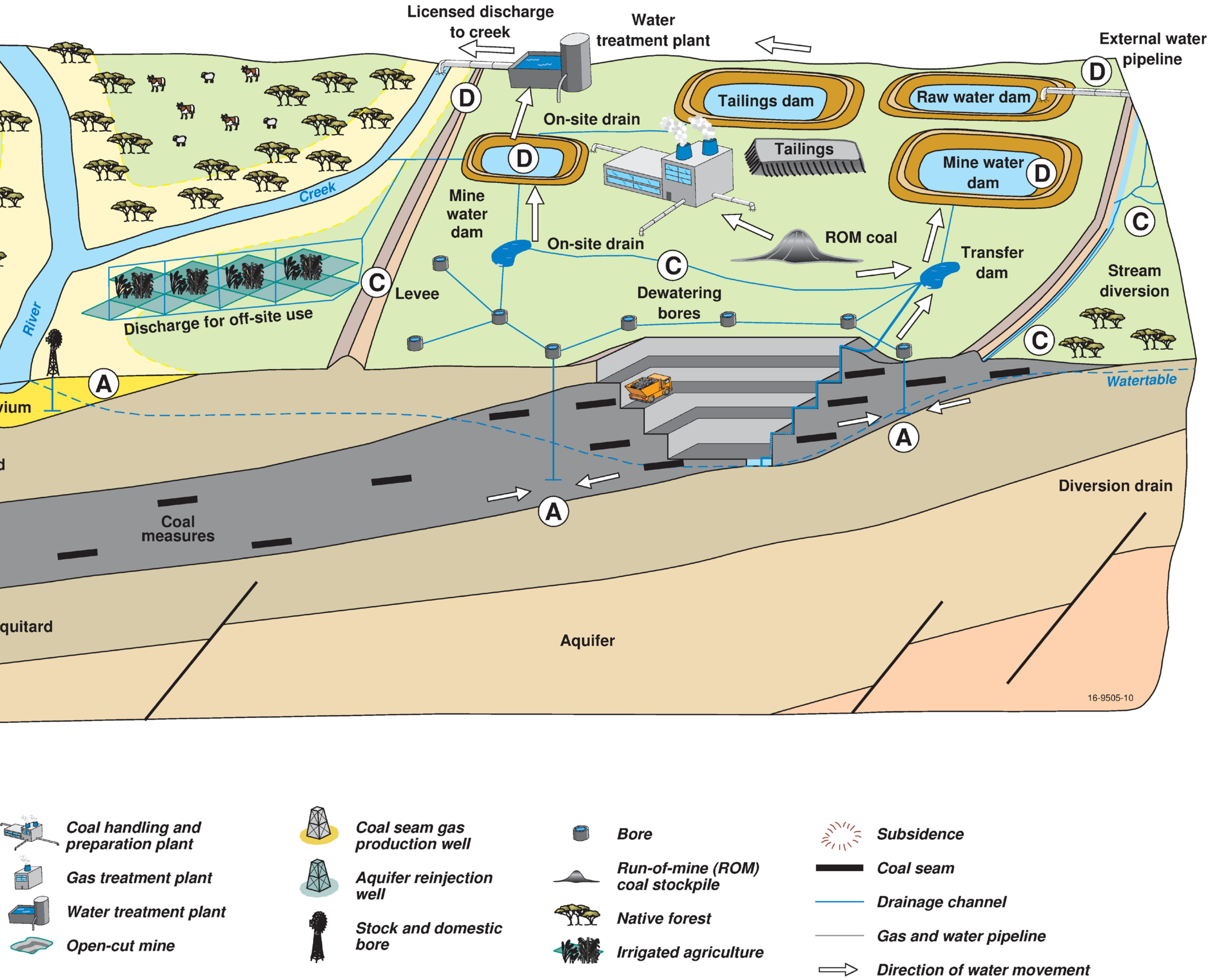
Conceptual modelling, product 2.3 (Holland et al., 2016)

Groundwater numerical modelling, product 2.6.2 (Janardhanan et al., 2016)

Developing a conceptual model for causal pathways, submethodology M05 (Henderson et al., 2016)

Systematic analysis of water-related hazards associated with coal resource development, submethodology M11 (Ford et al., 2016)

Impact Modes and Effects Analysis (hazard analysis) for the Maranoa-Balonne-Condamine subregion (Dataset 6)



oal seam gas operations and open-cut coal mines for the Maranoa-Balonne-Condamine subregion

face for the deeper confined aquifer is not shown. The inset schematic shows hydraulic fracturing of a coal seam, where a mixture emical additives, is injected at high pressure into the well to produce small cracks in the coal (lighter grey zone). This process enhances the from the well.

What are the potential hydrological changes?

In the Maranoa-Balonne-Condamine subregion, modelled hydrological changes are limited to groundwater because the groundwater model's (Box 3) limited capabilities with respect to simulating surface water – groundwater interactions meant that surface water modelling was not carried out for this assessment.

Figure 7 shows that baseline drawdown in the **regional watertable** is typically less than 20 m and occurs in the east and north of the subregion. Median baseline drawdown in the regional watertable is less than 3 m in the vicinity of New Acland Coal Mine and less than 8 m in the vicinity of The Range coal mine (Table 1).

Groundwater modelling (Box 3) showed that additional coal resource development potentially causes hydrological changes in the regional watertable within an area of 1631 km^2 (Figure 8 and Figure 9). This means the regional watertable is predicted to have a greater than 5% chance of exceeding 0.2 m additional drawdown (Box 4) over 1631 km^2. Subsequently in this synthesis the extent within the zone of potential hydrological change is reported as 1544 km^2, excluding the 87 km^2 within the modelled open-cut mine pits that are not included in the analysis.

Within this **zone of potential hydrological change** (Box 5), these additional coal resource developments might affect water-dependent landscapes and assets. Outside the zone, the hydrological changes are *very unlikely* (less than 5% chance, see Box 6) to have an appreciable impact on water-dependent landscapes or assets.

Key finding 2: 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.

Key finding 3: Drawdown in the regional watertable due to additional coal resource development has at least a 5% chance of exceeding 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).

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. This area is 11 times larger than the equivalent area due to additional coal resource development (1544 km^2).

Most ecological assets source water from the regional watertable. Results are also reported in Table 1 and Figure 11 for the Walloon Coal Measures and Hutton/Marburg Sandstone to indicate potential impacts on groundwater bores that access these deeper layers.

Box 3 Understanding the groundwater model

This assessment adopted the Office of Groundwater Impact Assessment's (OGIA) 2012 model and the CSG development profile from OGIA's *Annual report 2014 for the Surat underground water impact report* (OGIA, 2014). OGIA's most recent model from 2016 (OGIA, 2016) was not available for this assessment. 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 2.25 km^2 grid cells. The area within modelled pits is not reported in this synthesis.

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). Originally established to assess groundwater impacts from petroleum and gas resource developments, including both conventional hydrocarbon resources and unconventional resources such as CSG, OGIA has undertaken cumulative assessments to capture the CSG footprints for the Surat and southern Bowen basins in 2012 and 2016. These are reported through underground water impact reports (UWIRs). The assessments include predicted impacts on water supply bores and springs.

OGIA developed regional groundwater flow models to underpin cumulative assessments for the two UWIRs: one in 2012 (QWC, 2012) and a revised one in 2016 (OGIA, 2016; not available for this assessment). The models were built for regional groundwater impact assessment in aquifers overlying and underlying the CSG target formations.

Impacts on baseline drawdown in the Condamine Alluvium are estimated using the integrated Condamine and regional models (QWC, 2012). Additional drawdown is very *unlikely* to exceed 0.2 m in the Condamine Alluvium (Janardhanan et al., 2017).

In the Maranoa-Balonne-Condamine subregion, maximum **baseline drawdown** in the **Walloon Coal Measures** is predicted between the towns of Chinchilla and Roma (Janardhanan et al., 2016). This geological layer is 200 to 1000 m below the surface in this area and is the target for CSG development. In the vicinity of the two additional coal resource developments (Table 1 and Figure 11), an area of 2545 km^2 has at least a 5% chance of exceeding 0.2 m additional drawdown in the **Walloon Coal Measures**. An area of 2111 km^2 has this level of additional drawdown in the **Hutton/Marburg Sandstone**.

Table 1 Areas and range of median drawdown values under the baseline and due to additional coal resource development in the vicinity of New Acland Coal Mine Stage 3 and of The Range coal mine

Model layer	Area or range of groundwater drawdown values	New Acland Coal Mine Stage 3		The Range coal mine	
		Baseline	Additional	Baseline	Additional
Modelled mine pits	Pit area (km^2)	16	45	0	43
Regional watertable	Median drawdown (m)	0.0–3.0	0.0–65.0	0.2-8.3	0.1–10.2
	Zone area (km^2)	na	134	na	1409
Walloon Coal Measures	Median drawdown (m)	0.0–3.6	0.0–24.9	0.2–82.0	0.1–10.2
	Zone area (km^2)	na	849	na	1696
Hutton/Marburg Sandstone	Median drawdown (m)	0.0–0.7	0.1–1.7	0.2–1.1	0.1–0.2
	Zone area (km^2)	na	750	na	1361

The regional watertable in the zone includes the alluvium, Main Range Volcanics and outcropping areas of the Walloon Coal Measures and Hutton/Marburg Sandstone geological layers (Figure 3).
Median is a 50% chance (Box 6).
Zone area is the area outside of modelled mine pits with at least a 5% chance of exceeding 0.2 m drawdown due to additional coal resource development in the relevant aquifer.
'Baseline' is 'baseline coal resource development' and 'additional' is 'additional coal resource development'.
na = not applicable
Data: Bioregional Assessment Programme (Dataset 7, Dataset 8, Dataset 9)

Box 4 Calculating groundwater drawdown

Drawdown is a lowering of the groundwater level, caused, for example, by pumping. The groundwater model (Box 3) predicts drawdown under the CRDP and drawdown under the baseline (**baseline drawdown**). The difference in drawdown between the CRDP and baseline futures (referred to as **additional drawdown**) is 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 the watertable.

The maximum drawdown over the course of the groundwater model simulation (from 2013 to 2102) is reported for each 2.25 km^2 grid cell individually, and is expected to occur at different times across the area assessed. It is not expected that the year of maximum baseline drawdown coincides with the year of maximum additional drawdown. Therefore, simply adding the two figures will result in a drawdown that is not expected to eventuate.

Box 5 The zone of potential hydrological change

The predicted drawdown (Box 4) was used to define a zone to 'rule out' potential impacts. The zone is the area with at least a 5% chance of greater than 0.2 m drawdown due to additional coal resource development (Figure 8 and Figure 9). This threshold is consistent with the most conservative minimal impact thresholds in NSW and Queensland state regulations (Box 9). Because surface water modelling was not undertaken for this subregion, only groundwater hydrological changes were used to define the zone.

The zone was defined by changes in the regional watertable from which most ecological assets source water. Water-dependent landscapes and ecological assets outside of this zone are *very unlikely* to experience any hydrological change due to additional coal resource development. Within the zone, potential impacts may need to be considered further in the impact and risk analysis and smaller-scale analyses that take into account local conditions.

The zone of potential hydrological change was also defined for deeper geological layers (Figure 11) so that potential impacts can be identified for springs and groundwater bores that access these layers.

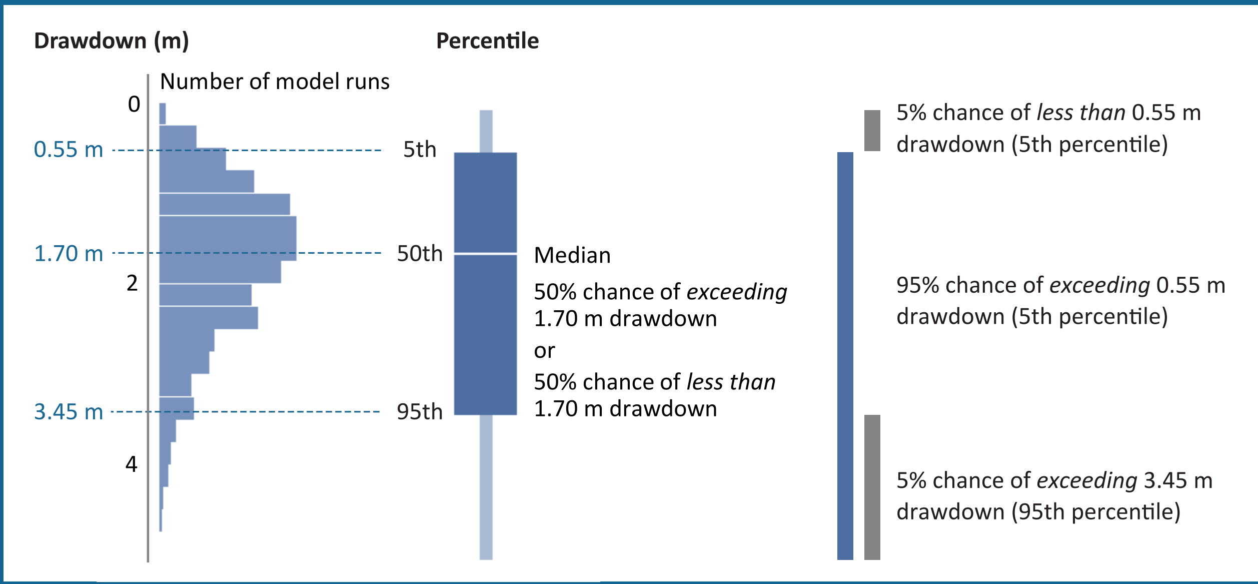


Figure 5 Illustrative example of probabilistic drawdown results using percentiles and percent chance

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.

Box 6 Understanding probabilities

The models used in the assessment produced a large number of predictions of groundwater drawdown rather than a single number. This results in a range or distribution of predictions, which are typically reported as probabilities – the percent chance of something occurring (Figure 5). This approach allows an assessment of the likelihood of exceeding a given magnitude of change, and underpins the assessment of risk.

Hydrological models require information about physical properties such as the thickness of geological layers and how porous aquifers are. It is unknown how these properties vary across the entire assessment extent (both at surface and at depth), and therefore the hydrological models were run thousands of times using different sets of values from credible ranges of those physical properties each time. The model runs were optimised to reproduce historical observations, such as groundwater level and changes in water movement and volume.

A narrow range of predictions indicates more agreement between the model runs, which enables decision makers to anticipate potential impacts more precisely. A wider range indicates less agreement between the model runs and hence more uncertainty in the outcome.

The distributions created from these model runs are expressed as probabilities that hydrological response variables (such as drawdown) exceed relevant thresholds, as there is no single 'best' estimate of change.

In this assessment, the estimates of drawdown are shown as a 95%, 50% or 5% chance of exceeding thresholds. Throughout this synthesis, the term '*very likely*' is used to describe where there is a greater than 95% chance that the model results exceed thresholds, and '*very unlikely*' is used where there is a less than 5% chance. While models are based on the best available information, if the range of parameters used is not realistic, or if the modelled system does not reflect reality sufficiently, these modelled probabilities might vary from the actual changes that occur in reality. These regional-level models provide evidence to 'rule out' potential cumulative impacts due to additional coal resource development in the future.

The assessment extent was divided into smaller square assessment units and the probability distribution (Figure 5) was calculated for each. In this synthesis, results are reported with respect to the following key areas (Figure 6):

A. outside the zone of potential hydrological change, where hydrological changes (and hence impacts) are *very unlikely* (defined by maps showing the 5% chance)

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 5% chance). 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 50% chance)

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 95% chance).

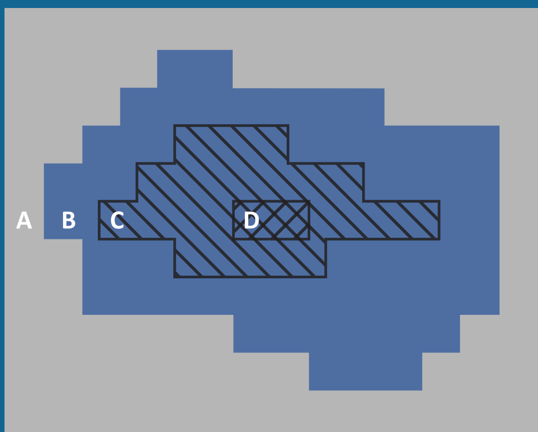


Figure 6 Key areas for reporting probabilistic results

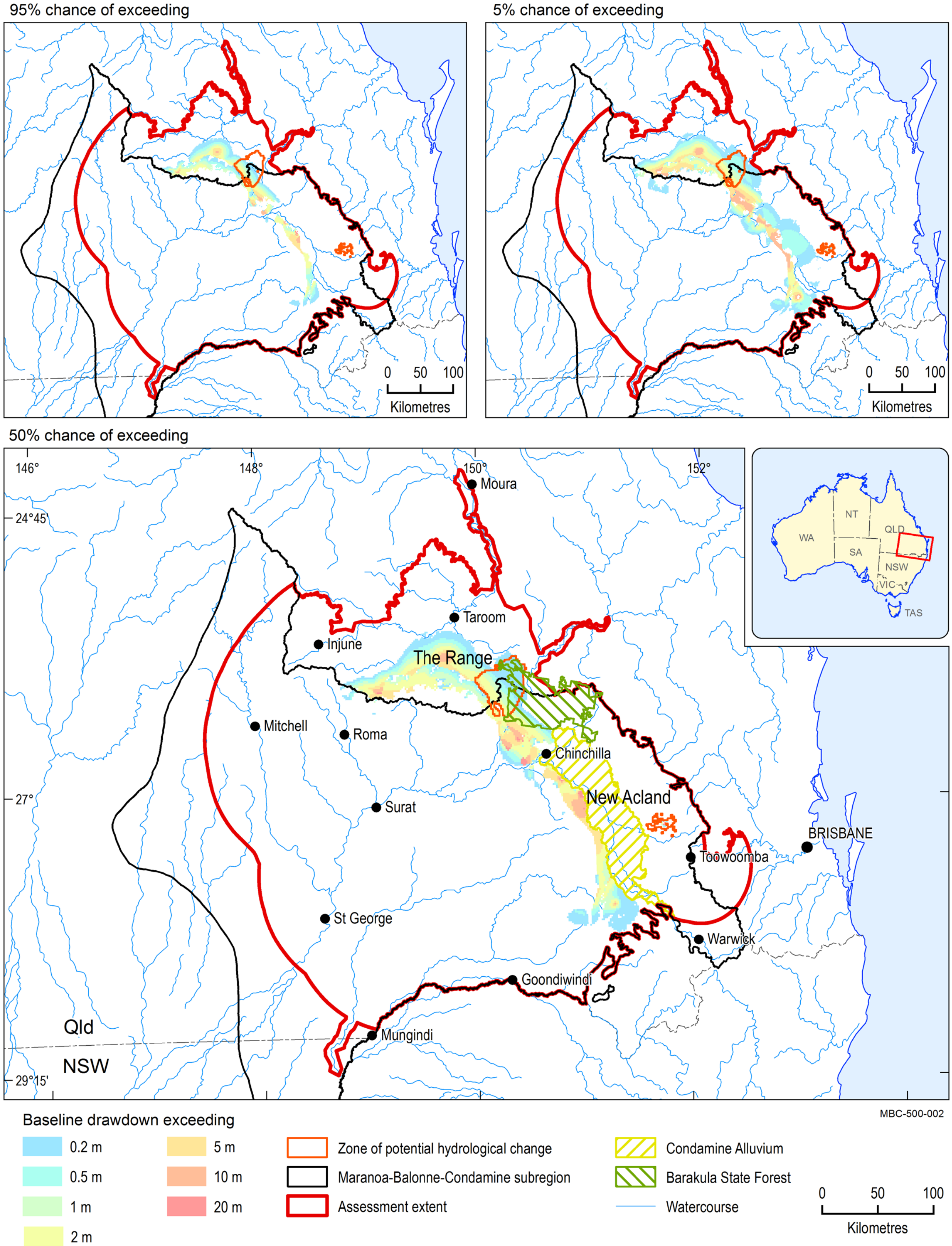


Figure 7 Baseline drawdown (metres (m)) in the regional watertable (95%, 50% and 5% chance of exceeding given values of drawdown)

Baseline drawdown is the maximum difference in drawdown under the baseline relative to no coal resource development (Box 4). Results are shown as percent chance of exceeding drawdown thresholds (Box 6). These appear in product 3-4 (impact and risk analysis) (Holland et al., 2017) as percentiles. The location of the Barakula State Forest near Miles is shown for reference.
Data: Bioregional Assessment Programme (Dataset 3, Dataset 7, Dataset 8, Dataset 10, Dataset 11, Dataset 13); Queensland Office of Groundwater Impact Assessment (Dataset 5, Dataset 12)

Key finding 4: Near New Acland Coal Mine Stage 3 (Figure 8), additional drawdown in the regional watertable in excess of 0.2 m is *very likely* 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).

The range of model predictions in the vicinity of **New Acland Coal Mine Stage 3** (Figure 8) indicates that additional drawdown in the **regional watertable** in excess of 5 m is *very likely* to be experienced in an area of 2 km^2 (which includes 1 km of streams) and *very unlikely* to extend beyond 20 km^2 (which includes 9 km of streams).

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 the **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 the **Walloon Coal Measures**. However, this does not overlap with the drawdown near the mine (Figure 11).

Key finding 5: Near The Range coal mine (Figure 9), 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).

The range of model predictions in the vicinity of **The Range coal mine** (Figure 9) indicates that additional drawdown in the **regional watertable** 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 is the regional watertable in the vicinity of The Range coal mine.

FIND MORE INFORMATION

Explore the hydrological changes in more detail at www.bioregionalassessments.gov.au/explorer/MBC/hydrologicalchanges

Groundwater numerical modelling, product 2.6.2 (Janardhanan et al., 2016)

Impact and risk analysis, product 3-4 (Holland et al., 2017)

Groundwater modelling, submethodology M07 (Crosbie et al., 2016)

Analysing impacts and risks, submethodology M10 (Henderson et al., 2017)

Regional watertable (Dataset 3)

Groundwater model uncertainty analysis (Dataset 8)

Summary of groundwater drawdown by assessment unit (Dataset 11)

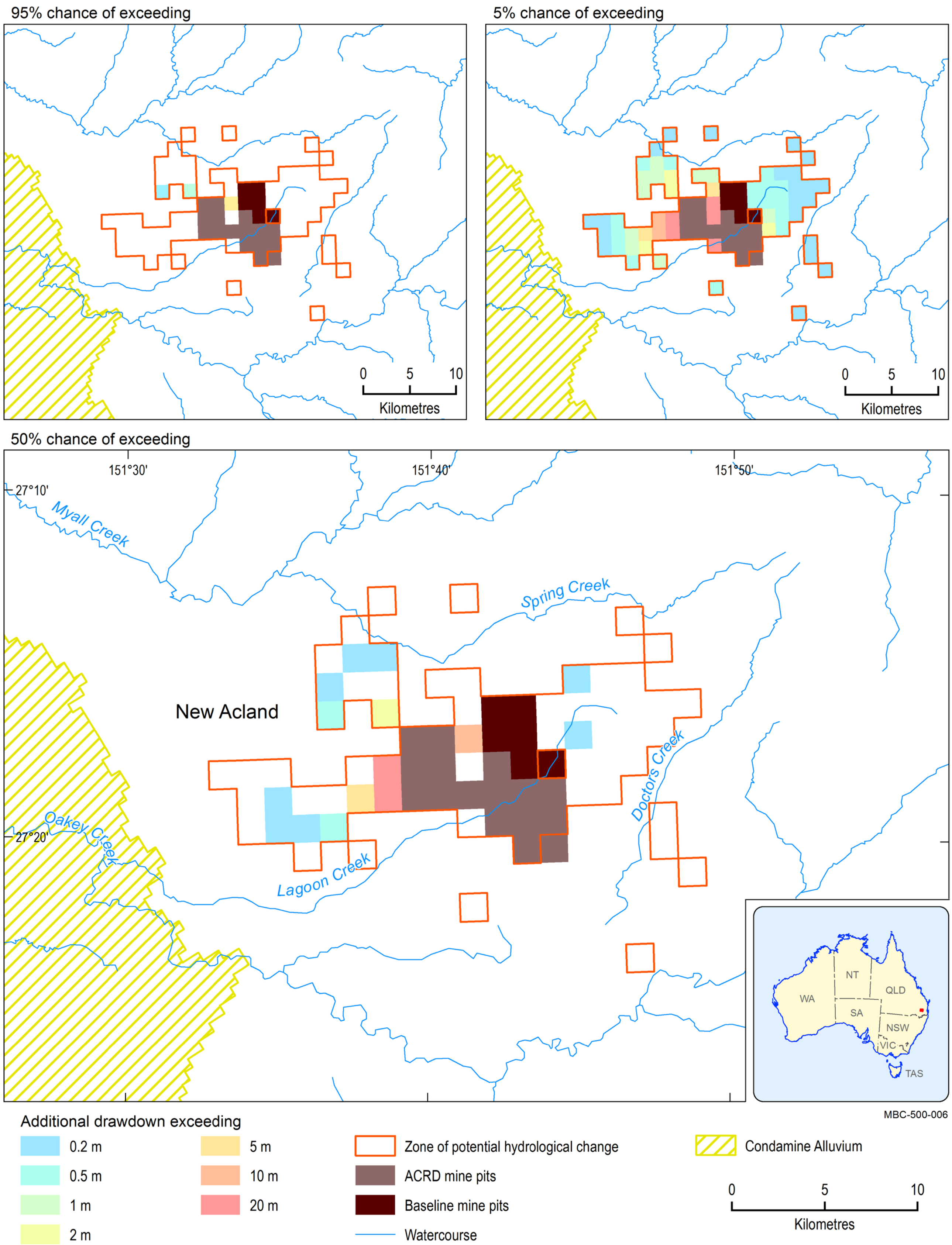


Figure 8 Additional drawdown (metres (m)) in the regional watertable in the vicinity of New Acland Coal Mine Stage 3 (95%, 50% and 5% chance of exceeding given values of drawdown)

Additional drawdown is the maximum difference in drawdown between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development (Box 4). Results are shown as a percent chance of exceeding drawdown thresholds (Box 6). These appear in product 3-4 (impact and risk analysis) (Holland et al., 2017) as percentiles. 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 7, Dataset 8, Dataset 11, Dataset 13); Queensland Office of Groundwater Impact Assessment (Dataset 5)

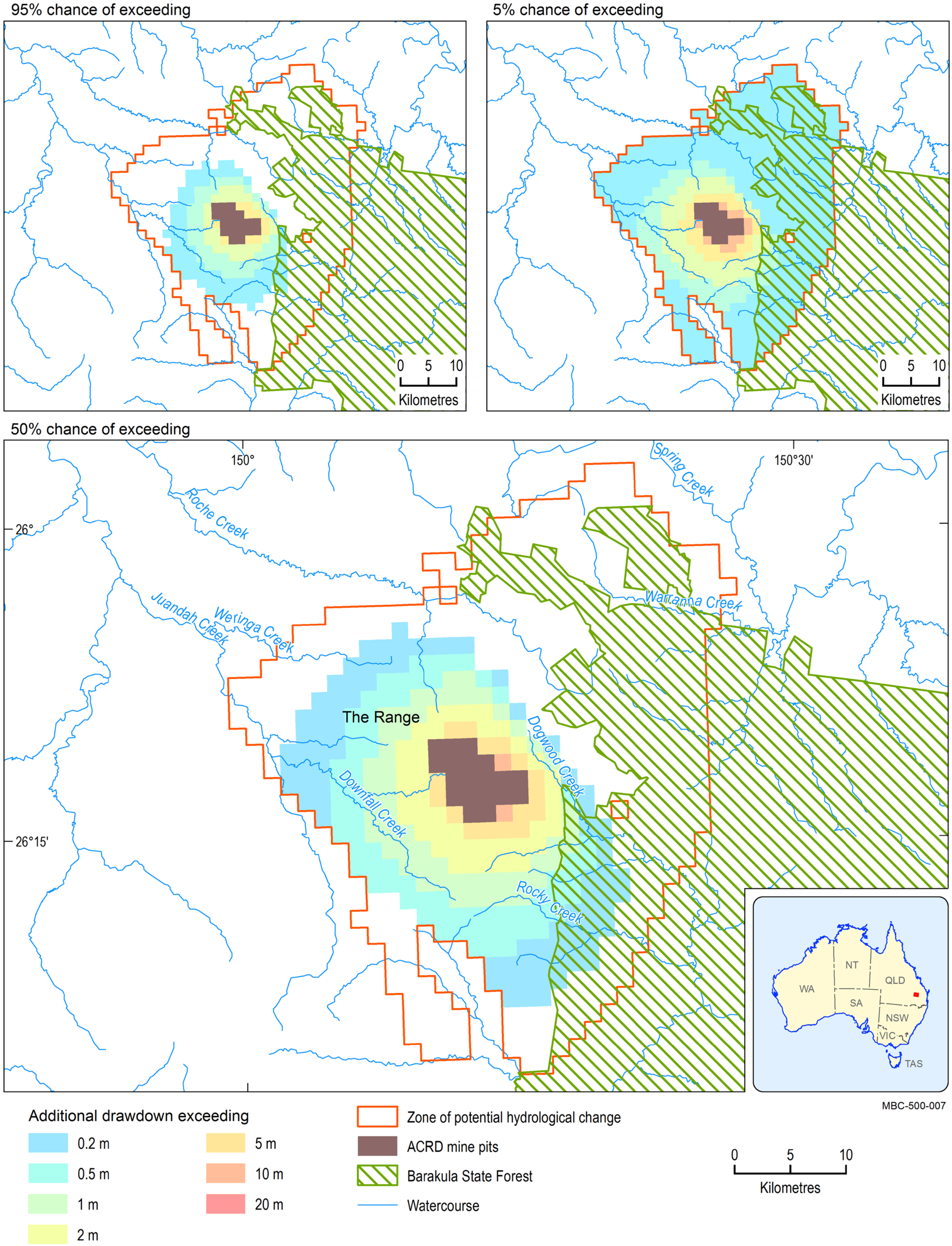


Figure 9 Additional drawdown (metres (m)) in the regional watertable in the vicinity of The Range coal mine (95%, 50% and 5% chance of exceeding given values of drawdown)

Additional drawdown is the maximum difference in drawdown between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development (Box 4). Results are shown as a percent chance of exceeding drawdown thresholds (Box 6). These appear in product 3-4 (impact and risk analysis) (Holland et al., 2017) as percentiles. The location of the Barakula State Forest near Miles is shown for reference.

Data: Bioregional Assessment Programme (Dataset 7, Dataset 8, Dataset 10, Dataset 11, Dataset 13); Queensland Office of Groundwater Impact Assessment (Dataset 5)

What are the potential impacts of additional coal resource development on the landscape?

The impact and risk analysis (Box 8) investigated how hydrological changes due to additional coal resource development may affect landscape-scale ecosystems, such as floodplains, irrigated agriculture or remnant vegetation. These ecosystems were classified into landscape classes and landscape groups (Box 7).

The landscape groups in the subregion are:

- **'Floodplain or lowland riverine':** fringing riverine, wetland and floodplain communities, including groundwater-dependent ecosystems (GDEs) that do not access Great Artesian Basin (GAB) aquifers. Fringing riverine and wetland communities depend on groundwater within natural watertable fluctuations (less than 2 m); floodplain communities are more tolerant of watertable fluctuations (less than 5 m); and lowland ecosystems rely on surface water and incident rainfall (they are less dependent on groundwater)
- **'GAB GDEs':** GDEs that are hydrologically connected to GAB aquifers including streams, springs, areas of floodplain or wetland habitat, and sandstone outcrop areas. These ecosystems typically contain endemic species or plants that are unique to the subregion, and depend on watertable levels within natural seasonal and climatic variations (less than 2 m). Groundwater discharge to streams from GAB aquifers also supports the maintenance of flow regimes and channel habitat
- **'Non-floodplain or upland riverine':** non-GAB GDEs that access perched, or isolated, watertables, such as inland sand ridges and basalt aquifers, such as the Main Range Volcanics. These communities depend on watertable levels within natural fluctuations (less than 2 m). Many of the upland streams flow through human-modified landscapes and rely on localised runoff from rainfall; they are less dependent on groundwater
- **'Human-modified':** ecosystems that rely heavily on groundwater and surface water extracted from nearby aquifers and streams, such as intensive uses and irrigated agriculture and plantations. Dryland cropping and grazing rely on incident rainfall and localised runoff and were not considered to be water dependent for this assessment
- **'Dryland remnant vegetation':** this ecosystem depends on incident rainfall and localised runoff. As such, it was not considered to be water dependent for this assessment.

Results are reported at the scale of landscape group in this synthesis, but further detail at the scale of landscape class is reported in the impact and risk analysis (Holland et al., 2017).

Box 7 Understanding the landscape

The natural and human-modified ecosystems in the subregion were classified into 34 landscape classes (Figure 17 in Holland et al. (2016)) to enable a systematic and comprehensive analysis of potential impacts on, and risks to, the water-dependent assets nominated by the community. These landscape classes were aggregated into five landscape groups (Figure 10), based on their likely response to hydrological changes. The landscape classification was based on the geology, geomorphology, hydrogeology, land use and ecology.

Box 8 Analysing impact and risk

Potential impacts to water-dependent landscapes and assets were assessed by overlaying their location on the zone of potential hydrological change (Box 5) to identify the hydrological changes that a particular asset or ecosystem might experience.

- **Outside this zone, landscapes and assets** are *very unlikely* **to be impacted** by hydrological changes due to additional coal resource development.
- **Inside this zone**, landscapes and assets are **potentially impacted**.

Within the zone, not all water-dependent landscapes or assets will be affected, as this depends on their reliance on groundwater or surface water. Hydrological changes due to additional coal resource development may be large, but within the range of natural seasonal and climatic variability, and thus may not affect water-dependent landscapes or assets. Alternatively, small changes may affect sensitive ecosystems that have a strong reliance on groundwater or surface water. See 'Building on this assessment' (p. 25) for how to gain more detailed information on the sensitivity of landscapes and assets to hydrological change.

For ecological assets, the assessment considered the potential impact to the habitat of species, not potential impacts to the species themselves.

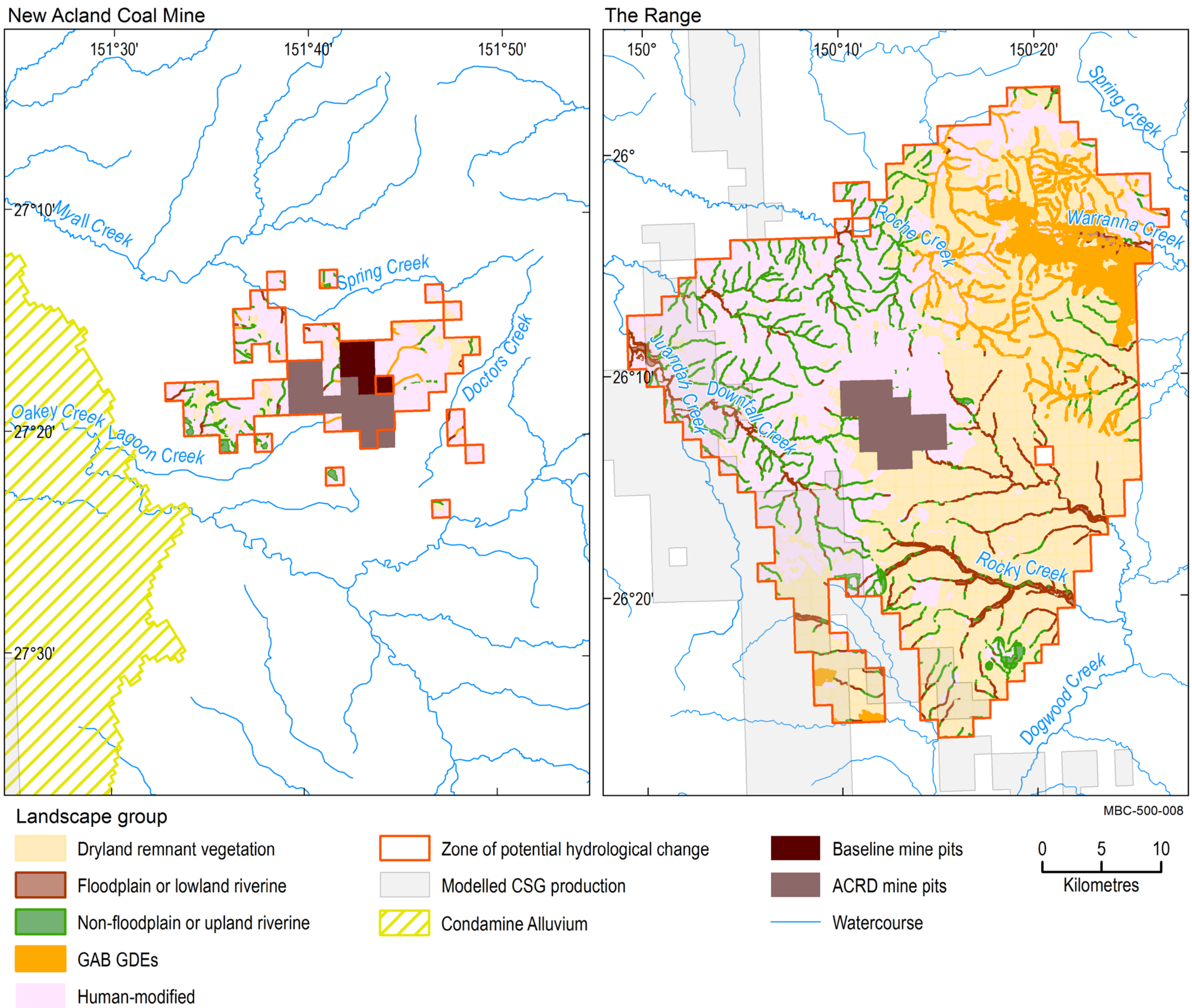


Figure 10 Landscape groups within the zone of potential hydrological change in the vicinity of New Acland Coal Mine Stage 3 and The Range proposed coal mine

CSG = coal seam gas, GAB = Great Artesian Basin, GDE = groundwater-dependent ecosystem. The mine pits in the coal resource development pathway are the sum of those in the baseline and the additional coal resource development (ACRD).
Data: Bioregional Assessment Programme (Dataset 14, Dataset 15)

Box 9 Choosing a threshold

Groundwater impacts of coal mines and coal seam gas projects are regulated under state legislation and state regulatory and management frameworks. The 0.2 m drawdown threshold used in bioregional assessments (Box 5) is consistent with the most conservative minimal impact threshold in Queensland's *Underground water impact report for the Surat Cumulative Management Area* (QWC, 2012; OGIA, 2016) from the Office of Groundwater Impact Assessment and the *NSW Aquifer Interference Policy* (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. The full impact and risk analysis database is provided (Dataset 9) so that readers can do their own overlays using other thresholds (see 'How to use this assessment' on p. 24).

In Queensland, 'make good' obligations for groundwater bores affected by coal seam gas extraction apply 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. Additionally, Queensland's *Water Act 2000* also requires prevention or mitigation options to be developed for springs where predicted pressure reductions in the source aquifer are greater than 0.2 m. Similarly, in NSW, 'make good' provisions apply in most aquifers where an activity results in drawdowns greater than 2 m. The exceptions are high-priority groundwater-dependent ecosystems and culturally significant sites in the Great Artesian Basin, where 'make good' provisions apply if drawdowns exceed 0.2 m. 'Make good' provisions are legally binding agreements where any impacts caused by a petroleum and gas operation are 'made good', for example, in the form of compensation, improved or alternative water access, or monitoring.

Landscape groups

Which landscape groups are *very unlikely* to be impacted?

Key finding 6: More than 35,000 km^2 of remnant vegetation, 59,000 km of streams, 1600 km^2 of wetlands and 93,000 km^2 of productive landscapes within the assessment extent are *very unlikely* to be impacted because they experience less than 0.2 m drawdown due to additional coal resource development.

Landscapes in the area where impacts are *very unlikely* (Table 2) include:

- 35,281 km^2 of **remnant vegetation**, including 5,846 km^2 classified as 'Floodplain or lowland riverine'; 1,670 km^2 classified as 'GAB GDEs'; 2,815 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 7,443 km of streams that access GAB aquifers
- 1,612 km^2 of **wetlands**, including 1,326 km^2 classified as 'Floodplain or lowland riverine'; 11 km^2 classified as 'GAB GDEs'; and 276 km^2 classified as 'Non-floodplain or lowland riverine'
- 93,044 km^2 of **productive landscapes** used for grazing and dryland agriculture.

Key finding 7: 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*.

The assessment extent contains 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.

Springs, near-permanent or temporary wetlands, and lowland streams are part of 12 landscape classes (Box 7) that all fall outside the zone of potential hydrological change (Box 5), meaning that they are *very unlikely* to be subject to hydrological changes due to additional coal resource development. None of the subregion's 153 springs sourced from GAB aquifers are within 50 km of where there is a 5% chance of exceeding 0.2 m additional drawdown in the source aquifer identified for each spring by OGIA.

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.

Which landscape groups are potentially impacted?

Outside the modelled mine pits, landscapes that are potentially impacted (Table 2) include:

- **'Floodplain or lowland riverine':** 20 km^2 (which is 0.3% of the total in the assessment extent) of remnant vegetation and 299 km (1.0%) 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 (less than 2 m) and of a comparable magnitude
- **'GAB GDEs':** 76 km^2 (4.4%) of remnant vegetation and 319 km (4.1%) of streams that are hydrologically connected to GAB aquifers. These include Warranna Creek to the north-east of The Range coal mine, which flows to the Auburn River in the Burnett river basin (Figure 10). Median drawdown due to additional coal resource development for GDEs associated with the GAB is in addition to the range of natural watertable fluctuation (less than 2 m) and of a comparable magnitude

- **'Non-floodplain or upland riverine':** 12 km^2 (0.4%) of remnant vegetation and 477 km (2.0%) of streams. This includes temporary upland streams and GDEs associated with basalt aquifers that flow through human-modified landscapes near New Acland Coal Mine toward Lagoon and Oakey creeks and upland streams to the west of The Range coal mine that flow into Juandah Creek and into the Dawson River. Median additional drawdown is predicted to exceed 5 m, which is likely to affect these GDEs. Local impact assessment and modelling is required to provide more detail to supplement results from this regional model
- **'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.

More detail on each landscape class, including information on water dependency, sensitivity to change and potential ecosystem relevance of hydrological changes, is contained in Section 3.4 of the impact and risk analysis for the subregion (Holland et al., 2017). Potential impacts on water-dependent assets are described in the next section.

FIND MORE INFORMATION

Explore landscapes in more detail at www.bioregionalassessments.gov.au/explorer/MBC/landscapes

Conceptual modelling, product 2.3 (Holland et al., 2016)

Impact and risk analysis, product 3-4 (Holland et al., 2017)

Assigning receptors to water-dependent assets, submethodology M03 (O'Grady et al., 2016)

Analysing impacts and risks, submethodology M10 (Henderson et al., 2017)

Impact and risk analysis database (Dataset 9)

Landscape classification (Dataset 14)

Landscape class spatial overlay by assessment unit (Dataset 15)

Summary of groundwater drawdown by assessment unit (Dataset 11)

Table 2 Extent of landscape groups in the assessment extent that are outside and in the zone of potential hydrological change (1544 km^2)

Landscape group	Area, length or number	Extent of landscape group outside zone of potential hydrological change	Extent of landscape group in zone of potential hydrological change[a]
Floodplain or lowland riverine (including non-GAB GDEs)	Area of remnant vegetation (km^2)	5,846	20
	Stream network length (km)	28,850	299
GAB GDEs (riverine, springs, floodplain or non-floodplain)	Area of remnant vegetation (km^2)	1,670	76
	Stream network length (km)	7,443	319
	GAB springs (number)	153	0
Non-floodplain or upland riverine (including non-GAB GDEs)	Area of remnant vegetation (km^2)	2,815	12
	Stream network length (km)	23,548	477
	Non-GAB springs (number)	24	0
Human-modified	Area of non-remnant vegetation (km^2)	93,044	685
Dryland remnant vegetation	Area of remnant vegetation (km^2)	24,949	750

[a]Extent within zone of potential hydrological change does not include extent within modelled mine pits.
GAB = Great Artesian Basin, GDE = groundwater-dependent ecosystem. See Table 6 in Holland et al. (2017) for more detail.
Data: Bioregional Assessment Programme (Dataset 9)

What are the potential impacts of additional coal resource development on water-dependent assets?

The impact and risk analysis (Box 8) investigated how hydrological changes due to additional coal resource development may affect water-dependent assets, such as bores, wetlands or heritage sites.

A total of **2660 water-dependent assets** (listed in Dataset 10 and Bioregional Assessment Programme (2017)) were identified for the subregion (Table 3):

- **2215 ecological assets**, including 23 groundwater assets, 1688 surface water assets (including the 177 springs described earlier) and 504 vegetation assets, including GDEs, riparian areas, protected reserves, and potential habitat of threatened species and communities
- **310 economic assets**, including 127 groundwater assets (which include multiple bores) and 183 surface water assets
- **135 sociocultural assets**, including cultural assets (50 heritage sites and 59 Indigenous sites) and social assets (26 recreation areas). There were 56 Indigenous cultural assets identified through consultation with Indigenous knowledge holders and 3 were nominated by the broader community; some of their locations were not provided.

Potential impacts on water-dependent assets were assessed by overlaying their extent on the zone of potential hydrological change (Table 3).

Key finding 8: 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.

Table 3 Water-dependent assets in the assessment extent and the zone of potential hydrological change

Asset group	Asset subgroup	Asset class	Number of assets in assessment extent	Number of assets in zone of potential hydrological change
Ecological assets	Groundwater feature (subsurface)	Aquifer, geological feature, alluvium or stratum	23	12
	Surface water feature	All	1688	29
	Vegetation	Groundwater-dependent ecosystem	313	33
	Vegetation	Habitat (potential species distribution) and riparian vegetation	191	41
Subtotal			**2215**	**115**
Economic assets[a]	Groundwater management zone or area (surface area)	All	127	13
	Surface water management zone or area (surface area)	All	183	1
Subtotal			310	14
Sociocultural assets	All	All	135[b]	1
Subtotal			**135**	**1**
Total	**All**	**All**	**2660**	**130**

[a]Numbers for economic assets are not individual bores; they are water access entitlements that could include one or multiple bores.
[b]Of the 135 sociocultural assets, 35 Indigenous cultural assets are cultural values associated with animals and plants that do not have geographic location information, which means they cannot be specifically assessed for potential impacts due to additional coal resource development. See Table 29 in the impact and risk analysis (Holland et al., 2017) for more details.
Data: Bioregional Assessment Programme (Dataset 9)

Ecological assets

Which ecological assets are *very unlikely* to be impacted?

No protected reserves, parks, bird habitats or key environmental assets are within the zone of potential hydrological change. Also, none of the 882 water-dependent assets classified as 'Floodplain', 'Lake, reservoir, lagoon or estuary', 'Marsh, sedgeland, bog, spring or soak' or 'Waterhole, pool, rock pool or billabong' are within the zone. This includes the 177 springs assessed in 'Which landscape groups are *very unlikely* to be impacted?' (p. 17).

Which ecological assets are potentially impacted?

Of the 2215 ecological water-dependent assets in the assessment extent, 115 are subject to potential hydrological change due to additional coal resource development. This does not mean that these 115 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.

Key finding 9: Forty-one ecosystems are in an area where there is at least a 5% chance of drawdown exceeding 0.2 m due to additional coal resource development.

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*; 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.

Water-dependent assets that are potentially impacted by drawdown due to additional coal resource development include:

- **Groundwater feature (subsurface)**: 11 aquifers or geological layers (including GAB recharge areas, sandstone aquifers and a groundwater flow system) and part of 1 asset (252 of the more than 13,000 groundwater production bores in the Condamine Alluvium)
- **Surface water feature:** 18 streams, including parts of the Auburn River in the Burnett river basin; Downfall, Juandah and Roche creeks in the Fitzroy river basin; Upper Oakey Creek in the Condamine river basin; and 11 wetlands in the Balonne, Burnett, Condamine and Fitzroy river basins
- **Vegetation – Groundwater-dependent ecosystem:** 17 assets described in the *National atlas of groundwater dependent ecosystems* (GDE Atlas) (Bureau of Meteorology, 2012) and 16 assets identified by the Queensland Government GDE mapping. This includes 6 vegetation communities associated with groundwater discharged to the surface as springs or baseflow to rivers and 11 vegetation communities that interact with a groundwater system beneath the surface described in the GDE Atlas
- **Vegetation – Habitat (potential species distribution):** 39 water-dependent assets, including:
    - 4 threatened ecological communities: 'Brigalow', 'Semi-evergreen vine thickets', 'Weeping Myall Woodlands' and 'Natural grasslands on basalt and fine-textured alluvial plains'
    - 18 species listed under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999*:
        - birds: black-faced monarch, cattle egret, fork-tailed swift, great egret, red goshawk, satin flycatcher, squatter pigeon (southern), star finch (eastern) and the white-bellied sea-eagle
        - mammals: grey-headed flying-fox and koala
        - plants: Belson's panic, blotched sarcochilus, finger panic grass and stream clematis
        - reptiles: Dunmall's snake, five-clawed worm-skink and yakka skink
    - 11 species and 6 endangered regional ecosystems listed under Queensland's *Nature Conservation Act 1992*
- **Vegetation – Riparian vegetation:** 2 water-dependent assets, excluding the riparian vegetation along the Lower Balonne System identified as a Murray–Darling Basin Authority Key Environmental Asset (KEA).

See Section 3.5.2 in the impact and risk analysis (Holland et al., 2017) for more details, including a literature review of the nature of the water dependency of these assets.

Economic assets

Which economic assets are *very unlikely* to be impacted?

Hydrological changes due to additional coal resource development are *very unlikely* to impact 296 of the 310 economic assets (Table 3 and Table 4). As seen in Table 4, these 296 unimpacted economic assets include 9827 bores, 182 surface water assets and all 13 water supply and monitoring infrastructure assets, including Atkinsons Dam, Bill Gunn Dam, Clarendon Dam, 3 weirs and 13 borefields (Bioregional Assessment Programme, 2017).

Which economic assets are potentially impacted?

Key finding 10: There is at least a 5% chance that 163 bores experience greater than 0.2 m drawdown due to additional coal resource development. The 163 bores are part of 13 economic assets that comprise 7 water access rights and 6 basic water rights (stock and domestic).

Of these 163 bores, it is *very likely* 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 Walloon Coal Measures.

There are 9990 individual bores within the assessment extent (Table 4). Of the 163 bores in the zone of potential hydrological change, 20 water access rights and 6 basic water rights (stock and domestic) have a greater than 50% chance of exceeding 5 m of drawdown due to additional coal resource development (Figure 11). The modelled open-cut mine pits for the New Acland Stage 3 coal mine and The Range coal mine contain 9 of these 163 economic bores. The larger values of maximum drawdown occur in bores close to the mines or within the modelled pits, which cover around 40 km^2, and the maximum drawdown in these bores occurs in the years immediately following mining activity (see Figure 25 and Figure 26 in Janardhanan et al. (2016)). Smaller values of maximum drawdown are observed in bores located further from the mines and occur in later years when the drawdown propagates to these bores.

The bores are managed by the Condamine and Balonne water plan and the Eastern Downs, Surat, Surat East and Surat North groundwater management units in the *Water Resource (Great Artesian Basin) Plan 2006*. No bores in the zone access groundwater in the deeper Bowen Basin aquifers underlying the GAB (see Table 33 in the impact and risk analysis (Holland et al., 2017)).

One water access right associated with a surface water management zone falls within the zone of potential hydrological change near The Range coal mine in the headwaters of Downfall Creek. As surface water modelling was not carried out in this assessment (Box 3), the potential impacts on this water access right were not assessed further.

Table 4 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[a]	Elements[a]	Assets[a]	Elements[a]
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**

[a]Assets are combinations of one or more elements (individual spatial features – points, lines and polygons). For example, an asset might be a collection of bores.
Data: Bioregional Assessment Programme (Dataset 9)

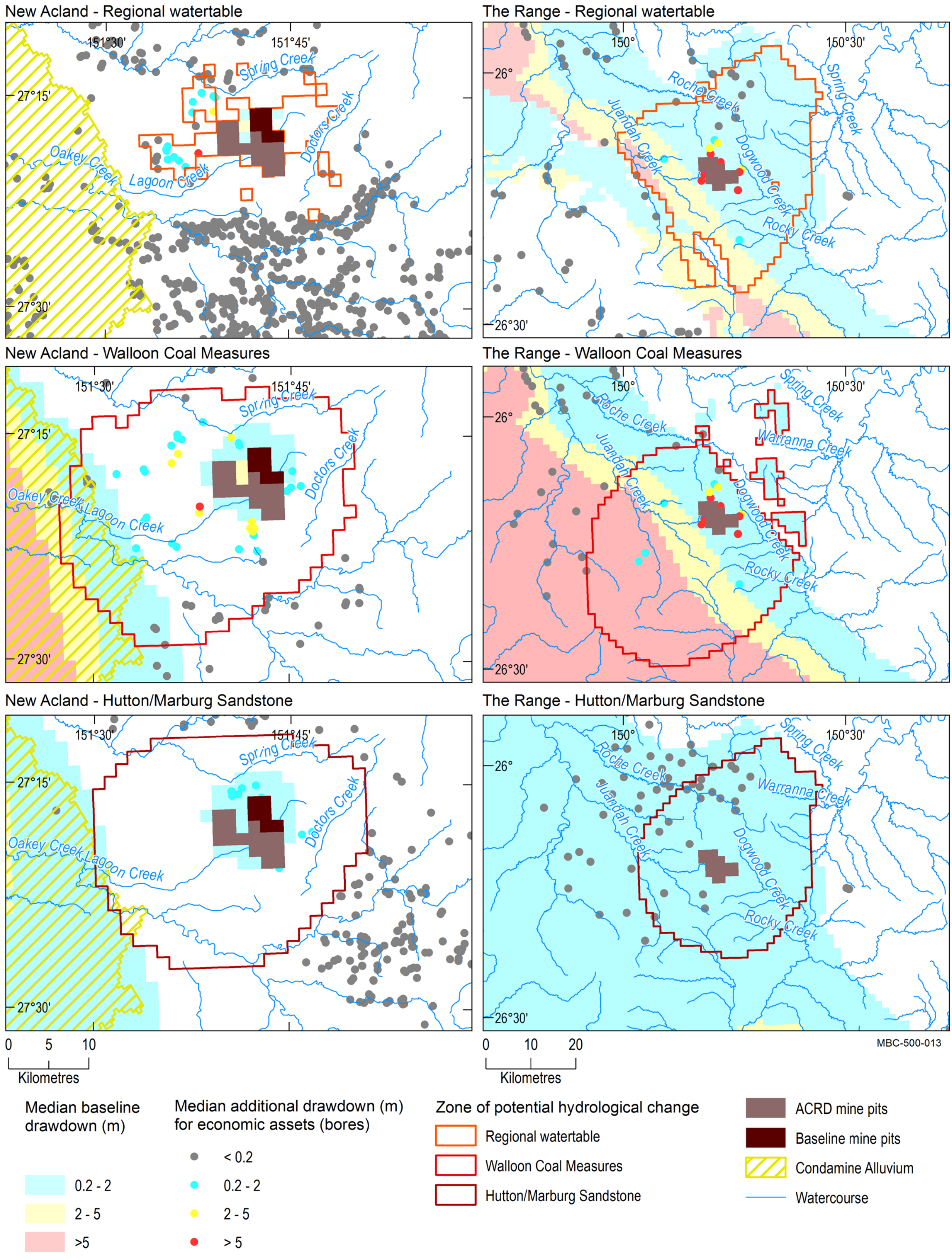


Figure 11 Median baseline drawdown (m) in the regional watertable, Walloon Coal Measures and Hutton/Marburg Sandstone, superimposed with median additional drawdown (m) of groundwater bores that access these aquifers

Most of this synthesis focuses on the zone of potential hydrological change in the regional watertable, but here the same threshold (Box 5) is used to define zones for deeper layers that bores access. Median is a 50% chance (Box 6). Baseline drawdown is the maximum difference in drawdown under the baseline relative to no coal resource development (Box 4). Additional drawdown is the maximum difference in drawdown between the coal resource development pathway (CRDP) and baseline, due to additional coal resource development.

Data: Bioregional Assessment Programme (Dataset 8, Dataset 9, Dataset 11, Dataset 16)

Sociocultural assets

Which sociocultural assets are *very unlikely* to be impacted?

Sociocultural assets that fall outside the zone of potential hydrological change include 50 heritage sites, 3 Indigenous sites and 26 recreation areas, including national parks and areas of remnant vegetation. These have a less than 5% chance of impacts due to additional coal resource development.

Separate reports on Indigenous water assets in the Queensland and NSW parts of the Maranoa-Balonne-Condamine subregion contributed to this assessment (Constable and Love, 2015). 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 (Bioregional Assessment Programme, 2017) and used for the impact and risk analysis. 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.

Which sociocultural assets are potentially impacted?

Key finding 11: The Barakula State Forest, near Miles in Queensland, is the sole sociocultural asset located in the area where drawdown due to additional coal resource development exceeds 0.2 m in the regional watertable with a greater than 5% chance. 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.

Additional drawdown in the regional watertable in excess of 2 m is not *very likely* within the forest and is *very unlikely* to include more than 6 km^2 of the forest.

Barakula State Forest is located along the eastern edge of the zone of potential hydrological change near The Range coal mine (Figure 7 and Figure 9). It is water dependent based on the presence of floodplain and wetland areas and shallow groundwater within its extent. However, finer resolution models are better placed to assess potential impacts at a local scale.

FIND MORE INFORMATION

Explore assets in more detail at www.bioregionalassessments.gov.au/explorer/MBC/assets

Description of the water-dependent asset register, product 1.3 (Mitchell et al., 2015)

Water-dependent asset register (Bioregional Assessment Programme, 2017)

Impact and risk analysis, product 3-4 (Holland et al., 2017)

Compiling water-dependent assets, submethodology M02 (Mount et al., 2015)

Analysing impacts and risks, submethodology M10 (Henderson et al., 2017)

Asset database (Dataset 10)

Impact and risk analysis database (Dataset 9)

Asset spatial overlay by assessment unit (Dataset 16)

Summary of groundwater drawdown by assessment unit (Dataset 11)

How to use this assessment

Findings from bioregional assessments 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. These assessments do not investigate the broader social, economic or human health impacts of coal resource development, nor do they consider risks of fugitive gases and non-water-related impacts.

Bioregional assessments 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.

Bioregional assessments 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 bioregion-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, including informationfor individual assets, is provided at www.bioregionalassessments.gov.au. 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 (Box 9); 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 (as listed in 'References and further reading' on p. 26).

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.

Building on this assessment

In the judgement of the Assessment team, extending this assessment should focus on incorporating surface water modelling and representing surface water – groundwater interactions, including analysing impacts to streams in areas where drawdown is predicted at the surface (within the zone of potential hydrological change). The following key knowledge gaps identify where confidence in results can be improved through future work.

Hydrological modelling

The revised OGIA model (OGIA, 2016) addressed many of the limitations identified in the qualitative uncertainty analysis (Table 13 in Janardhanan et al. (2016)). Improvements include representation of regional geology, hydrostratigraphy and faults, as well as model discretisation, parameterisation and calibration. 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. Water quality models and data would allow related hazards to be addressed.

Assessing impacts in the landscape

As surface water modelling was not undertaken, the assessment of ecological and ecosystem impacts is 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.

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.

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 on a landscape scale.

FIND MORE INFORMATION

See sections titled 'Gaps' in:

Description of water-dependent asset register, product 1.3 (Mitchell et al., 2015)

Current water accounts and water quality, product 1.5 (Cassel et al., 2015)

Conceptual modelling, product 2.3 (Holland et al., 2016)

Groundwater numerical modelling, product 2.6.2 (Janardhanan et al., 2016)

Impact and risk analysis, product 3-4 (Holland et al., 2017)

See www.bioregionalassessments.gov.au for links to information about all datasets used or created, most of which can be downloaded from data.gov.au.

References and further reading

The information presented in this product for the Maranoa-Balonne-Condamine subregion is based on the analysis and interpretation of existing data and knowledge, enhanced by new scientific studies of the geology, groundwater and ecology. All technical products developed for the Maranoa-Balonne-Condamine subregion are listed here. Also listed are the submethodologies that describe the key approaches used to undertake the assessments.

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Bioregional Assessment Programme (2017) Water-dependent asset register and asset list for the Maranoa-Balonne-Condamine subregion on 01 May 2017. A spreadsheet associated with product 1.3 for the Maranoa-Balonne-Condamine subregion from the Northern Inland Catchments Bioregional Assessment. Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia. http://data.bioregionalassessments.gov.au/product/NIC/MBC/1.3.

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Henderson BL, Barry S, Hayes KR, Hosack G, Holland K, Herron N, Mount R, Schmidt RK, Dambacher J, Ickowicz A, Lewis S and Post DA (2017) Impacts and risks. Submethodology M10 from the Bioregional Assessment Technical Programme. Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia. http://data.bioregionalassessments.gov.au/submethodology/M10.

Henderson BL, Hayes KR, Mount R, Schmidt RK, O'Grady A, Lewis S, Holland KL, Dambacher J, Barry S and Raiber M (2016) Developing the conceptual model of causal pathways. Submethodology M05 from the Bioregional Assessment Technical Programme. Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia. http://data.bioregionalassessments.gov.au/submethodology/M05.

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Datasets

Key datasets are listed here. The website www.bioregionalassessments.gov.au provides metadata for all datasets, most of which can be downloaded from data.gov.au.

Dataset 1 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 2 Queensland Department of Natural Resources and Mines (2014) Queensland Interactive resource and tenure maps. Bioregional Assessment Source Dataset. Viewed 01 March 2016, http://data.bioregionalassessments.gov.au/dataset/7b7af500-07f1-46a2-bc70-2d3dd8bbf073.

Dataset 3 Bioregional Assessment Programme (2016) MBC Assessment unit regional watertable. Bioregional Assessment Derived Dataset. Viewed 21 December 2016, http://data.bioregionalassessments.gov.au/dataset/82491c02-cdb7-4bf5-b81d-17891f67938f.

Dataset 4 Bioregional Assessment Programme (2015) MBC Groundwater model. Bioregional Assessment Derived Dataset. Viewed 10 February 2016, http://data.bioregionalassessments.gov.au/dataset/6fe25546-a6ca-44fc-a101-51b1758e2890.

Dataset 5 Queensland 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 Bioregional Assessment Programme (2015) Impact Modes and Effects Analysis for the MBC subregion. Bioregional Assessment Source Dataset. Viewed 25 February 2016, http://data.bioregionalassessments.gov.au/dataset/e338c1b2-359f-428a-959f-a4f65900ca04.

Dataset 7 Bioregional Assessment Programme (2016) MBC Zones of potential hydrological change. Bioregional Assessment Derived Dataset. Viewed 03 February 2017, http://data.bioregionalassessments.gov.au/dataset/c9f7f097-95b1-47a4-8854-a32a95635b83.

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 (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.

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Dataset 11 Bioregional Assessment Programme (2016) MBC Assessment unit summary tables - groundwater. Bioregional Assessment Derived Dataset. Viewed 06 February 2017, http://data.bioregionalassessments.gov.au/dataset/c123a642-099c-45a5-bd1d-e52c3e04b7b7.

Dataset 12 Queensland Office of Groundwater Impact Assessment (2012) Baseline drawdown Layer 1 - Condamine Alluvium. Bioregional Assessment Source Dataset. Viewed 03 February 2017, http://data.bioregionalassessments.gov.au/dataset/49b2cbac-c570-461d-b6e6-8e2e584aeaea.

Dataset 13 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 14 Bioregional Assessment Programme (2016) Landscape classification of the Maranoa-Balonne-Condamine preliminary assessment extent v02. Bioregional Assessment Derived Dataset. Viewed 22 January 2016, http://data.bioregionalassessments.gov.au/dataset/3bf1f159-8db0-404a-be47-1dbd6282ee54.

Dataset 15 Bioregional Assessment Programme (2016) MBC Landscape Classes for FAE split by Assessment Units v02. Bioregional Assessment Derived Dataset. Viewed 17 October 2016, http://data.bioregionalassessments.gov.au/dataset/3f041364-71e0-40ec-a1fd-fa48df696a36.

Dataset 16 Bioregional Assessment Programme (2016) MBC Assets 20160205 for FAE split by Assessment Units 20160818 v01. Bioregional Assessment Derived Dataset. Viewed 17 October 2016, http://data.bioregionalassessments.gov.au/dataset/4347ec59-da92-40da-9be3-a64246cb8592.

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.

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

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

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: for the Maranoa-Balonne-Condamine subregion, 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)

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.

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.

conceptual model: abstraction or simplification of reality

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

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.

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

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. 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.

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

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

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)

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

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 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).

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. 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.

recharge: see groundwater recharge

regional watertable: the upper groundwater level within the unconfined, near-surface aquifer (not perched), where pore water pressure is equal to atmospheric pressure. For bioregional assessment (BA) purposes, the regional watertable is developed by combining, at the subregion or bioregion scale, the watertable from all the near-surface geological units (or layers) in which it occurs, so that impacts to water-dependent assets and ecosystems can be assessed. As the regional watertable is not a contiguous geological layer, water may not move freely through it.

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

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. Some ecological assets solely depend on incident rainfall and will not be considered as water dependent if evidence does not support a linkage to groundwater or surface water.

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 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).

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The following individuals have contributed to the Technical Programme, the part of the Bioregional Assessment Programme that undertakes bioregional assessments.

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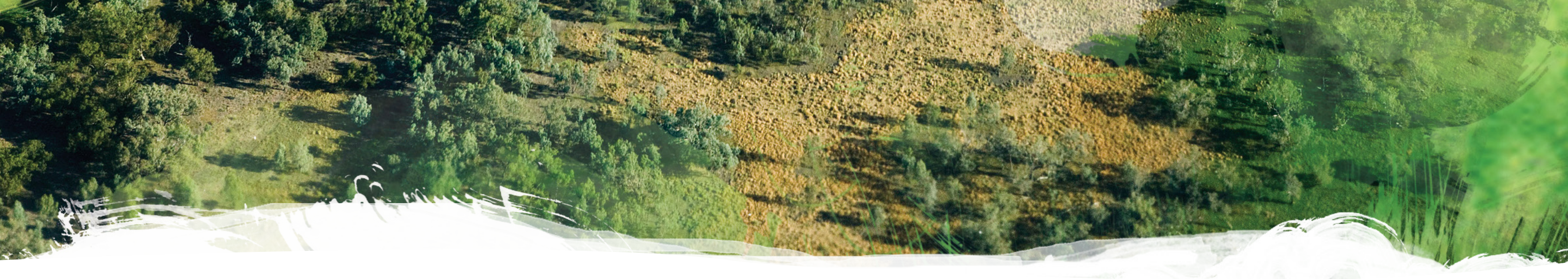

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