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

# Water balance assessment for the Namoi subregion

## Product 2.5 for the Namoi subregion from the Northern Inland Catchments Bioregional Assessment

2018

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 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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Authorship is listed in relative order of contribution.

## Copyright



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## Cover photograph

Gulligal Lagoon, which is located about halfway between Gunnedah and Boggabri on the western side of the Namoi River, NSW, 2005

Credit: Neal Foster

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# Acknowledgements

This technical product was reviewed by several groups:

- Discipline Leaders: Neil Viney (surface water hydrology)
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- 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.

# Currency of scientific results

The modelling results contained in this product were completed in December 2016 using the best available data, models and approaches available at that time. The product content was completed in December 2017.

All products in the model-data analysis, impact and risk analysis, and outcome synthesis (see Figure 1) were published as a suite when completed.

# 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 **Error! Reference source not found.**. 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.

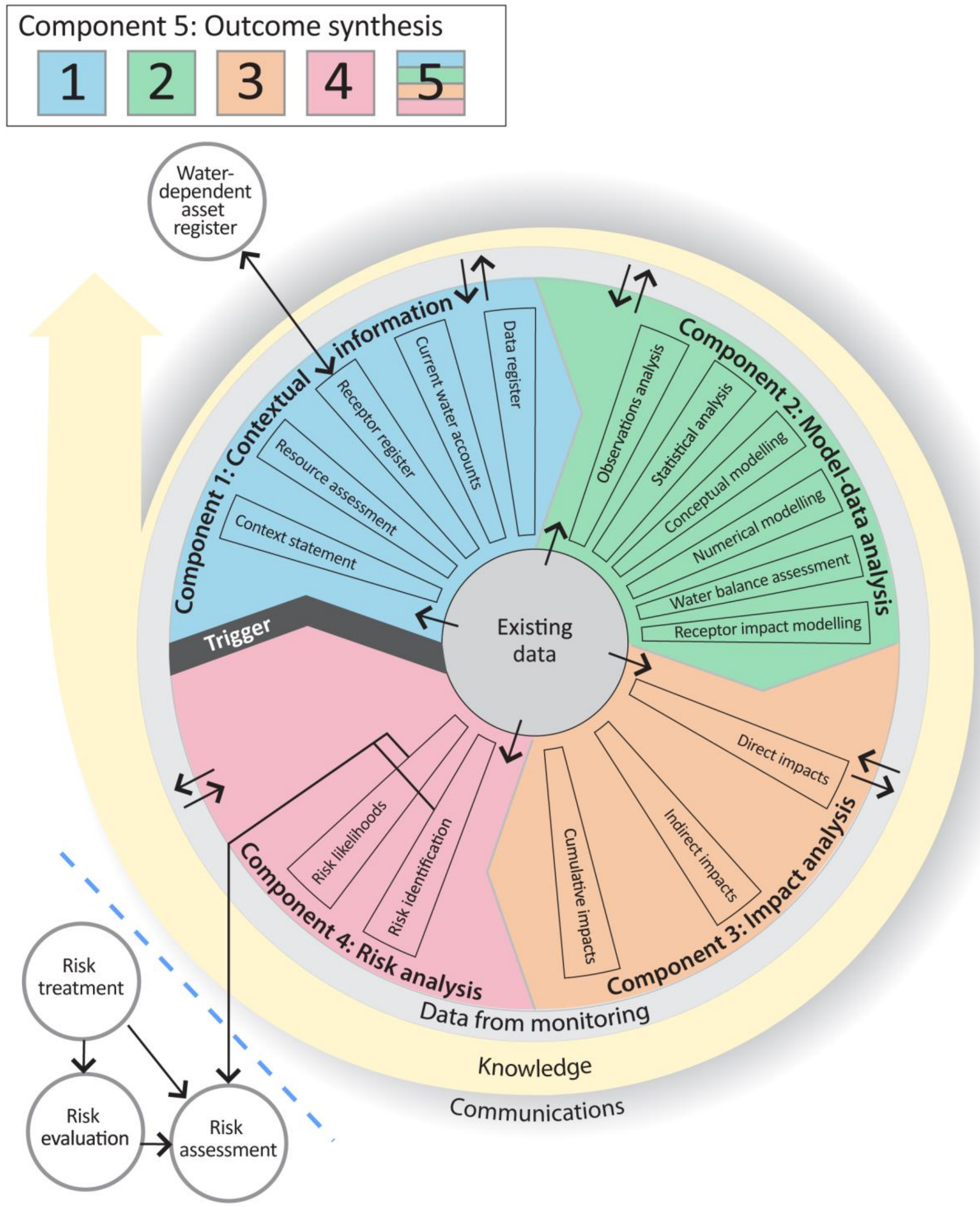


**Figure 1 Schematic diagram of the bioregional assessment methodology**

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 (**Error! Reference source not found.**), 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 **Error! Reference source not found.**. 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. **Error! Reference source not found.** shows the relationship of the technical products to BA components and submethodologies. **Error! Reference source not found.** 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 **Error! Reference source not found.** and **Error! Reference source not found.** 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.

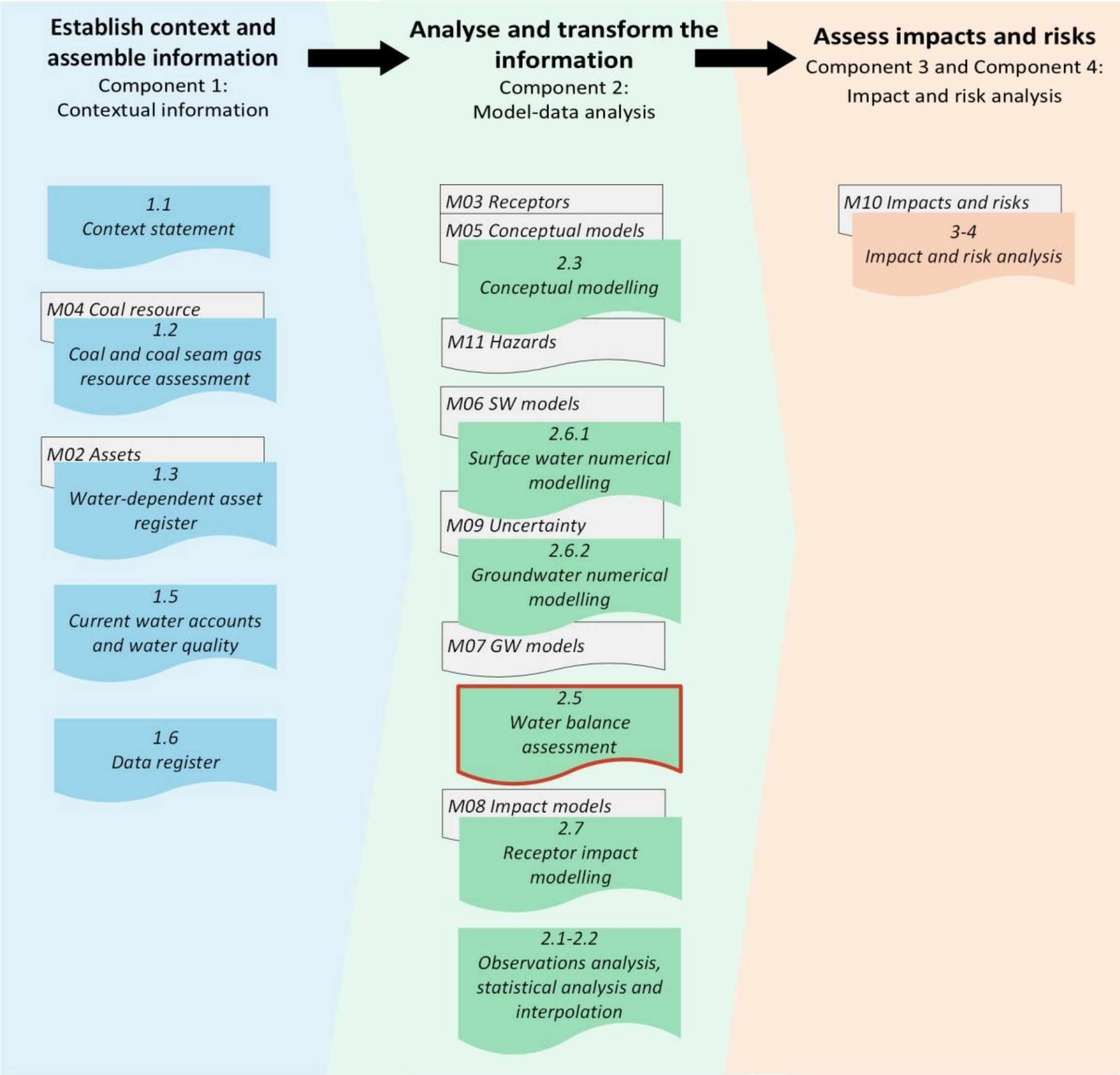


**Figure 2 Technical products and submethodologies associated with each component of a bioregional assessment**

In each component (**Error! Reference source not found.**) of a bioregional assessment, a number of technical products (coloured boxes, see also **Error! Reference source not found.**) are potentially created, depending on the availability of data and models. The light grey boxes indicate submethodologies (**Error! Reference source not found.**) 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 Namoi 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), product 2.6.1 (surface water numerical 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 Namoi 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 Namoi subregion | 2.1-2.2 | Observations analysis, statistical analysis and interpolation | 2.5.2.1, 2.5.2.2 | PDF, HTML |
| | 2.3 | Conceptual modelling | 2.5.2.3, 4.3 | PDF, HTML |
| | 2.5 | Water balance assessment | 2.5.2.4 | PDF, HTML |
| | 2.6.1 | Surface water numerical modelling | 4.4 | PDF, HTML |
| | 2.6.2 | Groundwater numerical modelling | 4.4 | PDF, HTML |
| | 2.7 | Receptor impact modelling | 2.5.2.6, 4.5 | PDF, HTML |
| Component 3 and Component 4: Impact and risk analysis for the Namoi subregion | 3-4 | Impact and risk analysis | 5.2.1, 2.5.4, 5.3 | PDF, HTML |
| Component 5: Outcome synthesis for the Namoi 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.

[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://www.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.

### *References*

Barrett DJ, Couch CA, Metcalfe DJ, Lytton L, Adhikary DP and Schmidt RK (2013) Methodology for bioregional assessments of the impacts of coal seam gas and coal mining development on water resources. A report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of the Environment. Department of the Environment, Australia. Viewed 6 April 2018, http://data.bioregionalassessments.gov.au/submethodology/bioregional-assessment-methodology.

IESC (2015) Information guidelines for the Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals. Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development, Australia. Viewed 6 April 2018, http://www.iesc.environment.gov.au/publications/information-guidelines-independent-expert-scientific-committee-advice-coal-seam-gas.

# 2.5 Water balance assessment for the Namoi subregion

This product presents mean annual water balances for the Namoi subregion using results from product 2.6.1 (surface water numerical modelling) and product 2.6.2 (groundwater numerical modelling). The water balances are reported over three 30-year periods, namely 2013 to 2042, 2043 to 2072 and 2073 to 2102, during which modelled global temperature increases of 1.0, 1.5 and 2.0 °C, respectively, have been assumed.

Water balances are reported for the two potential futures considered in a bioregional assessment:

- *baseline coal resource development (baseline)*: a future that includes all coal mines and coal seam gas (CSG) fields that are commercially producing as of December 2012
- *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 difference in results between CRDP and baseline is the change that is primarily reported in a bioregional assessment. 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.

This product reports results for only those developments in the baseline and CRDP that have been modelled.

Surface water balance terms will generally include rainfall, surface water outflow, licensed extraction and a residual term. Groundwater balance terms will generally include recharge, evapotranspiration, baseflow and change in storage. The exact set of water balance terms reported can vary from region to region.

The water balance reported here summarises volumetric changes and does not represent impacts on flow regime changes which may be more significant than changes in absolute flow volumes in some cases. For more details see product 2.6.1 (surface water numerical modelling) and product 2.6.2 (groundwater numerical modelling).

Impacts of flow volume and regime changes are considered in product 3-4 (impact and risk analysis).

## 2.5.1 Methods

**_Summary_**

Water balances are presented for the Namoi subregion for the reporting periods 2013 to 2042, 2043 to 2072, and 2073 to 2102. Each of the 30-year reporting periods includes some level of global warming, with the same variability as in the 1983 to 2012 historical sequence. For each time period, results from the baseline and coal resource development pathway (CRDP) are presented.

Water balances are reported for the Namoi groundwater model domain. They comprise recharge, evapotranspiration, non-mining groundwater extractions, mine pumping, surface water – groundwater flux, boundary flux and change in storage water balance terms. The groundwater balances are based on a subset of groundwater model simulations that showed closest agreement to observation data.

Surface water balances are provided for the minimum possible area which incorporates all hydrologically connected cumulative impacts at a point on the Namoi River for which model output is generated (this is 63% of the Namoi river basin). The surface water balances comprise annual rainfall, streamflow, licensed river extractions and a balancing term (residuals). The surface water balances are based on 300 of the 3000 surface water simulations that showed the best agreement with annual streamflow observation data.

### *2.5.1.1 Spatial and temporal extent of the water balances*

A water balance provides a summary of the inflows, outflows and change in storage for a defined area and period of time. Results from the numerical modelling reported in companion product 2.6.1 (Aryal et al., 2018) and companion product 2.6.2 (Janardhanan et al., 2018) for the Namoi subregion are reported as water balances in this product to provide summaries of the effect of coal resource development on key variables of the regional water balance. The CRDP in the Namoi subregion is comprised of open-cut and underground coal mines as well as a coal seam gas (CSG) development.

The water balances are reported for the two potential futures considered in bioregional assessments (BAs):

- baseline coal resource development (baseline): a future that includes all coal mines and CSG fields that are commercially producing as of December 2012
- 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 difference in results between CRDP and baseline is the change that is primarily reported in a BA. This change is due to 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. For the Namoi subregion the coal resource developments modelled under the baseline and under the CRDP are listed in Table 3.

**Table 3 Summary of developments modelled under the baseline and under the coal resource development pathway (CRDP)**

| Name | Development | Modelled in baseline | Modelled in CRDP | Start | Finish |
|---|---|---|---|---|---|
| Boggabri Coal Mine | Open-cut coal mine | Yes | Yes | 2006 | 2012 |
| Narrabri North Mine | Underground coal mine (longwall mining) | Yes | Yes | 2010 | 2035 |
| Rocglen Mine | Open-cut coal mine | Yes | Yes | 2009 | 2019 |
| Sunnyside Mine | Open-cut coal mine | Yes | Yes | 2008 | 2012 |
| Tarrawonga Mine | Open-cut coal mine | Yes | Yes | 2006 | 2012 |
| Werris Creek Mine[a] | Open-cut coal mine | No | No | 2005 | 2020 |
| Boggabri Coal Expansion Project | Open-cut coal mine | No | Yes | 2013 | 2033 |
| Caroona Coal Project | Underground coal mine (longwall mining) | No | Yes | 2020 | 2045 |
| Gunnedah Precinct[b] | Open-cut and underground coal mine | No | No | unknown | unknown |
| Maules Creek Project | Open-cut coal mine | No | Yes | 2015 | 2035 |
| Narrabri South | Underground coal mine (longwall mining) | No | Yes | 2030 | 2054 |
| Watermark Coal Project | Open-cut coal mine | No | Yes | 2018 | 2047 |
| Tarrawonga Coal Expansion Project | Open-cut coal mine | No | Yes | 2015 | 2031 |
| Vickery Coal Project | Open-cut coal mine | No | Yes | 2018 | 2047 |
| Vickery South Coal Project[b] | Open-cut coal mine | No | No | unknown | unknown |
| Narrabri Gas Project | CSG | No | Yes | 2017 | 2042 |

[a]Werris Creek Mine is modelled in the surface water modelling but is commentary only in the groundwater modelling.
[b]Gunnedah Precinct and Vickery South Coal Project are in the CRDP but are commentary only.
CSG = coal seam gas

In the Namoi subregion, groundwater and surface water have been modelled largely independently, but come together in the river model via a change in surface water – groundwater flux along a river network common to both models. Given this, separate groundwater and surface water balance domains are defined for the Namoi subregion, with some overlap in the surface water balances. Figure 3 summarises the water balance terms reported for (a) groundwater balances and (b) surface water balances. The surface water balance (Figure 3b) shows that evapotranspiration, leakage and change in storage are reported as a single residual term in the surface water balances. This is because the aim of the water balance report is to compare changes in water balance in three periods between baseline and CRDP. The change in overall water balance showing the rainfall, runoff, diversion and residuals is of interest rather than individual components like evaporation and leakage.

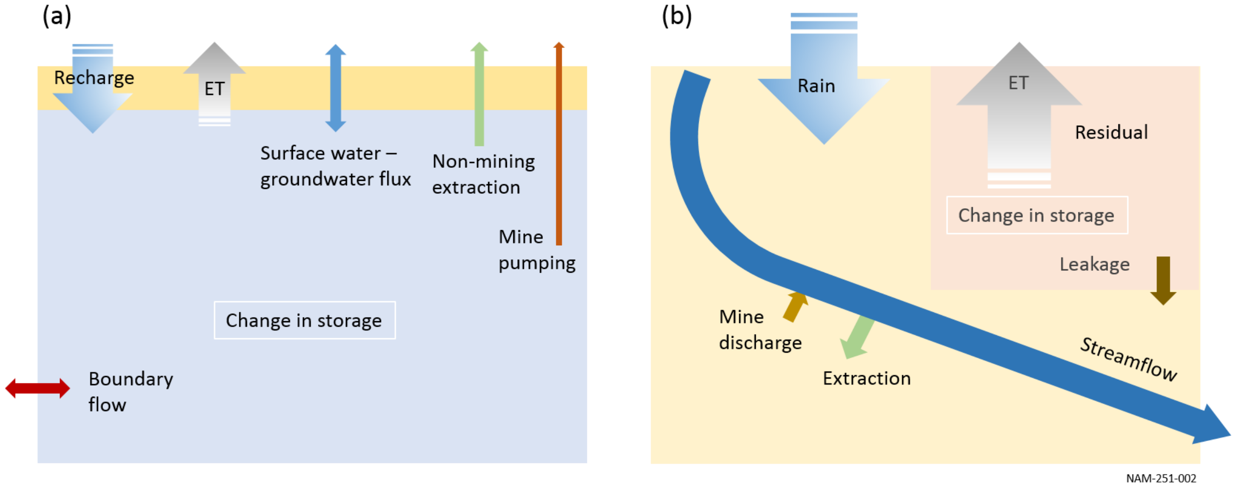


**Figure 3 Water balance terms for the Namoi subregion (a) groundwater balances and (b) surface water balances**

ET = evapotranspiration, Note: The groundwater balances figure is in cross-section view and the surface water figure is in plan view.

Water balance terms have been extracted from the various models for three 30-year periods (2013 to 2042, 2043 to 2072 and 2073 to 2102). These align with modelled temperature increases of 1.0, 1.5 and 2.0 °C under a future climate projection from the Institute of Atmospheric Physics (IAP) global climate model (GCM) which was the median of 15 models (more details are provided in companion product 2.6.1 for the Namoi subregion (Aryal et al., 2018)). These three time periods were generated from the 30-year historical sequence from 1983 to 2012 by modifying the historical sequence to reflect a warming trend. Thus the variability in the historical sequence is preserved, but the effect of droughts and floods does not confound the comparison between time periods. The water balance terms reported here represent the annual means for each 30-year period.

The groundwater modelling domain for the Namoi subregion encompasses an area greater than the subregion (Figure 4). As described in Janardhanan et al. (2018), the groundwater model represents groundwater in the Namoi subregion comprising the Gunnedah and Surat geological basins along with the alluvium along the major watercourses. A groundwater balance can be generated for the entire Namoi model domain, which comprises an inflow from recharge, outflows from evapotranspiration, mine and non-mine groundwater extractions, exchanges with the surface water system, boundary flows, and change in storage (Figure 3a). Boundary flows occur at the edges of the model domain and reflect inflows to or outflows from the subregion. The reported volumes are for an area of 59,000 $km^2$. Groundwater balances for subdomains of the Namoi subregion are not presented because the model was not configured to do this.

The high connectivity between alluvial aquifers and streams in the Namoi river basin means they are managed conjunctively. It is here that exchanges between groundwater and surface water predominantly occur. The groundwater model provides the change in surface water – groundwater fluxes to the Australian Water Resources Assessment (AWRA) river model (AWRA-R), hence this groundwater term is included in the surface water modelling and reported in the groundwater balance. No other groundwater fluxes (e.g. from seeps or springs) are represented in the surface water balances as they are not modelled.

Surface water balances can be reported for subdomains of a subregion because, if surface water – groundwater fluxes are assumed to be generated within the same contributing area as the surface flows, surface water catchments can be treated as relatively closed basins (with respect to inflows) with clearly defined outflow points. Surface water balance terms for the Namoi subdomains are rainfall, river diversions and river outflows, and were obtained from the AWRA landscape model (AWRA-L), AWRA-R and groundwater modelling.

Surface water balance model nodes were selected to quantify the cumulative hydrological changes due to coal resource development over the minimum possible area that they are all hydrologically connected and for which model outputs were generated. Thus these reporting areas summarise the 'maximum' impact on streamflow from the main groupings of hydrologically connected mines, rather than the maximum impact around individual mines.

One area was defined in the Namoi river basin (Figure 4) – the contributing areas to model node 13 (stream gauge 419039) on the Namoi River, just downstream of the junction of the Namoi River and Bohena Creek. This model node represents the cumulative changes from all coal mines in the Namoi subregion, as well as the additional coal resource development in the Narrabri Gas Project upstream of this point. The surface water contributing area for this basin is 26,534 $km^2$. This area includes 47% of the Namoi subregion and 63% of the Namoi river basin.

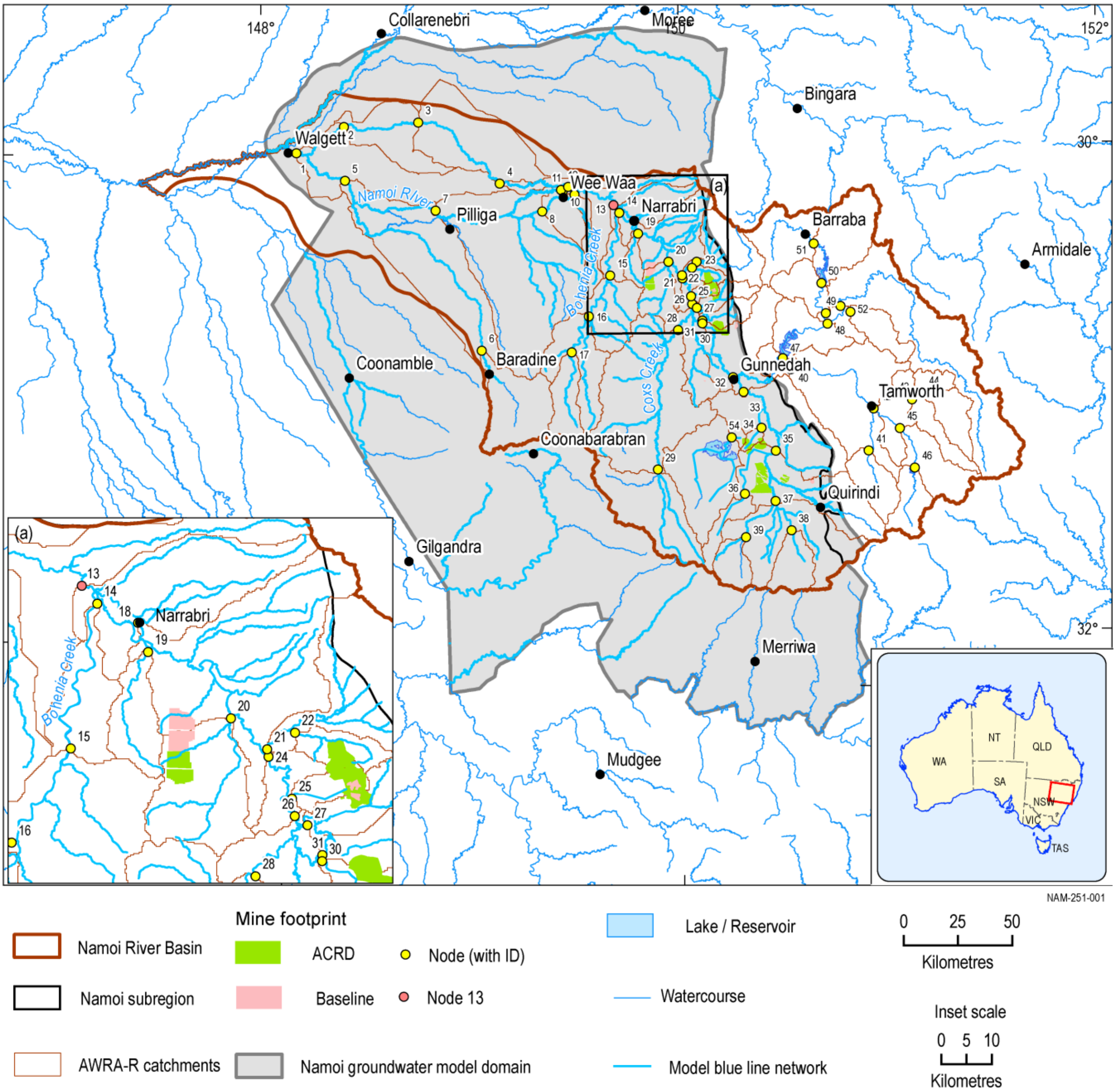


**Figure 4 Reporting areas for groundwater balance and model nodes for surface water balances**

AWRA-R = Australian Water Resources Assessment river model; ACRD = additional coal resource development
Data: Bioregional Assessment Programme (Dataset 1, Dataset 2, Dataset 3); Bureau of Meteorology (Dataset 4)

The water balance terms summarised here are a different set of model outputs to the hydrological response variables generated at model nodes, which are reported in companion product 2.6.1 (Aryal et al., 2018) and companion product 2.6.2 (Janardhanan et al., 2018) for the Namoi subregion. The range, as represented by the 10th and 90th percentile values for each groundwater and surface water balance term, summarises the results of selected groundwater and surface water model runs. This subset of model simulations was chosen through the uncertainty analysis described in Section 2.6.2.8 of companion product 2.6.2 (Janardhanan et al., 2018) and Section 2.6.1.5 of companion product 2.6.1 (Aryal et al., 2018). The chosen groundwater simulations are those in which the surface water – groundwater flux and the water extracted for coal resource development objective functions are met.

The range, as represented by the 10th and 90th percentile values for each surface water balance term, reflects the top 10% of the original 3000 model simulations, evaluated against annual streamflow observations at Namoi subregion gauges. The gauges chosen for evaluating model performance had at least 25 years of daily data and included unregulated and regulated parts of the river system.

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## *Datasets*

Dataset 1 Bioregional Assessment Programme (2016) Namoi groundwater model input shapefiles. Bioregional Assessment Derived Dataset. Viewed 16 December 2016, http://data.bioregionalassessments.gov.au/dataset/fb22671f-8b47-48e2-9fcd-232543fb8ad6.

Dataset 2 Bioregional Assessment Programme (2017) Namoi AWRA-R model implementation (post groundwater input). Bioregional Assessment Derived Dataset. Viewed 15 May 2017, http://data.bioregionalassessments.gov.au/dataset/8681bd56-1806-40a8-892e-4da13cda86b8.

Dataset 3 Bioregional Assessment Programme (2016) Namoi Surface Water Mine Footprints - digitised. Bioregional Assessment Derived Dataset. Viewed 16 May 2017, http://data.bioregionalassessments.gov.au/dataset/fa0a0d09-3780-498a-a412-242b25130291.

Dataset 4 Bureau of Meteorology (2011) Geofabric surface cartography - V2.1. Bioregional Assessment Source Dataset. Viewed 21 April 2015, http://data.bioregionalassessments.gov.au/dataset/5342c4ba-f094-4ac5-a65d-071ff5c642bc.

## 2.5.2 The water balances


### *Summary*

Hydrological changes due to coal resource development in the Namoi subregion are summarised in the form of water balances. Separate summaries are provided for groundwater and surface water; however, the streamflow term in the surface water balances includes a contribution from the groundwater model.

The groundwater balance covers the entire groundwater modelling domain. The key water balance term for the coal resource developments is the extractions for coal mining and coal seam gas (CSG) operations (this includes both deliberate and induced take). The reported values are based on mean annual extraction rates over each 30-year period and vary between simulations due to the parameter differences. Between 2013 and 2042, the increase in the median 30-year mean annual pumping rate due to additional coal resource development is 9.1 GL/year which is more than an order of magnitude greater than the baseline rate of 0.2 GL/year (but still very small (<3%) compared to the total licensed extractions of 316 GL/year). Between 2043 and 2072, all baseline developments cease, but there is a comparatively small amount of mine and CSG extractions (i.e. 30-year mean of 2.9 GL/year) for additional coal resource development. The modelled surface water – groundwater flux response to mine water pumping and hydraulic enhancement is a decreasing trend in river losses to groundwater over the three 30-year periods. The additional coal resource development results in losses of streamflow of 3.5 GL/year in the 2013 to 2042 period, 2.1 GL/year between 2043 and 2072, and 0.6 GL/year between 2073 and 2102. These additional losses are small compared to the trend in increasing stream losses through time in the baseline due to licensed extractions (40.7 GL/y for 2013 to 2042 up to 62 GL/y for 2073 to 2102).

The water balance at model node 13 on the Namoi River (Namoi River at Mollee) with a contributing catchment area of 26,534 km$^2$ shows less than 1% change in the streamflow between baseline and coal resource development pathway (CRDP) for all periods.

Although the changes in the water balance components are small, changes in other hydrological response variables may be significant (e.g. drawdown or no-flow days). These other metrics are reported in companion product 2.6.1 (Aryal et al., 2018) and companion product 2.6.2 (Janardhanan et al., 2018) for the Namoi subregion.


### *2.5.2.1 Groundwater balance for the groundwater modelling domain*

Groundwater balances for the Namoi subregion modelling domain (Figure 4) are provided in Table 4 for 2013 to 2042, Table 5 for 2043 to 2072 and Table 6 for 2073 to 2102. Water balance terms represent the mean annual volume in GL/year for each 30-year period across the entire groundwater modelling domain, an area of 59,000 km$^2$. The median and the 10th and 90th percentile values for each variable of the baseline and CRDP set of simulations are reported, whereas the difference reflects the change attributable to additional coal resource development, obtained from subtracting the median baseline value from the median CRDP value. As the values in the table represent percentiles of many model runs rather than the output of single model runs, the water balance components do not necessarily sum to zero (single model run water balance components sum to zero).

**Table 4 Groundwater balance for Namoi subregion groundwater model domain for 2013 to 2042**

| Water balance term | Under the baseline (GL/y) | Under the coal resource development pathway (GL/y) | Difference (GL/y) |
|---|---|---|---|
| Change in storage | 79 (59.6, 101.9) | 87.1 (67.4, 106.3) | 8.1 |
| Licensed extractions (non-mining uses) | –315.9 (–315.9, –315.9) | –315.9 (–315.9, –315.9) | 0.0 |
| Mine and coal seam gas extractions | –0.2 (–0.3, –0.1) | –9.1 (–11.2, –7.6) | –9.0 |
| Surface water – groundwater flux | 37.3 (–36.6, 83.3) | 40.7 (–34.4, 85) | 3.5 |
| Evapotranspiration from groundwater | –449.9 (–537.6, –256.7) | –449.6 (–537.3, –256.6) | 0.3 |
| Boundary flow | 0.2 (0.1, 0.5) | 0.2 (0.1, 0.5) | 0.0 |
| Recharge | 675.5 (391.4, 800.8) | 675.5 (391.4, 800.8) | 0.0 |

The first number is the median, and the 10th and 90th percentile numbers follow in brackets. The difference is between the two median values. Numbers are rounded to one decimal place. Positive values represent water entering the model domain; negative values represent water leaving the model domain.
Data: Bioregional Assessment Programme (Dataset 1)

**Table 5 Groundwater balance for Namoi subregion groundwater model domain for 2043 to 2072**

| Water balance term | Under the baseline (GL/y) | Under the coal resource development pathway (GL/y) | Difference (GL/y) |
|---|---|---|---|
| Change in storage | 66.8 (50.3, 80) | 68.3 (50.4, 79.1) | 1.4 |
| Licensed extractions (non-mining uses) | –315.9 (–315.9, –315.9) | –315.9 (–315.9, –315.9) | 0.0 |
| Mine and coal seam gas extractions | 0 (0, 0) | –2.9 (–3.1, –1.4) | –2.9 |
| Surface water – groundwater flux | 51.4 (–15.7, 98.5) | 53.4 (–14, 100.7) | 2.1 |
| Evapotranspiration from groundwater | –441.4 (–531.4, –251.4) | –440.7 (–530.8, –251.1) | 0.7 |
| Boundary flow | 0.2 (0.1, 0.5) | 0.2 (0.1, 0.5) | 0.0 |
| Recharge | 667 (386.2, 790.7) | 667 (386.2, 790.7) | 0.0 |

The first number is the median, and the 10th and 90th percentile numbers follow in brackets. The difference is between the two median values. Numbers are rounded to one decimal place. Positive values represent water entering the model domain; negative values represent water leaving the model domain.
Data: Bioregional Assessment Programme (Dataset 1)

**Table 6 Groundwater balance for Namoi subregion groundwater model domain for 2073 to 2102**

| Water balance term | Under the baseline (GL/y) | Under the coal resource development pathway (GL/y) | Difference (GL/y) |
|---|---|---|---|
| Change in storage | 59.3 (48.2, 70.2) | 57.8 (46.4, 69.1) | –1.5 |
| Licensed extractions (non-mining uses) | –315.9 (–315.9, –315.9) | –315.9 (–315.9, –315.9) | 0.0 |
| Mine and coal seam gas extractions | 0 (0, 0) | 0 (0, 0) | 0.0 |
| Surface water – groundwater flux | 61.4 (0, 110.3) | 62 (0.8, 111.6) | 0.6 |
| Evapotranspiration from groundwater | –427.5 (–519.4, –243.3) | –427.3 (–518.8, –243) | 0.3 |
| Boundary flow | 0.3 (0.1, 0.5) | 0.3 (0.1, 0.5) | 0.0 |
| Recharge | 648.8 (375.6, 769.1) | 648.8 (375.6, 769.1) | 0.0 |

The first number is the median, and the 10th and 90th percentile numbers follow in brackets. The difference is between the two median values. Numbers are rounded to one decimal place. Positive values represent water entering the model domain; negative values represent water leaving the model domain.
Data: Bioregional Assessment Programme (Dataset 1)

The dominant water balance terms are recharge and surface water – groundwater flux on the input side and licensed extractions and evapotranspiration on the output side. The recharge term in the baseline and CRDP simulations varies across the three periods due to changes in rainfall and evapotranspiration from the increases in temperature assumed in the modelling to reflect global warming (see companion submethodology M06 (as listed in Table 1) for surface water modelling (Viney, 2016)). However, the difference between the baseline and CRDP recharge in each 30-year period is predicted to be zero because the groundwater model does not account for changes in recharge that might arise as a result of mine subsidence or excavation of open-cut mines.

Licensed extractions (under NSW's *Water Management Act 2000*) for non-mining uses, such as irrigation, stock and domestic, town water supply and industrial uses, were modelled in the groundwater model. It was assumed that extractions were the same under the baseline and under the CRDP (i.e. changes in mine water use under the CRDP do not affect water use by other licence holders). It was assumed that rates of extraction were at the maximum entitlement under each licence and that there was no increase in licensed entitlements into the future. Thus the non-mining groundwater extractions do not differ between baseline and CRDP in any of the 30-year periods.

The primary differences in the water balance between the baseline and CRDP are due to the extractions for coal resource development; however, groundwater extraction for mining and CSG purposes is small (~3%) compared to the licensed extractions for non-mining uses. The greatest difference between the baseline and CRDP is seen in the first 30-year period (2013 to 2042) and by the last 30-year period all CRDP developments have completed and there are no extractions in either the baseline or CRDP.

The surface water – groundwater flux is the net volume of water exchanged between the groundwater and the river, calculated as the difference between groundwater flow to the river (i.e. baseflow) and leakage from the river to groundwater. A positive number indicates a stream leakage to groundwater. In all three 30-year periods, the median of the 30-year mean annual surface water – groundwater flux under the CRDP is greater than under baseline, indicating an increase in the river losses to groundwater with more intensive coal resource development.

Evapotranspiration from groundwater is a major component of the water balance in each 30-year period, this is consistent with remotely sensed actual evapotranspiration (AET) being greater than rainfall in large parts of the model domain (Guerschman et al., 2009). Evapotranspiration from groundwater is influenced by not just atmospheric conditions, but also the position of the watertable relative to the evapotranspiration extinction depth (a parameter in the model which approximates the maximum rooting depth below which vegetation and atmospheric processes cannot extract water). Since the hydrological change due to additional coal resource development is through pumping-induced drawdown of the watertable around the mining operations, there is a difference between the CRDP and baseline simulations in each of the 30-year periods, which reflects changes in the area of watertable above the evapotranspiration extinction depth.

The flow across the model boundaries is small and does not change between time periods or between the baseline and CRDP. The change in storage is always a positive value indicating a reduction in the stored volume through each time period. Under the baseline the change in storage is decreasing through the three time periods indicating that the model has not come to a dynamic equilibrium; this is caused by the licensed extractions and the reduction in recharge due to the global warming signal applied.

The changes in the groundwater balance due to additional coal resource development are small compared to the changes due to licenced extractions (not coal related) and reductions in recharge through time.

### *2.5.2.2 Surface water balances for the Namoi subregion*

Surface water balances are provided at model node 13 (Figure 4) in the Namoi River at Mollee. The model node is immediately downstream from major coal resource development activities in the Namoi subregion.

Rainfall was identical for baseline and CRDP, therefore only a single rainfall volume is provided for the water balance for each 30-year period. The decreasing mean annual rainfall input over the three 30-year periods reflects the global warming changes assumed in the modelling (see companion submethodology M06 (as listed in Table 1) for surface water modelling (Viney, 2016)).

The streamflow term in the surface water balances includes the surface water – groundwater flux component from the groundwater model. As stated in Section 2.5.1, water balances are reported separately for surface water and groundwater modelling, as they apply to different areas.

These water balances account for water that recharges groundwater but is not discharged to the stream as a residual. The residual is a balancing term that comprises evapotranspiration, change in storage and leakage from the river.

Surface water balances at model node 13 on the Namoi River are provided in Table 7 for 2013 to 2042, Table 8 for 2043 to 2072 and Table 9 for 2073 to 2102. The contributing area to model node 13 is about 26,534 $km^2$ and includes all coal resource development areas in the subregion.

The median and the 10th and 90th percentile values for each variable of the baseline and CRDP set of simulations are reported. The difference reflects the change attributable to additional coal resource development, obtained from subtracting the baseline value from the CRDP value.

**Table 7 Surface water balance for 2013 to 2042 at model node 13 (Namoi River)**

| Water balance term | Under the baseline (GL/y) | Under the coal resource development pathway (GL/y) | Difference (GL/y) |
|---|---|---|---|
| Rainfall | 18,871 | 18,871 | 0.0 |
| Streamflow | 761.6 (663; 832) | 760.3 (662; 831) | 1 |
| Mine discharge | NM | NM | NM |
| Diversion | 149.5 (136.0; 164.8) | 149.5 (136.0; 164.7) | 0.0 |
| Residuals | 17,960 (17,874; 18,072) | 17,961 (17,876; 18,073) | –1 |

NM = not modelled. There is no plan to discharge mine water to the river.
For some (but not all) terms, three numbers are provided. The first number is the median, and the 10th and 90th percentile numbers follow in brackets. Some numbers are rounded to whole numbers.
Data: Bioregional Assessment Programme (Dataset 2, Dataset 3)

**Table 8 Surface water balance for 2043 to 2072 at model node 13 (Namoi River)**

| Water balance term | Under the baseline (GL/y) | Under the coal resource development pathway (GL/y) | Difference (GL/y) |
|---|---|---|---|
| Rainfall | 18,710 | 18,710 | 0.0 |
| Streamflow | 736 (637; 806) | 735 (636; 805) | 1 |
| Mine discharge | NM | NM | NM |
| Diversion | 148.1 (134.2; 163.9) | 148.1 (134.1; 163.8) | 0.0 |
| Residuals | 17,826 (17,740; 17,939) | 17,827 (17,742; 17,940) | –1 |

NM = not modelled. There is no plan to discharge mine water to the river.
For some (but not all) terms, three numbers are provided. The first number is the median, and the 10th and 90th percentile numbers follow in brackets. Some numbers are rounded to whole numbers.
Data: Bioregional Assessment Programme (Dataset 2, Dataset 3)

**Table 9 Surface water balance for 2073 to 2102 at model node 13 (Namoi River)**

| Water balance term | Under the baseline (GL/y) | Under the coal resource development pathway (GL/y) | Difference (GL/y) |
|---|---|---|---|
| Rainfall | 18,554 | 18,554 | 0.0 |
| Streamflow | 704 (611; 774) | 703 (611; 774) | 1 |
| Mine discharge | NM | NM | NM |
| Diversion | 145.7 (131.7; 162.0) | 145.6 (131.7; 161.9) | 0.1 |
| Residuals | 17,704 (17,618; 17,811) | 17,705 (17,619; 17,812) | –1 |

NM = not modelled. There is no plan to discharge mine water to the river.
For some (but not all) terms, three numbers are provided. The first number is the median, and the 10th and 90th percentile numbers follow in brackets. Some numbers are rounded to whole numbers.
Data: Bioregional Assessment Programme (Dataset 2, Dataset 3)

Diversions from the river for irrigation use were modelled in the Namoi Regulated River. Regulated rivers are the main source of water to meet the needs of irrigators and town water supply along these reaches. Diversion from the river does not vary between the baseline and CRDP, but the model may predict a decrease in extractions over the 90 years in response to a drying climate.

The additional coal resource developments are predicted to cause negligible reductions in streamflow at model node 13 in all three periods relative to the baseline streamflow. The difference between CRDP and baseline is 1 GL/year for all periods (less than 0.1% reduction relative to the baseline). The discharges from Narrabri Gas Project are not modelled because they are negligible at the regional scale (Santos, no date).

### *2.5.2.3 Gaps*

The groundwater model was not constructed to generate subdomain groundwater balances. The surface water modelling domain overlapped, but did not conform exactly to, the groundwater modelling domain. Generating a single, integrated water balance for the Namoi subregion or for subdomains of the subregion that draws on water balance terms from both models was not possible. This mismatch in the spatial extent of the model domains does not affect the calculation of the hydrological response variables that are used in the receptor impact models.

Mine discharges from additional coal resource development were not included in the river modelling.

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## *Datasets*

Dataset 1 Bioregional Assessment Programme (2017) Namoi groundwater balance results. Bioregional Assessment Derived Dataset. Viewed 16 May 2017, http://data.bioregionalassessments.gov.au/dataset/1adf48a0-5c2d-4ef6-a811-e1155cde4c65.

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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

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

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.

baseflow: the portion of streamflow that comes from shallow and deep subsurface flow, and is an important part of the groundwater system

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

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.

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

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

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).

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.

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

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.

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 flow 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.

inflow: surface water runoff and deep drainage to groundwater (groundwater recharge) and transfers into the water system (both surface water and groundwater) for a defined area

model node: a point in the landscape where hydrological changes (and their uncertainty) are assessed. Hydrological changes at points other than model nodes are obtained by interpolation.

Namoi subregion: The Namoi subregion is located within the Murray–Darling Basin in central New South Wales. The subregion lies within the Namoi river basin, which includes the Namoi, Peel and Manilla rivers. However, the subregion being assessed is smaller than the Namoi river basin because the eastern part of the river basin does not overlie a coal-bearing geological basin. The largest towns in the subregion are Gunnedah, Narrabri and Walgett. The main surface water resource of the Namoi subregion is the Namoi River. There are three large dams that supply water to the subregion, of which Keepit Dam is the main water storage. More than half of the water released from Keepit Dam and river inflow may be extracted for use for agriculture, towns and households. Of this, the great majority is used for agricultural irrigation. The landscape has been considerably altered since European settlement for agriculture. Significant volumes of groundwater are also used for agriculture (cropping). Across the subregion there are a number of water-dependent ecological communities, and plant and animal species that are listed as threatened under either Commonwealth or New South Wales legislation. The subregion also contains Lake Goran, a wetland of national importance, and sites of international importance for bird conservation.

percentile: a specific type of quantile where the range of a distribution or set of runs is divided into 100 contiguous intervals, each with probability 0.01. An individual percentile may be used to indicate the value below which a given percentage or proportion of observations in a group of observations fall. For example, the 95th percentile is the value below which 95% of the observations may be found.

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

receptor impact model: a function that translates hydrological changes into the distribution or range of potential ecosystem outcomes that may arise from those changes. Within bioregional assessments, hydrological changes are described by hydrological response variables, ecosystem outcomes are described by receptor impact variables, and a receptor impact model determines the relationship between a particular receptor impact variable and one or more hydrological response variables. Receptor impact models are relevant to specific landscape classes, and play a crucial role in quantifying potential impacts for ecological water-dependent assets that are within the landscape class. In the broader scientific literature receptor impact models are often known as ‘ecological response functions’.

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.

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.

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

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.

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 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)

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.

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

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