Australian Government

BIOREGIONAL ASSESSMENTS

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

Description of the water-dependent asset register for the Sydney Basin bioregion

Product 1.3 from the Sydney Basin 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 Office of Water Science, within the Australian Government Department of the Environment and Energy, is strengthening the regulation of coal seam gas and large coal mining development by ensuring that future decisions are informed by substantially improved science and independent expert advice about the potential water related impacts of those developments. For more information, visit http://www.environment.gov.au/coal-seam-gas-mining/.

Bureau of Meteorology

The Bureau of Meteorology is Australia's national weather, climate and water agency. Under the *Water Act 2007*, the Bureau is responsible for compiling and disseminating Australia's water information. The Bureau is committed to increasing access to water information to support informed decision making about the management of water resources. For more information, visit http://www.bom.gov.au/water/.

CSIRO

Australia is founding its future on science and innovation. Its national science agency, CSIRO, is a powerhouse of ideas, technologies and skills for building prosperity, growth, health and sustainability. It serves governments, industries, business and communities across the nation. For more information, visit http://www.csiro.au.

Geoscience Australia

Geoscience Australia is Australia's national geoscience agency and exists to apply geoscience to Australia's most important challenges. Geoscience Australia provides geoscientific advice and information to the Australian Government to support current priorities. These include contributing to responsible resource development; cleaner and low emission energy technologies; community safety; and improving marine planning and protection. The outcome of Geoscience Australia's work is an enhanced potential for the Australian community to obtain economic, social and environmental benefits through the application of first class research and information. For more information, visit http://www.ga.gov.au.

ISBN-PDF 978-1-925315-49-3

Citation

Herron NF, McVicar TR, Rachakonda PK, Macfarlane C, Pritchard J, Marvanek SP, Li LT, Crosbie RS, Wilkes PG, Dawes WR, Slegers S, Wang J, Guo L and Bell J (2018) Description of the water-dependent asset register for the Sydney Basin bioregion. Product 1.3 from the Sydney Basin Bioregional Assessment. Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia.
http://data.bioregionalassessments.gov.au/product/SSB/SSB/1.3.

Authorship is listed in relative order of contribution.

Copyright

Disclaimer

Cover photograph

Surface infrastructure of the Clarence underground coal mine located approximately 15 km east of Lithgow, adjacent to the Greater Blue Mountains World Heritage Area, showing vegetation recovering from bushfire in October 2013. The hillslope drains into the Wollangambe River

v20180304

Australian Government
Department of the Environment and Energy
Bureau of Meteorology
Geoscience Australia

CSIRO

Contents

Figures

Tables

Contributors to the Technical Programme

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

Role or team	Contributor(s)
Assistant Secretary	Department of the Environment and Energy: Matthew Whitfort
Programme Director	Department of the Environment and Energy: Anthony Swirepik
Technical Programme Director	Bureau of Meteorology: Julie Burke
Projects Director	CSIRO: David Post
Principal Science Advisor	Department of the Environment and Energy: Peter Baker
Science Directors	CSIRO: Brent Henderson Geoscience Australia: Steven Lewis
Integration	Bureau of Meteorology: Richard Mount (Integration Leader) CSIRO: Becky Schmidt
Programme management	Bureau of Meteorology: Louise Minty CSIRO: Paul Hardisty, Warwick McDonald Geoscience Australia: Stuart Minchin
Project Leaders	CSIRO: Alexander Herr, Kate Holland, Tim McVicar, David Rassam Geoscience Australia: Tim Evans Bureau of Meteorology: Natasha Herron
Assets and receptors	Bureau of Meteorology: Richard Mount (Discipline Leader) Department of the Environment and Energy: Glenn Johnstone, Wasantha Perera, Jin Wang
Bioregional Assessment Information Platform	Bureau of Meteorology: Lakshmi Devanathan (Team Leader), Derek Chen, Trevor Christie-Taylor, Melita Dahl, Angus MacAulay, Christine Panton, Paul Sheahan, Kellie Stuart, Carl Sudholz CSIRO: Peter Fitch, Ashley Sommer Geoscience Australia: Neal Evans
Communications	Bureau of Meteorology: Karen de Plater CSIRO: Helen Beringen, Chris Gerbing Department of the Environment and Energy: Amanda Forman, John Higgins, Lea Locke, Milica Milanja Geoscience Australia: Michelle McGranahan
Coordination	Bureau of Meteorology: Julie Burke, Eliane Prideaux, Sarah van Rooyen CSIRO: Ruth Palmer Department of the Environment and Energy: Anisa Coric, James Hill, Bronwyn McMaster, Emily Turner
Ecology	CSIRO: Anthony O'Grady (Discipline Leader), Caroline Bruce, Tanya Doody, Brendan Ebner, Craig MacFarlane, Patrick Mitchell, Justine Murray, Chris Pavey, Jodie Pritchard, Nat Raisbeck-Brown, Ashley Sparrow
Geology	CSIRO: Deepak Adhikary, Emanuelle Frery, Mike Gresham, Jane Hodgkinson, Zhejun Pan, Matthias Raiber, Regina Sander, Paul Wilkes Geoscience Australia: Steven Lewis (Discipline Leader)

Role or team	Contributor(s)
Geographic information systems	CSIRO: Jody Bruce, Debbie Crawford, Daniel Gonzales, Mike Gresham, Steve Marvanek, Arthur Read Geoscience Australia: Adrian Dehelean, Joe Bell
Groundwater modelling	CSIRO: Russell Crosbie (Discipline Leader), Tao Cui, Warrick Dawes, Lei Gao, Sreekanth Janardhanan, Luk Peeters, Praveen Kumar Rachakonda, Adam Ramage, Wolfgang Schmid, Saeed Torkzaban, Chris Turnadge, Andy Wilkins, Binzhong Zhou
Hydrogeology	Geoscience Australia: Tim Ransley (Discipline Leader), Chris Harris-Pascal, Jessica Northey, Emily Slatter
Information management	Bureau of Meteorology: Belinda Allison (Team Leader) CSIRO: Qifeng Bai, Simon Cox, Phil Davies, Mick Hartcher, Geoff Hodgson, Brad Lane, Ben Leighton, David Lemon, Trevor Pickett, Shane Seaton, Ramneek Singh, Matt Stenson Geoscience Australia: Matti Peljo
Products	CSIRO: Becky Schmidt (Products Manager), Maryam Ahmad, Clare Brandon, Heinz Buettikofer, Sonja Chandler, Simon Gallant, Karin Hosking, Allison Johnston, Maryanne McKay, Linda Merrin, Joely Taylor, Sally Tetreault-Campbell, Catherine Ticehurst Geoscience Australia: Penny Kilgour, Kathryn Owen
Risk and uncertainty	CSIRO: Simon Barry (Discipline Leader), Jeffrey Dambacher, Jess Ford, Keith Hayes, Geoff Hosack, Adrian Ickowicz, Warren Jin, Yang Liu, Dan Pagendam
Surface water hydrology	CSIRO: Neil Viney (Discipline Leader), Santosh Aryal, Mat Gilfedder, Fazlul Karim, Lingtao Li, Dave McJannet, Jorge Luis Peña-Arancibia, Xiaogang Shi, Tom Van Niel, Jai Vaze, Bill Wang, Ang Yang, Yongqiang Zhang

Acknowledgements

This technical product was reviewed by several groups:

- Discipline Leaders: Russell Crosbie (groundwater modelling)
- Senior Science Leaders: David Post (Projects Director), Steven Lewis (Science Director, Geoscience Australia), Brent Henderson (Science Director, CSIRO), Maryam Ahmad (Products Manager)
- Technical Assurance Reference Group: Chaired by Peter Baker (Principal Science Advisor, Department of the Environment), this group comprises officials from the NSW, Queensland, South Australian and Victorian governments.

Introduction

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) was established to provide advice to the federal Minister for the Environment on potential water-related impacts of coal seam gas (CSG) and large coal mining developments (IESC, 2015).

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

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

The Bioregional Assessment Programme

The Bioregional Assessment Programme is a collaboration between the Department of the Environment 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, will undertake BAs for the following bioregions and subregions (see http://www.bioregionalassessments.gov.au/assessments for a map and further information):

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

- the Sydney Basin bioregion
- the Gippsland Basin bioregion.

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

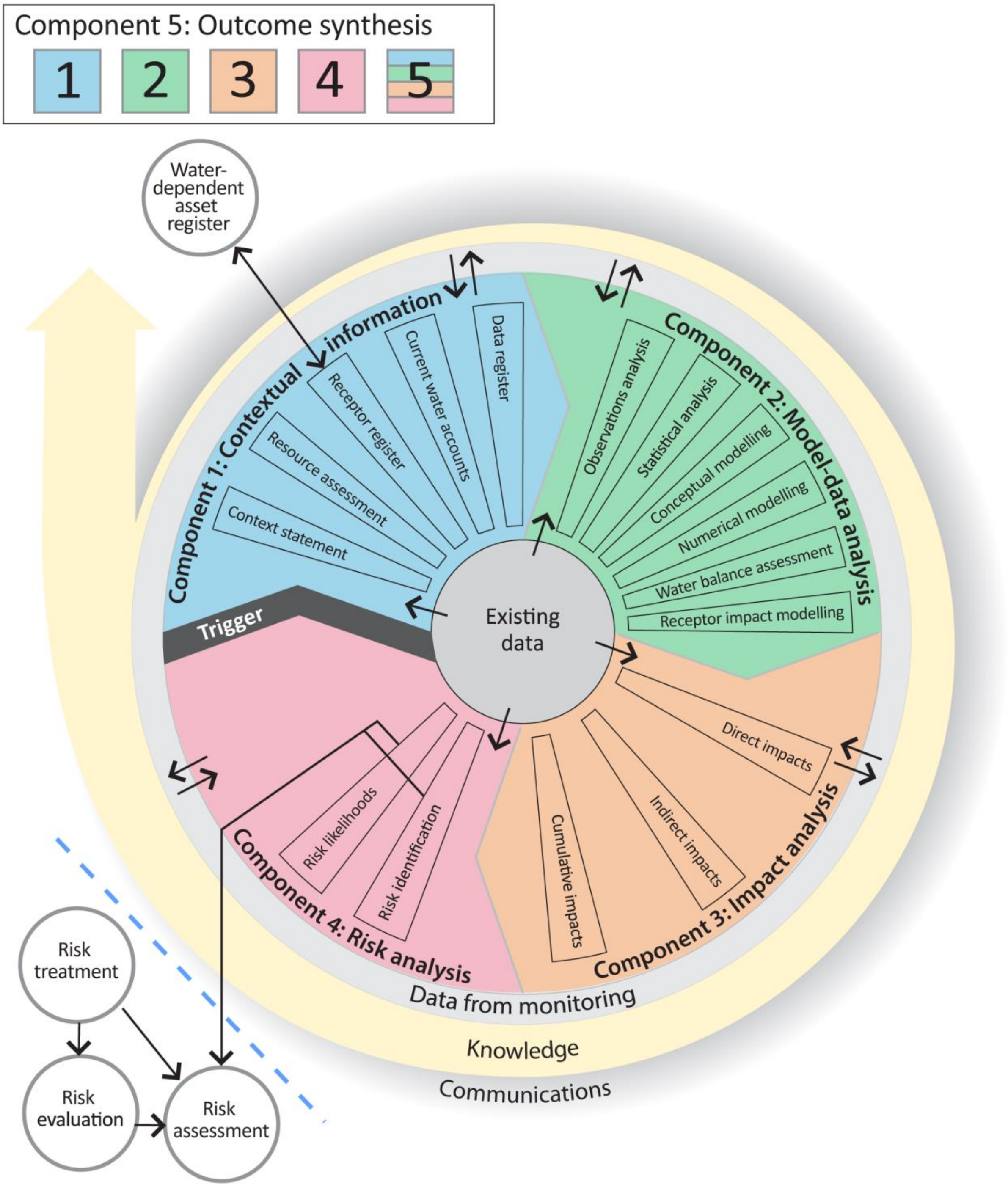

Figure 1 Schematic diagram of the bioregional assessment methodology

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

Methodologies

The overall scientific and intellectual basis of the BAs is provided in the BA methodology (Barrett et al., 2013). Additional guidance is required, however, about how to apply the BA methodology to a range of subregions and bioregions. To this end, the teams undertaking the BAs have developed and documented detailed scientific submethodologies (Table 1) to, in the first instance, 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 – in this case an explanation will be supplied in the technical products of that BA. Ultimately the Programme anticipates publishing a consolidated 'operational BA methodology' with fully worked examples based on the experience and lessons learned through applying the methods to 13 bioregions and subregions.

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

Table 1 Methodologies

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

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

Technical products

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

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

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

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

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

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

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

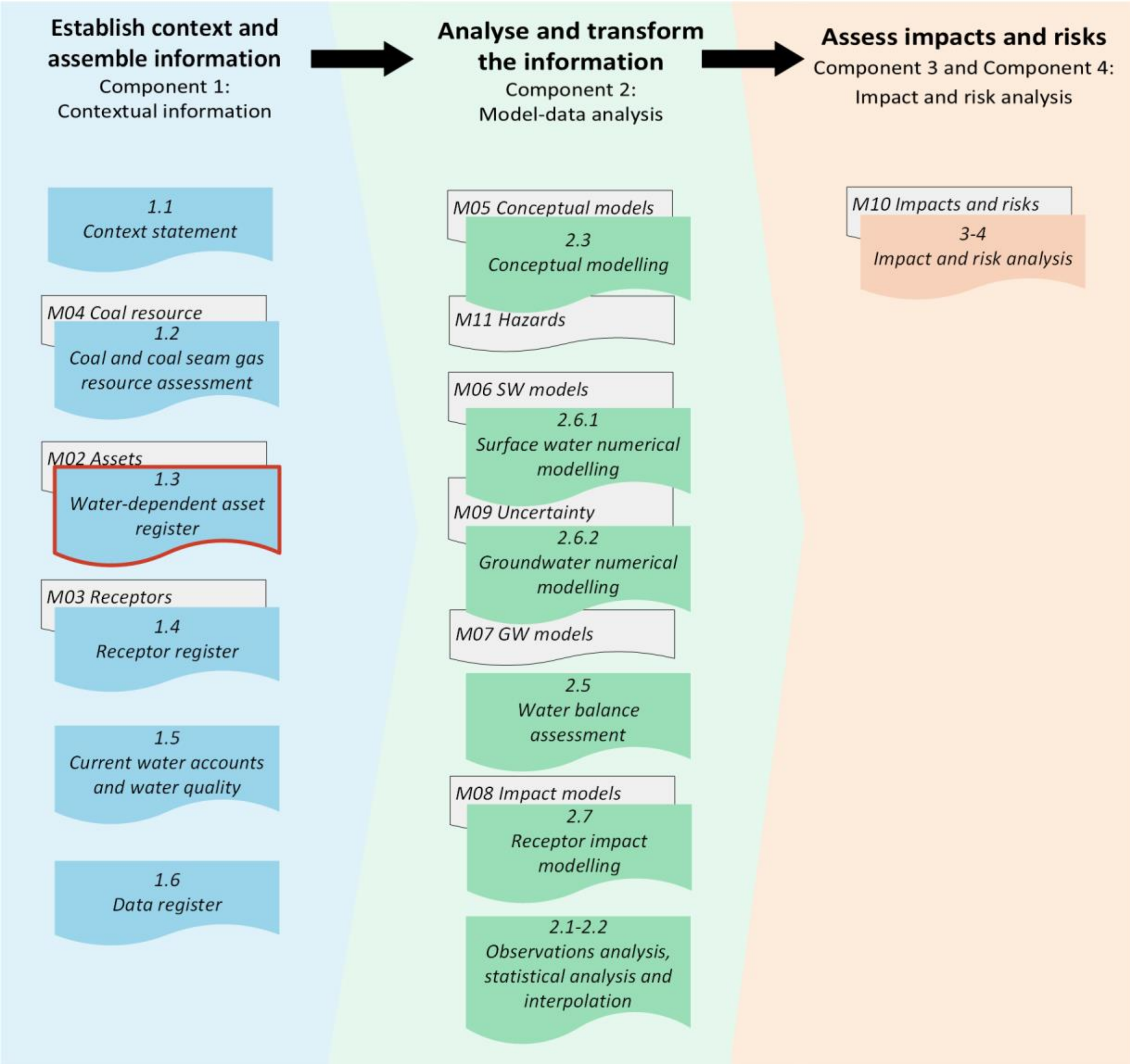

Figure 2 Technical products and submethodologies associated with each component of a bioregional assessment

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

Table 2 Technical products delivered for the Sydney Basin bioregion

For the Sydney Basin 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 products 2.6.1 (surface water modelling) and 2.6.2 (groundwater 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 other products.

Component	Product code	Title	Section in the BA methodology[b]	Type[a]
Component 1: Contextual information for the Sydney Basin bioregion	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	HTML-only
	1.6	Data register	2.5.1.6	Register
Component 2: Model-data analysis for the Sydney Basin bioregion	2.1-2.2	Observations analysis, statistical analysis and interpolation	2.5.2.1, 2.5.2.2	Not produced
	2.3	Conceptual modelling	2.5.2.3, 4.3	Not produced
	2.5	Water balance assessment	2.5.2.4	Not produced
	2.6.1	Surface water numerical modelling	4.4	Not produced
	2.6.2	Groundwater numerical modelling	4.4	Not produced
	2.7	Receptor impact modelling	2.5.2.6, 4.5	Not produced
Component 3 and Component 4: Impact and risk analysis for the Sydney Basin bioregion	3-4	Impact and risk analysis	5.2.1, 2.5.4, 5.3	Not produced
Component 5: Outcome synthesis for the Sydney Basin bioregion	5	Outcome synthesis	2.5.5	Not produced

[a]The types of products are as follows:

- 'PDF' indicates a PDF document that is developed by the Sydney Basin 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.
- 'HTML-only' indicates content that is only delivered as webpages (with no accompanying PDF document). This content is developed by the Sydney Basin Bioregional Assessment using the structure, standards and format specified by the Programme.
- '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. The copyright owners of the following figures, however, did not grant permission to do so: Figure 5. It should be assumed that third parties are not entitled to use this material without permission from the copyright owner.
- All maps created as part of this BA for inclusion in this product used the Albers equal area projection with a central meridian of 151.0° East for the Sydney Basin bioregion and two standard parallels of –18.0° and –36.0°.
- Visit http://bioregionalassessments.gov.au to access metadata (including copyright, attribution and licensing information) for datasets cited or used to make figures in this product.
- In addition, the datasets are published online if they are unencumbered (able to be published according to conditions in the licence or any applicable legislation). The Bureau of Meteorology archives a copy of all datasets used in the BAs. This archive includes datasets that are too large to be stored online and datasets that are encumbered. The community can request a copy of these archived data at http://www.bioregionalassessments.gov.au.
- The citation details of datasets are correct to the best of the knowledge of the Bioregional Assessment Programme at the publication date of this product. Readers should use the hyperlinks provided to access the most up-to-date information about these data; where there are discrepancies, the information provided online should be considered correct. The dates used to identify Bioregional Assessment Source Datasets are the dataset's published date. Where the published date is not available, the last updated date or created date is used. For Bioregional Assessment Derived Datasets, the created date is used.

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 4 March 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 4 March 2018, http://www.iesc.environment.gov.au/publications/information-guidelines-independent-expert-scientific-committee-advice-coal-seam-gas.

1.3 Description of the water-dependent asset register for the Sydney Basin bioregion

A water-dependent asset has a particular meaning for bioregional assessments; it is an asset potentially impacted by changes in groundwater and/or surface water due to coal or coal seam gas 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.

This product describes water-dependent assets that have been identified in the bioregional assessment as of September 2016 and are listed in the water-dependent asset register (available at http://data.bioregionalassessments.gov.au/product/SSB/SSB/1.3).

1.3.1 Methods

Summary

The water-dependent asset register is a list of water-dependent assets identified for use in the bioregional assessment (BA) of the Sydney Basin bioregion. This section details the specific application to the Sydney Basin bioregion of methods described in the companion submethodology M02 for compiling water-dependent assets (Mount et al., 2015). Key concepts and terminology are also explained.

The methods covered include: defining the preliminary assessment extent (PAE) of the Sydney Basin bioregion and the processes for compiling assets, determining their water dependency, and seeking and incorporating NSW state and local government feedback.

The asset list for the Sydney Basin bioregion contains 1460 assets that intersect the Sydney Basin PAE, comprising 1148 ecological assets, 61 economic assets and 251 sociocultural assets.

Not all assets in the asset list met the criteria for inclusion in the water-dependent asset register. Section 1.3.2 and Section 1.3.4 provide details of ecological and sociocultural assets that did not meet the criteria for inclusion in the water-dependent asset register for the Sydney Basin bioregion. All the economic assets in the asset list are water dependent.

The water-dependent asset register for the Sydney Basin bioregion contains 1002 assets, comprising 751 ecological assets, 61 economic assets and 190 sociocultural assets.

1.3.1.1 Background and context

This product presents information about the water-dependent asset register developed for the Sydney Basin bioregion. The name of the dated snapshot of the asset register this description refers to is 'Water-dependent asset register and asset list for the Sydney Basin bioregion on 29 March 2016’ (Wang et al., 2018). The point-of-truth version of the asset register that this snapshot was extracted from resides in the asset database (Bioregional Assessment Programme, Dataset 1). The asset database and the water-dependent asset register can be updated so a more current version might be available at http://data.bioregionalassessments.gov.au/product/SSB/SSB/1.3.

Development of the register used methods and processes defined and outlined in the companion submethodology M02 (as listed in Table 1) for compiling water-dependent assets (Mount et al., 2015); their specific application to the Sydney Basin bioregion is described in the following sections.

An *asset* is an entity that has value to the community and, for BA 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. A *bioregion* is 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 BAs are conducted. A *subregion* is an identified area wholly contained within a bioregion.

A water-dependent asset has a particular meaning for BAs; it is an asset potentially impacted, either positively or negatively, by changes in the groundwater and/or surface water regime due to coal resource development. Some assets are solely dependent on incident rainfall and will not be considered as water dependent if evidence does not support a linkage to groundwater or surface water.

The *water-dependent asset register* is a simple and authoritative listing of the assets within the *PAE* (discussed in Section 1.3.1.3) that are potentially subject to water-related impacts. A PAE is the geographic area associated with a bioregion or subregion in which the potential water-related impact of coal resource development on assets is assessed. The compiling of the asset register is the first step to identifying and analysing potentially impacted assets, which is the goal of the overall BA.

The asset source data are compiled into an *asset database*, including the geographic location, which are designated as *elements* (individual spatial features – points, lines and polygons e.g. components of a larger system) and *assets* (combinations of one or more elements). During the compilation process, assets are classified into three groups: (i) ecological, (ii) economic and (iii) sociocultural. Many assets are obtained from state and national databases and an important group of assets is provided by natural resource management organisations (NRMs) via the BA-purpose-built *Water Asset Information Tool* (WAIT) database. The Office of Water Science liaised with Indigenous knowledge holders about Indigenous sociocultural water-dependent assets (further discussed in Section 1.3.4.1).

The *asset list* is created through selection of assets in the asset database that occur within the PAE. The assets in the asset list that pass the BA water-dependency test are then 'registered' in the water-dependent asset register. A preliminary version of the asset register is presented to experts and organisations with local knowledge at organised workshops. Feedback is sought about whether the asset register is complete and correct; appropriate amendments are then made. It is at this stage – when assets have been selected using the PAE and the amended water-dependent assets have been recorded in the database – that the water-dependent asset register is complete for the purposes of producing product 1.3 Description of the water-dependent asset register. Note, however, that the addition of new assets to the asset database, or a review of the status of existing assets in the database will mean that the asset register may be updated. As this has implications for other BA components, any updates must be documented. The product 1.3 Description of the water-dependent asset register will not be updated or republished as part of BAs but an updated version of the asset register (derived from the asset database) may be published at the same time as other products, for example, those associated with Component 3: Impact analysis (Figure 1 and Figure 2).

1.3.1.2 Compiling assets and developing the water-dependent asset register

1.3.1.2.1 Ecological assets

Four natural resource management organisations (NRMs) contributed data to the WAIT database (Table 3). These NRM-nominated assets were added to the asset database. When the Sydney Basin bioregion was defined in 2012, it comprised all of the Sydney Metropolitan Catchment Management Authority (CMA) area, a significant proportion of the Hawkesbury-Nepean CMA, part of the Southern Rivers CMA and a small area within the Central West CMA. From 1 January 2014, NSW CMAs transitioned into local land services (LLS) regions, however, the data continues to be attributed to the CMAs. Table 3 also includes some *Atlas of living Australia* data, which were added to the WAIT database following the request of participants at asset workshops in the Gloucester, Hunter and Sydney Basin asset workshops to include the platypus. All of the assets from the WAIT database are ecological assets.

Table 3 Natural resources management organisations that contributed data to the Water Asset Information Tool database

Organisation	Description in asset register
Central West (NRM)	WAIT_Central West
Hawkesbury-Nepean (NRM)	WAIT_Hawkesbury Nepean
Southern Rivers (NRM)	WAIT_Southern Rivers
Sydney Metro (NRM)	WAIT_Sydney Metro
Atlas of living Australia (ALA) (ERIN)[a]	WAIT_ALA_ERIN

[a]added by the Bioregional Assessment Programme in response to community requests to include platypus as an asset

All data sources used to define ecological assets in the Sydney Basin bioregion are listed in Table 4. Included are assets that were identified by local and state government workshop participants during the Sydney Basin assets workshop in August 2015 (see Section 1.3.1.4). Not all assets suggested at the workshops made it into the asset list for the Sydney Basin bioregion because they either failed the ‘fit-for-BA’ test or were not in the PAE. The fit-for-BA test is intended to ensure that data included in the water-dependent asset register meet BA quality standards. The tests enable the exclusion of duplicate data, irrelevant data, superseded data and data with inadequate information content (e.g. lacking spatial coverage). Despite these tests, some duplication of elements obtained from the various local, state and Australian Government agencies and NRM bodies does occur. This means that the total number of reported assets includes multiple occurrences of some assets, which can reflect the assets’ different values and/or different mapping programmes. For example, Lake Illawarra appears in the ‘Directory of Important Wetlands’ (Australian Government Department of the Environment, Dataset 2); the ‘National Groundwater Dependent Ecosystems (GDE) Atlas’ (Bureau of Meteorology, Dataset 3); NSW Wetlands (NSW Office of Environment and Heritage, Dataset 4); NSW water source areas (Bioregional Assessment Programme, Dataset 5); and in relation to various GDE vegetation and habitat (potential species distribution) datasets.

Table 4 Data sources for ecological assets in the asset list for the Sydney Basin bioregion

Dataset[a]	Dataset citation	Elements	Assets (in asset list)
Water Asset Information Tool (WAIT) database	Australian Government Department of the Environment (Dataset 6)	206	114
Collaborative Australian Protected Areas Database (CAPAD)	Australian Government Department of the Environment (Dataset 7)	27	27
Directory of Important Wetlands in Australia (DIWA)	Australian Government Department of the Environment (Dataset 2)	73	6
National Groundwater Dependent Ecosystems (GDE) Atlas including: • subsurface presence of groundwater data • surface expression of groundwater	Bureau of Meteorology (Dataset 3)	38,319	475
Important Bird Areas	Birds Australia (Dataset 8)	3	3
Key Environmental Assets of the Murray-Darling Basin	Murray-Darling Basin Authority (Dataset 9)	249	1
Threatened ecological communities listed under the Commonwealth's Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)	Australian Government Department of the Environment (Dataset 10)	11,000	8
Threatened species listed under the EPBC Act	Bioregional Assessment Programme (Dataset 11)	4,420	144
NSW Wetlands	DECCW[b] (Dataset 4)	191	36
Estuarine Macrophytes	DPI – Fisheries (Dataset 12)	340	13
NSW Travelling Stock Reserve Conservation Values	DECCW[b] (Dataset 13)	5	4
NSW Native Vegetation Management (NVM)	DECCW[b] (Dataset 14)	378	4
Threatened migratory shorebird habitat mapping	DECCW[b] (Dataset 15)	1	1
NSW Spatial Threatened Species and Communities - species (aspatial)	OEH (Dataset 16)	202	202
NSW Spatial Threatened Species and Communities - ecological community (aspatial)	OEH (Dataset 16)	43	43
Water Asset Information Tool database – Atlas of Living Australia	OEH (Dataset 17)	127	1
Cumberland Subregion BIO Map Core Areas	OEH (Dataset 18)	10	1
Cumberland Subregion BIO Map Biodiversity Corridors of Regional Significance	OEH (Dataset 19)	14	2

Dataset[a]	Dataset citation	Elements	Assets (in asset list)
Illawarra Region BIO Map - Core Areas	OEH (Dataset 20)	458	1
Illawarra Region BIO Map Corridors	OEH (Dataset 21)	1	1
Map of Critically Endangered Ecological Communities NSW Version 3	OEH (Dataset 22)	9	4
Threatened Fish - Fisheries Management • Fitzroy Falls spiny crayfish • Macquarie Perch • Purple Spotted Gudgeon	 DPI (Dataset 23) DPI (Dataset 24) DPI (Dataset 25)	35	3
An Estuarine Inventory for New South Wales, Australia (VIS_ID 2224)	DECCW[b] (Dataset 26)	77	1
Karst from NSW Office of Water identified GDEs	NSW Office of Water (Dataset 27)	2	2
Endangered Ecological Communities from Southeast NSW Native Vegetation Classification and Mapping - SCIVI VIS ID 2230	DECCW[b] (Dataset 28)	34	34
Floodplain from NSW State Wetlands	DECCW[b] (Dataset 4)	9	1
NSW Wild Rivers	OEH (Dataset 29)	6,703	2
Old Growth Forest Mapping Broad, Central	OEH (Dataset 30)	9	1
State Environment Planning Policy no. 14 Coastal Wetlands	DP&I (Dataset 31)	16	1
State Environmental Planning Policy no. 26 Littoral Rainforest	DP&I (Dataset 32)	1	1
Geofabric Surface Network (Rivers)	Bureau of Meteorology (Dataset 33)	2,492	11
Total		**65,454**	**1,148**

[a]The asset database (Bioregional Assessment Programme, Dataset 1) is a collation of all these source datasets. Some assets may be captured in multiple databases. Typology and punctuation are given as provided in the metadata for these datasets.
[b]NSW Office of Environment and Heritage (OEH) is custodian of these datasets generated by the former NSW Department of Environment Climate Change and Water (DECCW).
OEH = New South Wales Office of Environment and Heritage; DPI = New South Wales Department of Primary Industries; DP&I = New South Wales Department of Planning & Infrastructure

1.3.1.2.2 Economic assets

Economic assets can be broadly classified as water sources, *water access entitlements* (either *water access rights* or *basic water rights*) or water infrastructure. In NSW, water access entitlements are known as 'water access licences'. Within the asset database, every water access entitlement is an element. Elements are grouped by entitlement type and also spatially to create assets. *Basic landholder rights* (i.e. a type of basic water right), including riparian rights, maintain the right of those adjacent to rivers, estuaries, lakes or aquifers underlying the land to extract water for domestic and stock use without a water access licence. Basic landholder rights are defined by the jurisdiction based on the location of the water source and may include an estimated volume of use based on the number of landholders with adjacent water sources.

For the economic assets, the water access entitlements are divided into two classes:

- basic water right (domestic and stock) – this is the right to take water for domestic and stock purposes only. A basic right for 'take of groundwater' requires approval for the works (bore) but does not require a licence for the extraction of groundwater. A basic right for 'take of surface water' does not require an approval for the works or approval for the extraction of surface water.
- water access right – this right requires an approval for the works and a licence for the extraction of the water. The extraction of the water can be for a range of purposes including irrigation, commercial, industrial, farming, dewatering, mining, intensive agriculture, etc.

Data sources used to create economic assets for the Sydney Basin bioregion are listed in Table 5. Water access licence and entitlement data for surface water and groundwater sources in the Sydney Basin PAE were collated by the Bureau of Meteorology based on groundwater bore and surface water offtake locations and water access entitlements data from the NSW Department of Primary Industries Water (DPI Water; formerly NSW Office of Water). The data supplied included current or active water access entitlements on issue under the NSW *Water Act 1912* and the NSW *Water Management Act 2000* as of July 2015. The NSW water access entitlement data are currently not publicly available and were obtained by special request from DPI Water. Consistent with how water licensing information is published under the Commonwealth's *Water Act 2007*, DPI Water have consented to publication of these data in an aggregated form that protects the privacy of individual licence holders. Data about basic landholder rights, essentially non-licensed stock and domestic use, were sourced from water sharing plans (NSW Department of Primary Industries, 2014).

The DPI Water spatial layers were clipped to the PAE for the Sydney Basin bioregion to identify just those works within the PAE. A work refers to a bore or pump and provides the location where water under a licence can be extracted. Where a water access licence is associated with multiple works, it was assumed that each of the works accounts for an equal share of the licensed volume. Thus, for a groundwater licence of 80 ML/year, associated with four works (bores), 20 ML/year was assigned to each work; however, it is possible that the majority of extraction occurs at a single works location and is not evenly distributed across all works associated with the licence.

The class of asset was assigned using the NSW Office of Water 'purpose' field which records the purpose that water is used for. Any purpose that was listed as 'domestic' and/or 'stock' was classed as a 'basic water right'. Where the purpose is commercial, irrigation, farming, industrial or dewatering, the asset is classed as a 'water access right'. Where a purpose included 'stock' or 'domestic' and another licensed purpose, it was classed as a water access right.

Groundwater works that were not classified as a basic water right or a water access right were classed as 'null'. These included test bores, bores installed for groundwater remediation, exploratory bores, exploratory research and monitoring bores. These elements are 'flagged' in the asset database and are not included in the water-dependent asset register. Once data checking and spatial attribution were completed, these derived datasets were incorporated into the asset database (Bioregional Assessment Programme, Dataset 5, Dataset 34).

To determine which water sources should be included in the asset list, the spatial layers of NSW water sharing plan water source areas (NSW Office of Water, Dataset 35) and groundwater source areas (Bureau of Meteorology, Dataset 36)) were intersected with the Sydney Basin PAE (Table 5). Eleven groundwater source areas and seven surface water source areas intersect the Sydney Basin PAE.

Table 5 Data sources for economic assets in the Sydney Basin bioregion asset list

Dataset[a]	Dataset citation	Elements	Assets (in asset list)
Sydney Basin groundwater bores and entitlements	Bioregional Assessment Programme (Dataset 34, restricted access)	3361	21
Sydney Basin surface water licences and entitlements	Bioregional Assessment Programme (Dataset 5, restricted access)	610	12
NSW groundwater source areas	Bioregional Assessment Programme (Dataset 34, restricted access); Bureau of Meteorology (Dataset 36)	11	11
NSW surface water source areas	Bioregional Assessment Programme (Dataset 5, restricted access); NSW Office of Water (Dataset 35)	7	7
Sydney water supply – water storages	Australian Government Department of Environment (Dataset 37); DECCW[b] (Dataset 4)	10	10
Total		**3999**	**61**

[a]The asset database (Bioregional Assessment Programme, Dataset 1) is a collation of all these source datasets. Some assets may be captured in multiple databases.
[b]NSW Office of Environment and Heritage (OEH) is custodian of these datasets generated by the former NSW Department of Environment Climate Change and Water (DECCW).

Unlike the water entitlements held by individual licence holders, which are associated with licensed works (point features) and hence a specific location where water extraction occurs, the water entitlements held by WaterNSW (formerly the Sydney Catchment Authority), who manage the supply of water to the Greater Sydney region, pertain to water source areas (or water supply catchments). Thus WaterNSW water entitlements, which represent the bulk of water entitlements in the Sydney Basin bioregion, have been attributed to the surface water source areas (polygon features) specified in the Greater Metropolitan Region Unregulated Rivers Water Sources Water Sharing Plan (NSW Office of Water, Dataset 35), which intersect the PAE.

The asset list also includes nine water storages, which form part of the Greater Sydney region's water supply network (Australian Government Department of Environment, Dataset 37), plus one storage near Lithgow, which was given a spatial location from the NSW Wetlands dataset (DECCW, Dataset 4). The subregion includes other storages, but not physically within the PAE.

1.3.1.2.3 Sociocultural assets

Sociocultural assets were primarily sourced from heritage and national estate lists within the Australian Heritage Database (Department of the Environment, 2013).

Indigenous sociocultural assets were primarily sourced from existing Commonwealth heritage databases (Table 6). Two additional assets (CSIRO, Dataset 38) were derived from a report by Moggridge (2010), which identified a couple of culturally significant groundwater-dependent ecosystems (GDEs) within the bioregion. There were no BA Programme specific meetings held with Indigenous knowledge holders in the Sydney Basin bioregion to identify additional culturally significant assets.

Table 6 Datasets used to identify sociocultural assets in the Sydney Basin bioregion

Dataset[a]	Dataset citation	Elements	Assets (in asset list)
World Heritage List (WHL)	Australian Government Department of the Environment (Dataset 39)	1	1
National Heritage List (NHL)	Australian Government Department of the Environment (Dataset 40)	3	3
Commonwealth Heritage List (CHL)	Australian Government Department of the Environment (Dataset 41)	2	2
Register of the National Estate (RNE)	Australian Government Department of the Environment (Dataset 42)	243	243
Identification of Culturally Significant Groundwater Dependent Ecosystems and reaches within management zones to support Aboriginal Community Development Licences (for Hawkesbury-Nepean CMA)	CSIRO (Dataset 38)	2	2
Total		**251**	**251**

[a]The asset database (Bioregional Assessment Programme, Dataset 1) is a collation of all these source datasets. Some assets may be captured in multiple databases.

Typically, sociocultural assets that are landscape water features are included within the ecological asset classes to avoid repetition of assets, but as noted earlier, the asset list does contain some duplication of assets.

1.3.1.3 Determining the preliminary assessment extent

The Sydney Basin bioregion is defined to the north by the surface water catchment divide between the Hawkesbury-Nepean river system and Hunter River, to the east mainly by the coastline, and to the south and west by the geological boundary defining the Sydney geological basin. This western geologically-defined boundary only approximates the surface water divide between east-flowing coastal rivers and those flowing westward as part of the Murray-Darling Basin. Most (94%) of the Sydney Basin bioregion land area drains east to the Tasman Sea or to coastal lakes, with the remaining 6% (or 153,018 ha) being part of the Macquarie-Bogan river basin that is part of the Murray-Darling Basin (see Section 1.3.1.4).

To help guide the development of the PAE, a list of new coal mine proposals and existing coal mines with plans to expand mining areas, extend timelines and/or modify existing development approvals beyond December 2012 was compiled by the Assessment team in mid-March 2015. The list was compiled primarily from the NSW Major Projects website (NSW Planning and Environment, 2016), which tracks the assessment of development proposals of state significance, and mining company websites. Areas with identified coal resources with no development application were not included, although they are identified in companion product 1.2 for the Sydney Basin bioregion (Hodgkinson et al., 2018). The March 2015 PAE mines included 13 coal mines in the bioregion, comprising 10 underground mines (Airly, Angus Place, Appin, Clarence, Dendrobium, Russell Vale, Springvale, Tahmoor, Wongawilli and West Cliff) and three open-cut coal mines (Cullen Valley, Invincible and Pine Dale). Although there is an existing CSG development at Camden, there were no proposals for post-2012 expansions or new CSG developments at this time. At March 2016, when the coal resource assessment for the Sydney Basin was completed (Hodgkinson et al., 2018), only seven of the PAE mines were identified as having post-2012 development plans (i.e. Airly, Angus Place, Hume, Pine Dale, Russell Vale, Springvale and Wongawilli). The impact of including the six other mines in defining the PAE means that the PAE could be larger than it needs to be, with the consequence that potentially more assets have been included in the water-dependent asset register for the Sydney Basin bioregion. Since March 2015, Director-General’s Environmental Assessment Requirements (DGRs) have been issued for Hume Coal mine and an environmental impact statement (EIS) is expected to be completed in 2016. This development proposal was not sufficiently progressed at the time to be included in the list of mines used to define the PAE, and development of this proposal has occurred quite quickly. Centennial Coal is undertaking exploration drilling at Inglenook and Neubeck, both areas with identified coal resources. While they were not used to define the PAE, they are located within the PAE that has been defined using the 13 coal mines. Note Cullen Valley was mistakenly treated as an underground mine (historically it was) in the analysis to define the PAE. This has no impact on the resultant PAE as the mine is close to the Sydney Geological Basin boundary (which limits extent of groundwater impacts), close to other mines used in defining the PAE (i.e. large overlapping potential impact zone), and has been in care and maintenance since December 2012 with no future development plans.

Mine site locations were obtained from either the OZMIN database (Geoscience Australia, Dataset 43) or the MinView database (Trade and Investment, NSW, Dataset 44), and these were then checked against existing tenement boundaries (such as mining leases) to confirm the locations. Figure 3 shows the location of these mines. To define the PAE, that is, the area surrounding the mines that could potentially be affected by current and future coal resource developments, the approach needs to reflect potential impacts upon groundwater, surface water and surface water – groundwater connectivity. Each of these is considered in the following sections.

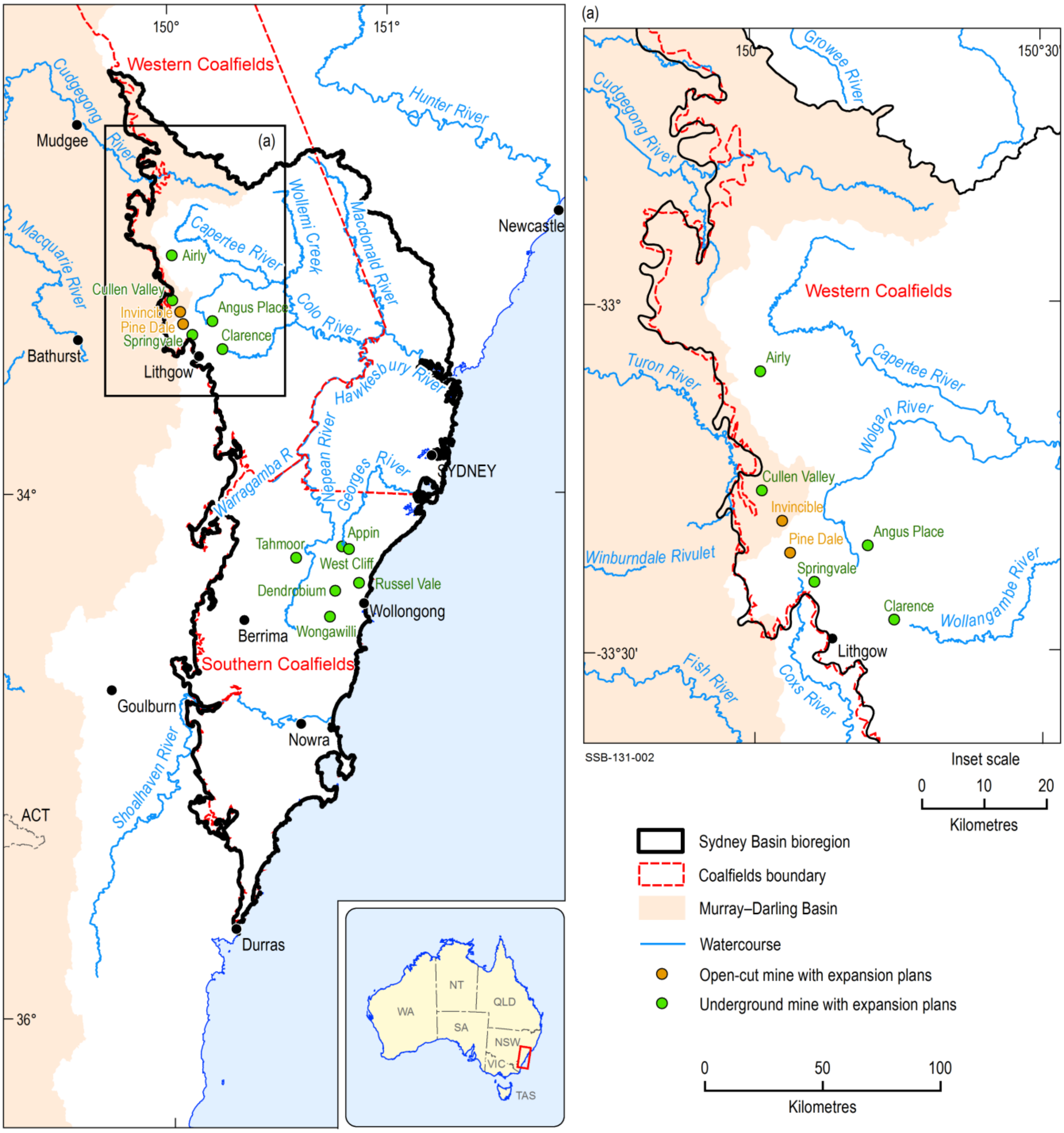

Figure 3 Location of the Sydney Basin bioregion, coal mines with expansion plans, and major rivers

Data: DTIRIS (Dataset 45); Geoscience Australia (Dataset 43); NSW Trade and Investment (Dataset 44)

1.3.1.3.1 Groundwater considerations

To define the PAE based on groundwater impacts for the Sydney Basin bioregion, the maximum distance from each mine site that could be affected by groundwater drawdown was estimated. In the Western Coalfield, the western boundary of the geological Sydney Basin (which defines the western boundary of the Sydney Basin bioregion) forms a hydrogeological boundary across which it is assumed there is no groundwater connectivity (strictly speaking, this will not necessarily hold true for an alluvial aquifer sitting atop the geological Sydney Basin strata, from which groundwater could flow across a geological divide, but this connectivity is dealt with in defining the surface water PAE). Thus, it is assumed that deeper groundwater units to the west of this divide are not influenced by the longwall coal mines located in the bioregion. In the Southern Coalfield, the coastline to the east forms a natural boundary beyond which any impacts on groundwater from coal mining are swamped by the influence of the Tasman Sea and occur outside the bioregion for the purposes of the BA.

In the longwall operations, the target coal seams can be many hundreds of metres below ground level and separated from the surface assets via a sequence of aquitards and aquifers (see companion product 1.1 for the Sydney Basin bioregion (Herron et al., 2018a) for more detail). The sequence of aquitards and aquifers will attenuate the drawdown signal such that it will be reduced, possibly not even evident, at the surface and delayed in time. Drawdowns from open-cut mines will occur where the operations intersect the water table aquifer. The groundwater numerical modelling for the BAs for the Gloucester subregion (companion product 2.6.2 for the Gloucester subregion (Peeters et al., 2018)) and Hunter subregion (companion product 2.6.2 for the Hunter subregion (Herron et al., 2018b)) show that drawdowns at the surface do not propagate more than 20 km from any of the mines in those regions by 2102. Based on the geological similarity of the Sydney Basin bioregion and Hunter subregion in particular, a maximum radius of 20 km from each mine was adopted to define the groundwater PAE for the Sydney Basin bioregion. The combined effect of these natural and 20 km radial boundaries are shown in Figure 4, leading to two disparate groundwater PAE components: one in the Western Coalfield around the mining developments near Lithgow, and the second in the Southern Coalfield around the mining developments west of Wollongong.

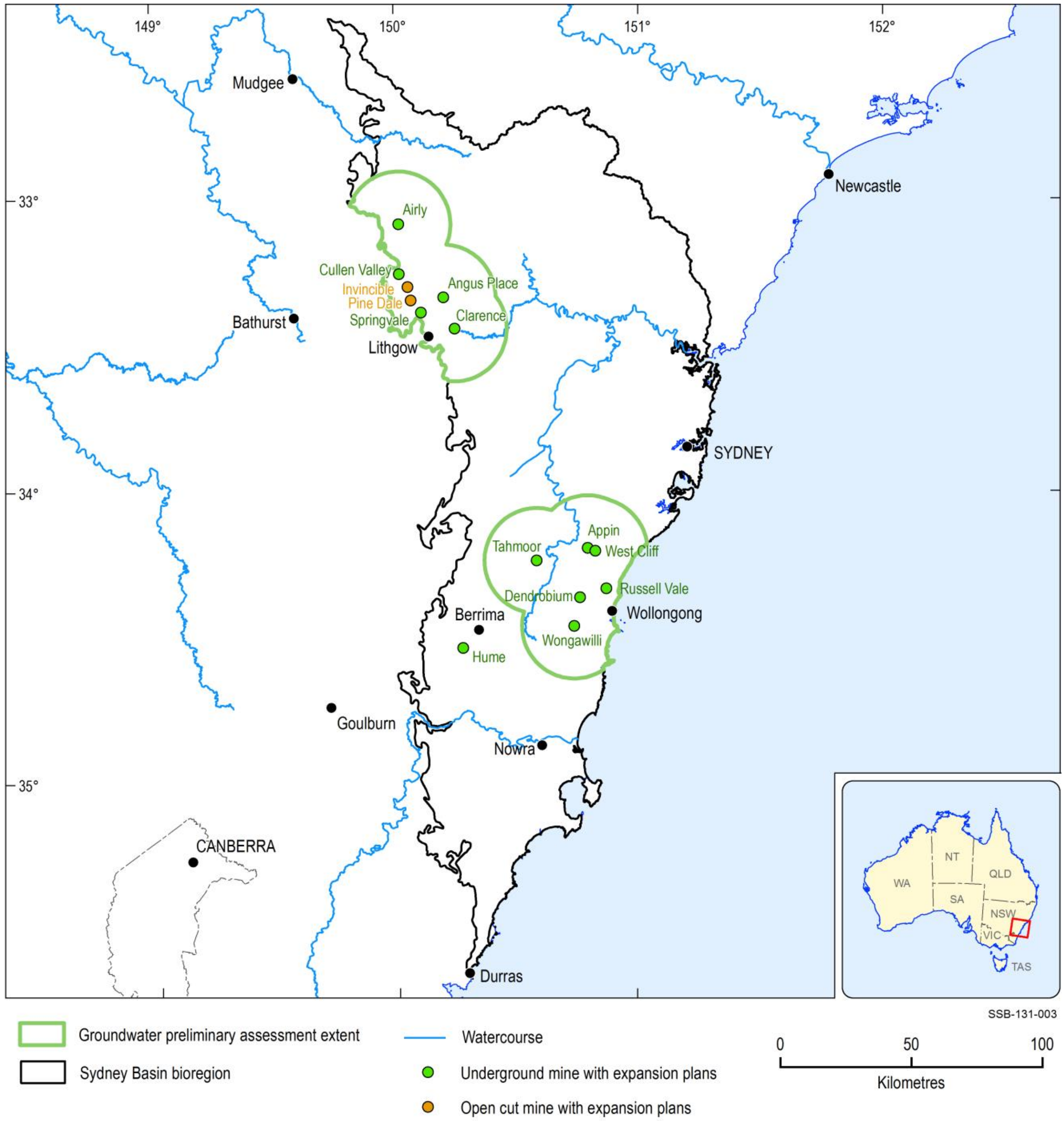

Figure 4 Groundwater preliminary assessment extent (PAE) in the Sydney Basin bioregion

Data: Geoscience Australia (Dataset 43); NSW Trade and Investment (Dataset 44); Bioregional Assessment Programme (Dataset 46)

1.3.1.3.2 Surface water considerations: open-cut mines

To determine the extent to which the hydrological impacts of open-cut coal mines propagate downstream of the mine sites, the runoff contribution from the mine footprint relative to the runoff contribution of the rest of the catchment is compared at different distances from the mine site. This modelling requires three main inputs (i) locations of the open-cut coal mine pits in December 2012 as determined from satellite imagery; (ii) a set of catchments that include, and are downstream from, the open-cut mines – obtained here from the Australian Hydrological Geospatial Fabric (Geofabric) (Bureau of Meteorology, 2012); and (iii) climate grids, which are the basis of the Budyko framework (Budyko, 1974). For purposes of defining the PAE, surface water impacts from longwall mines are assumed to be negligible (although subsidence can potentially have impacts on surface water through disruption to drainage and enhanced recharge) and that the groundwater PAE will capture the affected area along the stream.

Estimates of surface runoff generation from the open-cut mines and related catchments were generated using a spatial implementation of the Budyko framework. Over the long term, the relative proportion of the streamflow generated in a catchment relates to its area and the spatial changes in climate across the catchment (Budyko, 1974; Donohue et al., 2011). Donohue et al. (2007, 2010) provide general introductions to the Budyko framework. The summary presented in this product is from McVicar et al. (2012).

The catchment water balance describes the partitioning of the inward flux, or supply, of water (assumed here to be solely precipitation) into the outward fluxes of water and the within-catchment storage of water. With respect to streamflow, the water balance is:

$$Q = P - AET - DD - \frac{dS_w}{dt} \quad (1)$$

Here Q is streamflow at some point in the stream network, and P, AET, and DD represent, precipitation, actual evapotranspiration and deep drainage over the catchment contributing to that point, respectively. They all have the same units (mm a^{-1}). S_w is soil water storage (mm). In unregulated catchments the partitioning of P into Q and AET predominantly depends on the processes that determine AET. In general, AET is limited by either the supply of (i) water or (ii) energy (this can be termed atmospheric evaporative demand (AED) and is commonly represented as potential evapotranspiration (PET)). This means that AET from a catchment can be described as being either 'water-limited' or 'energy-limited', respectively. This supply-demand limitation is a crucial over-arching framework for understanding catchment hydroclimatology; it does not account for changes in soil properties and assumes groundwater and surface water are in steady-state equilibrium, with groundwater recharge to and discharge from the stream being negligible.

Assuming steady state, Budyko (1974) described a long-term catchment balance using the supply-demand framework (Figure 5). Formally, a water-limited environment occurs when the long-term catchment average AED for water exceeds the supply of water (i.e. $P < PET$) and the opposite is true for an energy-limited environment (i.e. $P > PET$). Over large catchments and long timescale, Budyko showed that the evaporative index (ε, the ratio of AET to P) is dependent on the climatic dryness index (Φ, the ratio of PET to P) and closely follows a curvilinear relationship (the 'Budyko curve', shown in Figure 5). As water limitation increases (i.e. as one moves to the right in Figure 5), then AET approaches P and Q approaches 0. Conversely, as the water availability increases (i.e. as one moves to the left in Figure 5), AET approaches PET, with a larger fraction of P being partitioned into Q.

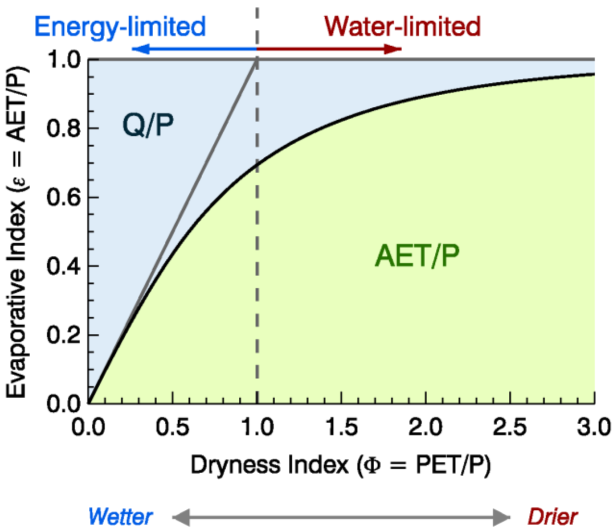

Figure 5 The Budyko curve and the supply–demand framework

The Budyko curve (black line) describes the relationship between the long-term catchment averages of the evaporative index (ε = AET / P) and the dryness index (Φ = PET / P). The horizontal grey line represents the water-limit, where 100% of P becomes AET, and the diagonal grey line is the energy-limit, where 100% of AED (i.e. PET) is converted to AET. The green shaded area represents the fraction of P that becomes AET and the blue shaded area represents the fraction of P that becomes Q.
AED = atmospheric evaporative demand, AET = actual evapotranspiration, P= precipitation, PET = potential evapotranspiration, Q = streamflow
Source: McVicar et al. (2012) from Budyko (1974). This figure is not covered by a Creative Commons Attribution licence. © 2012 Commonwealth of Australia.

Using Choudhury's (1999) formulation of the Budyko curve, with (i) available energy being represented as PET (Donohue et al., 2012) and, (ii) adopting a catchment properties parameter, which alters the partitioning of P between modelled AET and R (runoff), of *n* = 1.9 (Donohue et al., 2011) and (iii) assuming steady-state conditions, R can be simply calculated as the difference between P and AET:

$$\mathrm{R} = \mathrm{P} - \mathrm{AET} = \mathrm{P} - \frac{\mathrm{P} \cdot \mathrm{PET}}{\left(\mathrm{P}^n + \mathrm{PET}^n\right)^{1/n}} . \qquad (2)$$

Note that in the introduction to the Budyko framework, in which the smallest spatial element considered is a subcatchment, Q is used, whereas for spatially explicit modelling using gridded meteorological data the term R is used. These are not identical in meaning and in the Budyko framework there is no routing within a catchment or down the river network. To define the PAE it is the relative proportions of the spatially explicit runoff, R, that are required.

The footprints (areas) of the two open-cut coal mine pits were derived from Landsat-7 ETM+ imagery acquired on 3 December 2012 (path/row is 90/83) (Bioregional Assessment Programme, Dataset 47) and are shown in the inset map of Figure 6. Based on catchment delineation in the Geofabric, four subcatchments were identified as hydrologically connected to the Invincible open-cut coal mine and three subcatchments to the Pine Dale open-cut coal mine (Figure 6). The footprint and subcatchment areas are summarised in Table 7.

Using readily available gridded meteorological datasets of P (Jones et al., 2009) and Penman's formulation of PET (Donohue et al., 2010), which is fully physically based using a dynamic wind speed (McVicar et al., 2008), Choudhury's formulation of the Budyko framework was used to model the climatological (1982 to 2010) partitioning of P in AET and R. Figure 7a and Figure 7b show the input meteorological grids used in Choudhury's formulation of the Budyko framework; the resultant modelled runoff is shown in Figure 7c. To provide a more meaningful illustration of the grid-cell modelling, Figure 8 shows how this aggregates given the surface water network taking into account the catchment topology (i.e. size and spatial relationships) thereby showing the accumulation of flow downstream and the relative differences in streamflow (due primarily to differences in catchment size and climatic conditions). Note the differences in flow scales between the main diagram and Inset (a) and Inset (b).

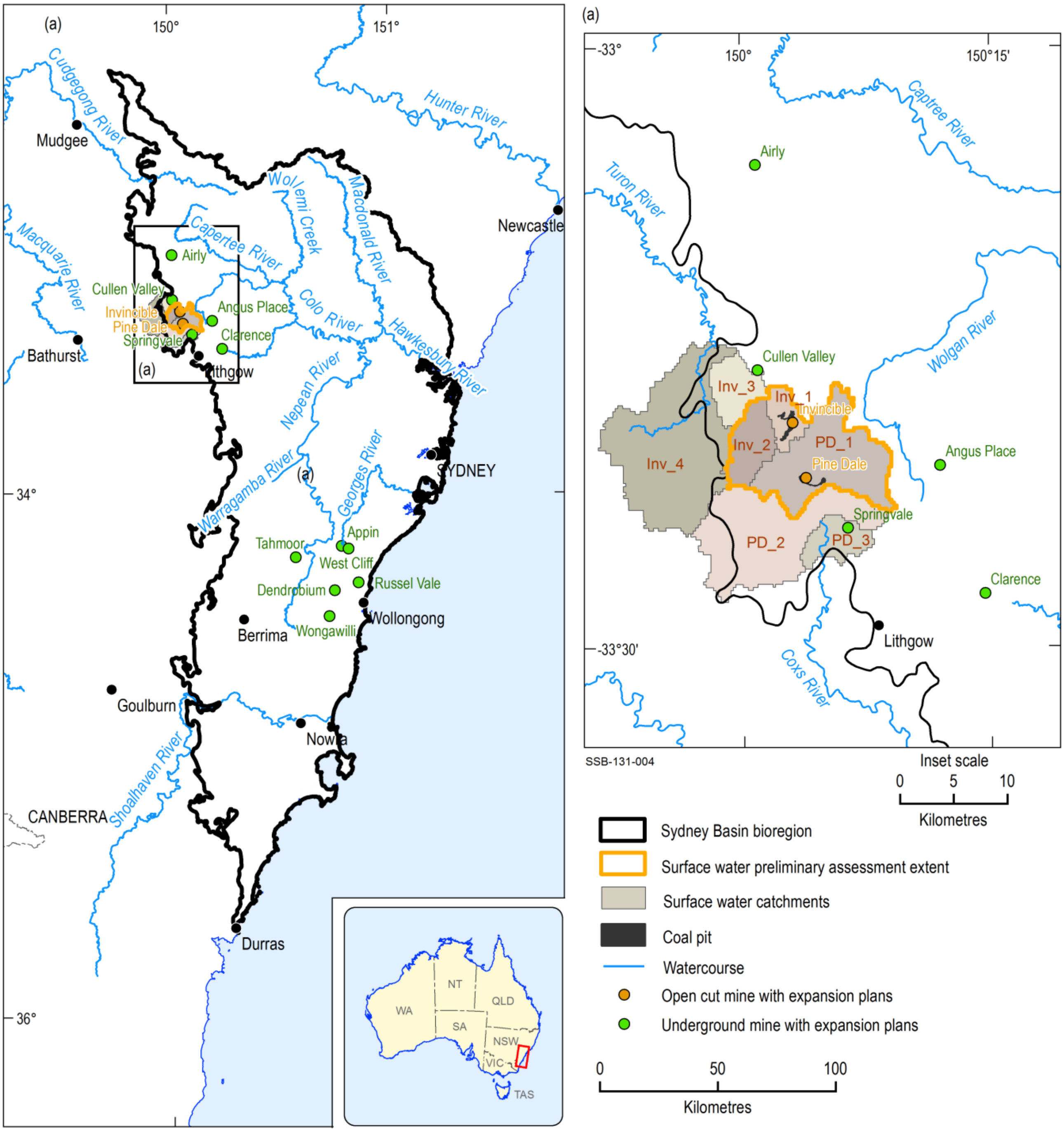

Figure 6 Features used to calculate the surface water preliminary assessment extent (PAE) in the Sydney Basin bioregion

Surface water catchments used in subsequent analysis are shown in the inset map. Codes have been assigned and are shown in orange (see Table 7).

Data: Geoscience Australia (Dataset 43); NSW Trade and Investment (Dataset 44); Bioregional Assessment Programme (Dataset 46, Dataset 47)

Table 7 Subcatchments connected to the Invincible and Pine Dale open-cut coal mines

Mine	Subcatchment level	Subcatchment name (subcatchment code)	Area (km^2)	Percentage of total area
Invincible	Mine footprint	Invincible	1.2	0.6%
	First level	Invincible_1 (Inv_1)	14.4	7.3%
	Second level	Invincible_2 (Inv_2)	25.0	12.7%
	Third level	Invincible_3 (Inv_3)	22.8	11.6%
	Fourth level	Invincible_4 (Inv_4)	133.1	67.7%
	Total all subcatchments		**196.5**	99.9%
Pine Dale	Mine footprint	PineDale	0.7	0.4%
	First level	PineDale_1 (PD_1)	77.7	39.8%
	Second level	PineDale_2 (PD_2)	96.8	49.6%
	Third level	PineDale_3 (PD_3)	20.1	10.3%
	Total all subcatchments		**195.3**	100.1%

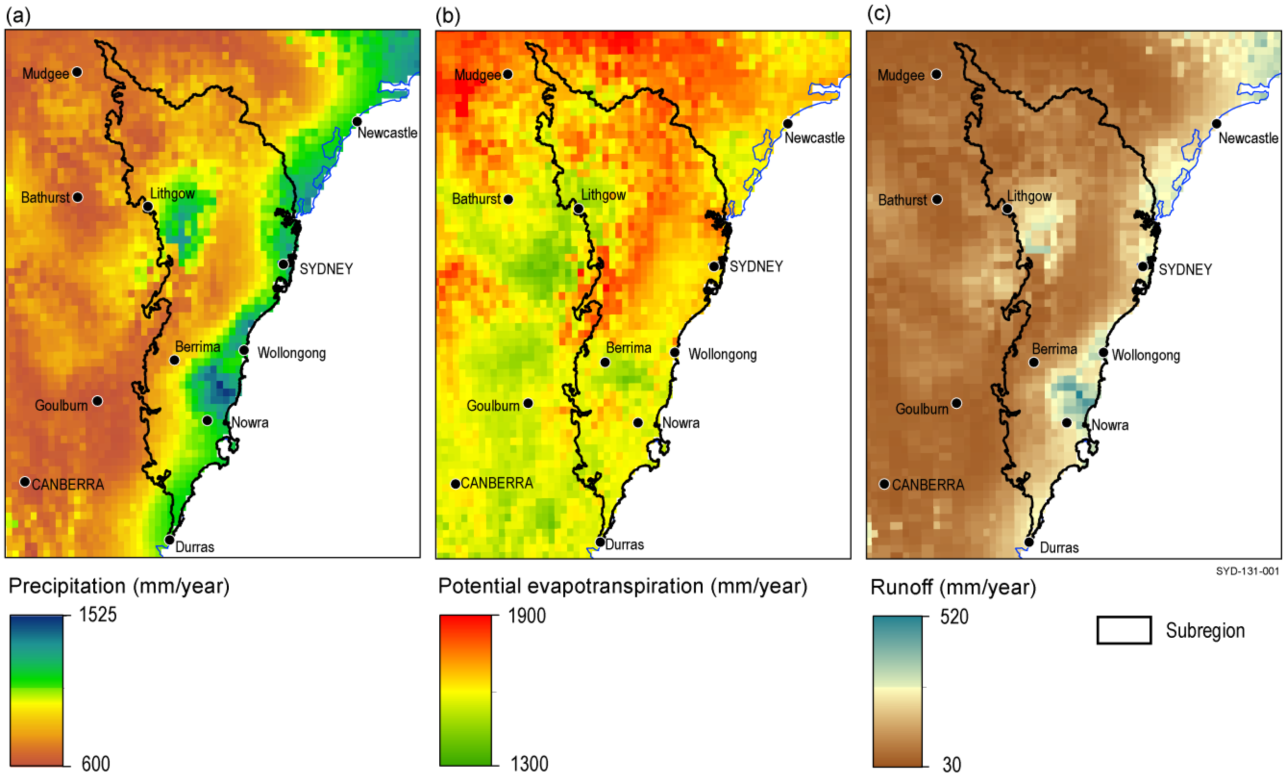

Figure 7 Average annual (1982 to 2010) (a) precipitation, (b) potential evapotranspiration and (c) predicted runoff for the Sydney Basin bioregion

Data: Bioregional Assessment Programme (Dataset 48); CSIRO (Dataset 49)

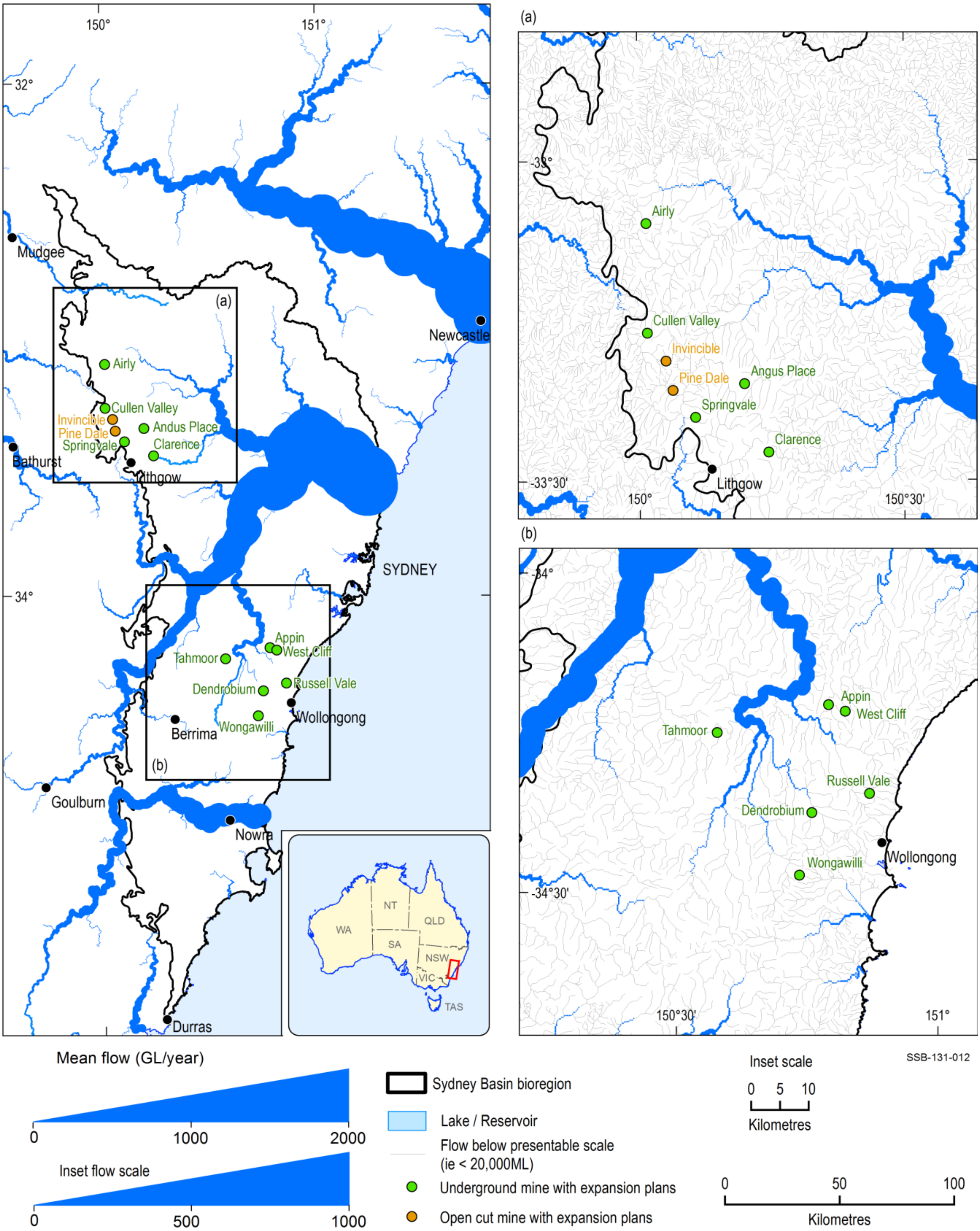

Figure 8 Average annual (1982 to 2010) predicted runoff accumulated for the Sydney Basin bioregion

Inset (a) is a close-up of the Western Coalfield; (b) is a close-up of the Southern Coalfield. Only stream segments with greater than 20,000 ML/year are shown; below this threshold, the drainage lines (not streamflow associated with it) are shown.
Data: Bioregional Assessment Programme (Dataset 50)

Annual average P, PET and R were calculated for the two open-cut mine areas and associated subcatchments. These are summarised in Table 8 for each mine as the percentage contribution from each area to the total from all subcatchment areas. The Invincible mine footprint contributes less than 1% of the long-term total P, PET and R of the four Invincible subcatchments, and the Pine Dale mine footprint contributes about 0.5% of the long-term P, PET and R of the three Pine Dale subcatchments (Table 8).

Table 8 Annual average water balance components for Invincible and Pine Dale open-cut coal mines, and their related surface water subcatchments

Mine	Subcatchments	Annual average precipitation (%)	Annual average potential evapotranspiration (%)	Annual average runoff (%)
Invincible	Mine footprint	0.61%	0.61%	0.47%
	Inv_1	7.23%	6.98%	7.58%
	Inv_2	13.30%	13.57%	12.80%
	Inv_3	12.69%	13.18%	11.85%
	Inv_4	66.77%	66.27%	67.77%
Pine Dale	Mine footprint	0.47%	0.52%	0.41%
	PD_1	41.72%	41.05%	43.03%
	PD_2	47.92%	48.76%	46.31%
	PD_3	10.36%	10.19%	10.66%

Annual average (1982 to 2010) water balance components are shown for precipitation, potential evapotranspiration (PET calculated with the Penman formulation) and Choudhury's modelled runoff for the two open-cut mines and each of their related surface water subcatchments. Percentages are calculated relative to the respective mine-subcatchment totals. Definitions for the subcatchment codes are provided in Table 7, and their spatial extents are shown in Figure 6.

Table 9 expresses the P, PET and R contributions from the Invincible mine footprint as percentages of total P, PET and R with increasing contributing area. Within the smallest subcatchment in which it is located (Inv_1), the Invincible open-cut mine contributes 6.25% of runoff; moving down catchment and the addition of subcatchment Inv_2, the mine contribution to total runoff decreases to 2.33%; with the addition of Inv_3, this reduces to 1.47%; and then to 0.47% when subcatchment Inv_4 is included. Generally, changes in runoff that are less than about 10% of the long-term average are difficult to detect given the large variability in runoff response, and changes of less than 5% of the total runoff are beyond detection level. Any changes to surface water flows downstream of the outlet to subcatchment Inv_2 are predicted to be negligible, hence the catchments of Inv_1 and Inv_2 are used to define the surface water PAE for the Invincible open-cut mine.

Table 9 Percentage contribution of the Invincible open-cut mine footprint to increasing subcatchment areas

Subcatchment	Annual average precipitation (%)	Annual average potential evapotranspiration (%)	Annual average runoff (%)
Mine / Inv_1	8.47%	8.76%	6.25%
Mine / (Inv_1 + Inv_2)	2.99%	2.97%	2.33%
Mine / (Inv_1 + Inv_2 + Inv_3)	1.85%	1.81%	1.47%
Mine / (Inv_1 + Inv_2 + Inv3 + Inv_4)	0.61%	0.61%	0.47%

Annual average (1982 to 2010) water balance components for precipitation, potential evapotranspiration (calculated with the Penman formulation) and Choudhury's modelled runoff. The percentage contributions of the mine footprint relative to the subcatchments, indicated by the denominator, are reported. Definitions for the subcatchment codes are provided in Table 7, and their locations are illustrated in Figure 6 (specifically the inset map).

Table 10 provides a similar analysis for Pine Dale open-cut mine. The area occupied by this mine contributes only 0.95% of the runoff of subcatchment PD_1. This is below the 5% threshold for detection of change (as discussed for Invincible open-cut mine), thus subcatchment PD_1 is used to define the surface water PAE for the Pine Dale open-cut mine.

Table 10 Percentage contribution of the Pine Dale open-cut mine footprint to increasing subcatchment areas

Subcatchment	Annual average precipitation (%)	Annual average potential evapotranspiration (%)	Annual average runoff (%)
Mine / PD_1	1.12%	1.27%	0.95%
Mine / (PD_1 + PD_2)	0.52%	0.58%	0.46%
Mine / (PD_1 + PD_2 + PD_3)	0.47%	0.52%	0.41%

Annual average (1982 to 2010) water balance components for precipitation, potential evapotranspiration (calculated with the Penman formulation) and Choudhury's modelled runoff. The percentage contributions of the mine footprint relative to the subcatchments, indicated by the denominator, are reported. Definitions for the subcatchment codes are provided in Table 7, and their locations are illustrated in Figure 6 (specifically the inset map).

The total surface water PAE is shown in Figure 6 and comprises Inv_1, Inv_2 and PD_1.

1.3.1.3.3 Surface water – groundwater considerations: longwall mines

To model impacts upon surface water from longwall coal mines, an approach was developed to define the PAE based on surface water – groundwater connectivity considerations. Generally, watercourses in the Sydney Basin bioregion are considered to be gaining streams, which means there is a flow of groundwater to the stream. Jankowski (2007, 2009) has identified some general characteristics of how watercourses near longwall mining operations are affected. In undisturbed systems, the direction of groundwater flow is typically towards the stream as baseflow, with discharges coming from springs or through the streambed in areas of significant vertical faulting and fracturing. During longwall mining operations, impacts can include changes to the strength and direction of the local groundwater gradient to the stream, with consequent flow changes. Structural changes that increase fracturing of bedrock under the stream and more widely can lead to reductions in surface water flow to the stream and increased losses through the streambed through new or expanded fracture zones. Given sufficient changes, the stream can become disconnected from the underlying groundwater, leading to a reversal of hydraulic gradients and the stream losing water to groundwater. Structural alterations from mining operations increase the complexity of the flow paths controlling surface water – groundwater interactions. Furthermore, they almost exclusively result in decreased flow in creeks and potentially less groundwater discharge to other creeks in the immediate surface water catchment. It is not known the extent to which local-scale streamflow losses impact river flow in increasingly higher order streams down the network, but they must be considered as potentially affecting streamflow downstream from mining operations.

As there are several recorded cases of watercourses (rivers and creeks) and water bodies (upland swamps) being drained following longwall mining operations in the Southern Coalfield area of the Sydney Basin bioregion (Krogh, 2007; McNally and Evans 2007; and the references therein), a conservative approach has been adopted to the calculation of this component of the PAE and it is assumed that all groundwater and surface water flowing from the catchment is intercepted by longwall mining activity. While this assumption almost certainly exaggerates the potential impact of longwall coal mining in many cases, it was used to define an upper bound for calculations and to ensure that this component of defining the PAE will not result in potentially affected assets being excluded. The Budyko framework (introduced above) was used to quantify the volume of runoff intercepted by each mine and then calculate the percentages of total runoff it represented for increasing catchment areas, as was done in Section 1.3.1.3.2. When the contribution from the 100% perturbed mine-containing catchment was less than 5% of the subcatchment total, it was assumed that its contribution was negligible. The threshold follows the same logic as presented for the surface water PAE calculations. For those subcatchments in which the mine site contribution to runoff was deemed significant, a buffer was put around the main channel running through the subcatchments and this was used to define that part of the PAE where surface water – groundwater interactions could potentially be affected by mining developments in the bioregion. The locations of subcatchments for each mine in the Western and Southern coalfields are shown in Figure 9 and Figure 10 respectively.

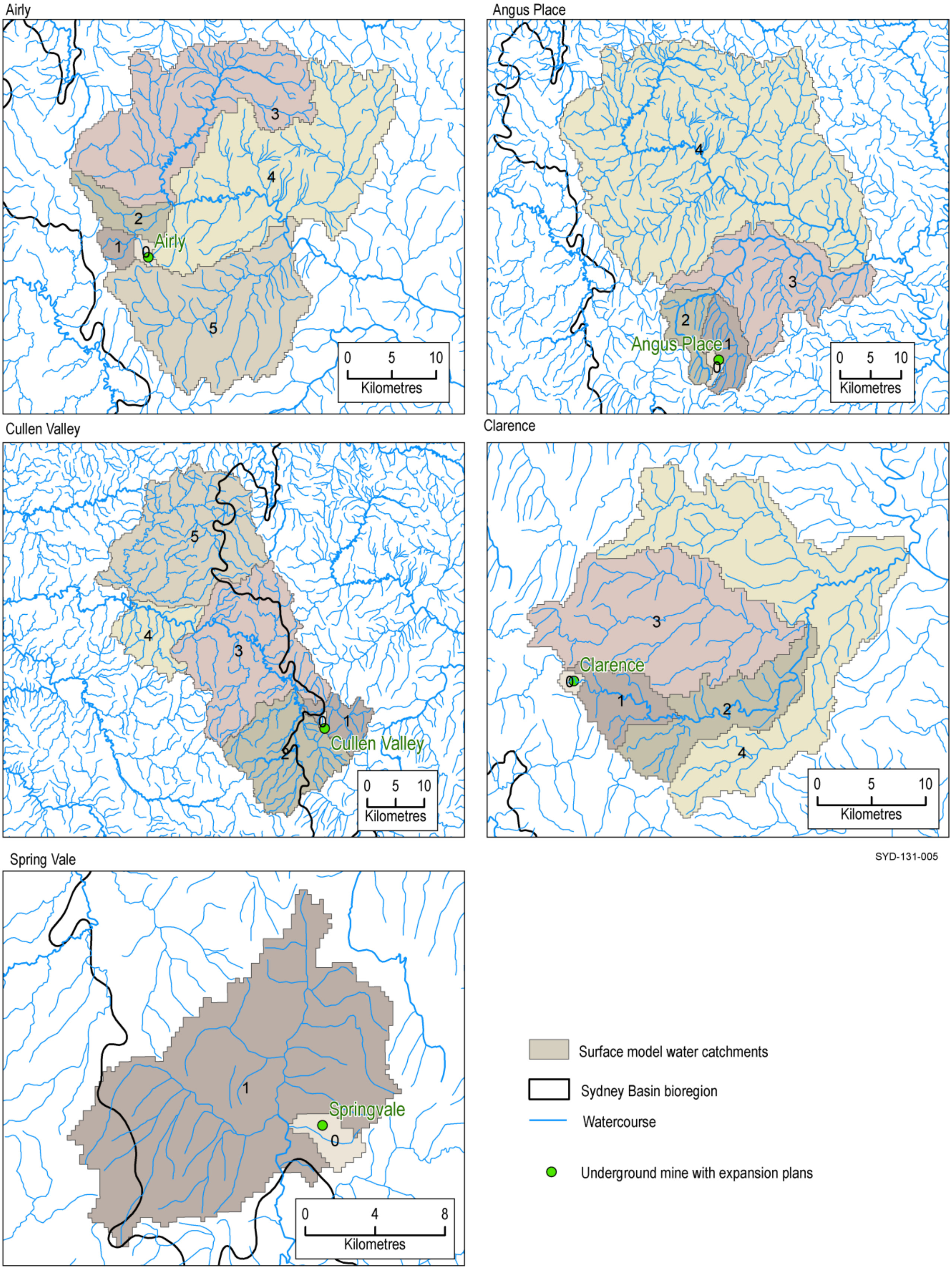

Figure 9 Features used to calculate the surface water – groundwater preliminary assessment extent (PAE) in the Western Coalfield

Airly, Angus Place, Cullen Valley, Clarence and Springvale underground coal mines are shown. Catchments are numbered in order of increasing catchment area, with '0' always assigned to the first order stream catchment in which the mine is located.
Data: Geoscience Australia (Dataset 43); NSW Trade and Investment (Dataset 44); Bioregional Assessment Programme (Dataset 46)

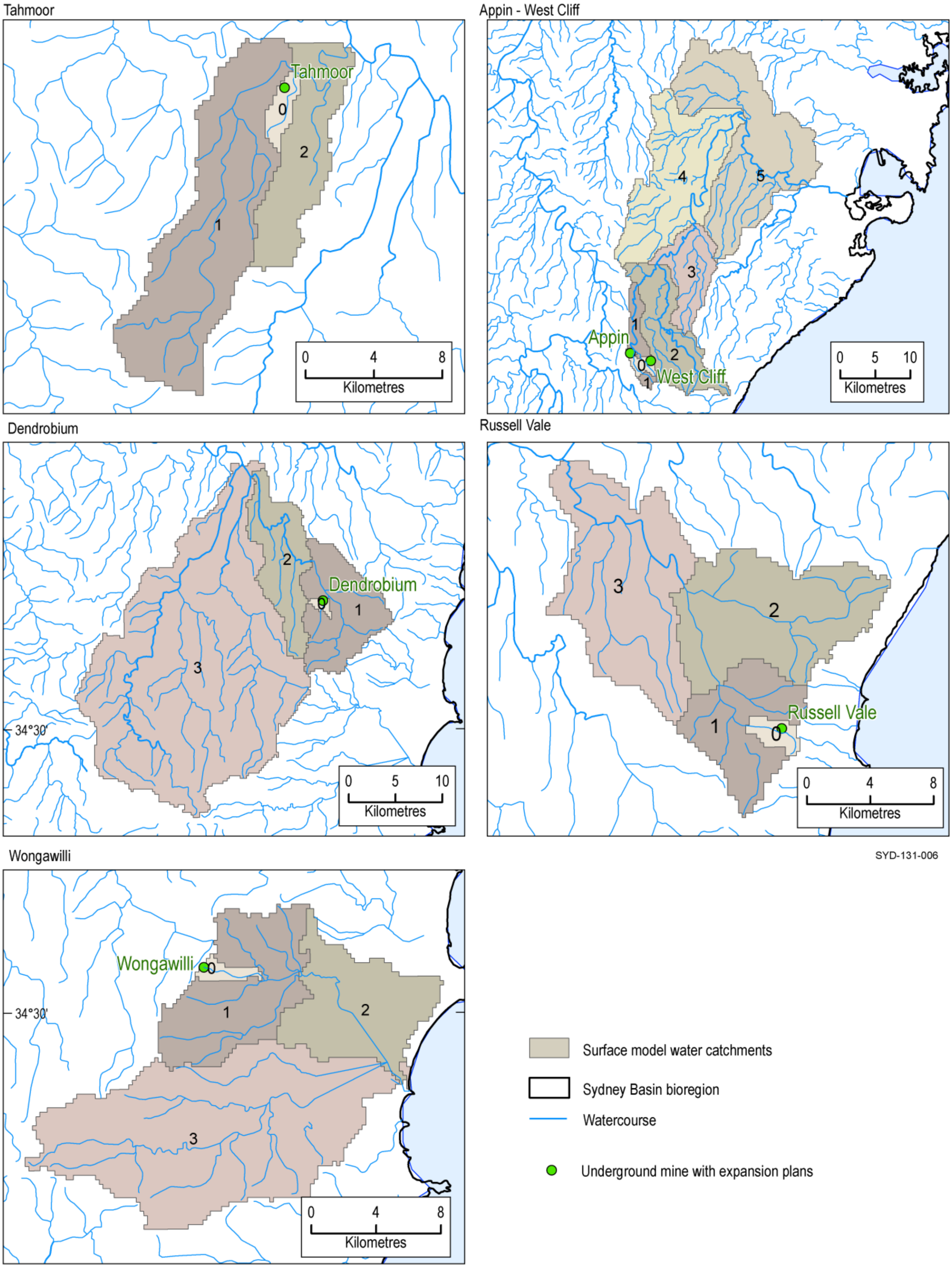

Figure 10 Features used to calculate the surface water – groundwater preliminary assessment extent (PAE) in the Southern Coalfield

Tahmoor, Appin – West Cliff, Dendrobium, Russell Vale and Wongawilli underground coal mines are shown. Catchments are numbered in order of increasing catchment area, with '0' always assigned to the first order stream catchment in which the mine is located.

Data: Geoscience Australia (Dataset 43); NSW Trade and Investment (Dataset 44); Bioregional Assessment Programme (Dataset 46)

Table 11 summarises subcatchment codes, subcatchment areas, and average annual runoff from each area, expressed as a percentage of total average annual runoff for the five underground coal mines in the Western Coalfield around Lithgow. The relative runoff contributions with increasing subcatchment level are provided in Table 12. The subcatchment level at which the runoff contribution from the mine was less than 5% of total runoff was:

- Airly: Level 3 (i.e. L1+L2+L3)
- Cullen Valley: Level 2
- Angus Place: Level 3
- Springvale: Level 1
- Clarence: Level 2.

There are six underground mines in the Southern Coalfield. Appin and West Cliff mines are located in adjacent first-order surface water catchments and were grouped together for this analysis. Details of subcatchment codes, areas and percentage runoff contributions are summarised in Table 13. For mines in the Southern Coalfield, the relative contribution of runoff from the subcatchment containing the mine was less than 5% for the following mine-subcatchment levels (Table 14):

- Appin + West Cliff: Level 3
- Russell Vale: Level 3
- Dendrobium: Level 1
- Wongawilli: Level 2.

Table 11 Details of subcatchments around the Western Coalfield underground coal mines

Mine	Subcatchment level	Subcatchment code	Area (km^2)	Annual average runoff (%)
Airly	Containing mine	Airly	6.2	0.97%
	First level	Air_1	14.7	1.65%
	Second level	Air_2	37.4	4.41%
	Third level	Air_3	269.0	26.78%
	Fourth level	Air_4	348.9	34.54%
	Fifth level	Air_5	258.3	31.66%
Cullen Valley	Containing mine	Cullen Valley	3.2	0.35%
	First level	CV_1	67.1	6.46%
	Second level	CV_2	268.6	10.25%
	Third level	CV_3	458.6	31.41%
	Fourth level	CV_4	129.3	3.98%
	Fifth level	CV_5	473.0	47.54%
Angus Place	Containing mine	Angus Place	10.1	1.02%
	First level	AP_1	78.7	7.75%
	Second level	AP_2	79.2	6.28%
	Third level	AP_3	338.3	27.47%
	Fourth level	AP_4	1360.8	57.48%
	Fifth level	na	na	na
Springvale	Containing mine	Springvale	7.7	4.61%
	First level	SV_1	187.1	95.39%
	Second level	na	na	na
	Third level	na	na	na
	Fourth level	na	na	na
	Fifth level	na	na	na
Clarence	Containing mine	Clarence	3.8	0.30%
	First level	CL_1	42.4	2.74%
	Second level	CL_2	89.6	9.37%
	Third level	CL_3	213.2	23.00%
	Fourth level	CL_4	299.6	64.60%
	Fifth level	na	na	na

The annual average runoff calculation is relative to the highest level shown for each mine and results are not nested.
'na' means not applicable as not all mines required analysis to the fifth level. The mines are reported from north to south. Locations of subcatchments for each mine are shown in Figure 9.

Table 12 Relative runoff contribution of Western Coalfield catchments containing an underground coal mine in wider regional context

Mine / level(s)	Airly Mine annual average runoff (%)	Cullen Valley annual average runoff (%)	Angus Place annual average runoff (%)	Springvale annual average runoff (%)	Clarence annual average runoff (%)
Mine / L1	37.05%	5.19%	11.63%	4.61%	9.77%
Mine / (L1 + L2)	13.8%	2.07%	6.78%	na	2.39%
Mine / (L1 + L2 + L3)	2.87%	0.73%	2.40%	na	0.84%
Mine / (L1 + L2 + L3 + L4)	1.42%	0.68%	1.02%	na	0.30%
Mine / (L1 + L2 + L3 + L4+L5)	0.97%	0.35%	na	na	na

‘na’ means not applicable as not all mines required analysis to the fifth level. The mines are reported from north to south. Locations of subcatchments for each mine are shown in Figure 9.

Table 13 Details of subcatchments around the underground coal mines in the Southern Coalfield

Mine	Subcatchment level	Subcatchment code	Area (km^2)	Annual average runoff (%)
Appin + West Cliff	Containing mine	Appin+West Cliff	8.74	1.22%
	First level	AWC_1	24.25	3.45%
	Second level	AWC _2	114.43	17.03%
	Third level	AWC _3	75.66	11.27%
	Fourth level	AWC _4	230.59	24.60%
	Fifth level	AWC _5	294.61	42.44%
Tahmoor	Containing mine	Tahmoor	5.19	5.10%
	First level	Tah_1	92.93	58.50%
	Second level	Tah_2	37.34	36.40%
	Third level	na	na	na
	Fourth level	na	na	na
	Fifth level	na	na	na
Russell Vale	Containing mine	Russell Vale	5.25	4.13%
	First level	RV_1	40.29	24.58%
	Second level	RV _2	81.00	41.72%
	Third level	RV _3	92.72	29.56%
	Fourth level	na	na	na
	Fifth level	na	na	na
Dendrobium	Containing mine	Dendrobium	2.78	0.84%
	First level	Den_1	85.30	27.40%
	Second level	Den_2	74.90	12.21%
	Third level	Den_3	510.11	59.55%
	Fourth level	na	na	na
	Fifth level	na	na	na
Wongawilli	Containing mine	Wongawilli / 3.67 km^2 / 2.09 %	3.67	2.09%
	First level	Won_1	55.54	21.15%
	Second level	Won_2	51.88	19.58%
	Third level	Won_3	157.89	57.19%
	Fourth level	na	na	na
	Fifth level	na	na	na

The annual average runoff calculation is relative to the highest level shown for each mine and results are not nested.
'na' means not applicable as not all mines required analysis to the fifth level. The mines are reported from north to south. Locations of subcatchments for each mine are shown in Figure 10.

Table 14 Relative runoff contribution of Southern Coalfield catchments containing one or more underground coal mines when placed in wider regional context

Mine / level(s)	Appin + West Cliff annual average runoff (%)	Tahmoor annual average runoff (%)	Russell Vale annual average runoff (%)	Dendrobium annual average runoff (%)	Wongawilli annual average runoff (%)
Mine / L1	26.08%	8.03%	14.40%	2.96%	9.00%
Mine / (L1 + L2)	5.61%	5.10%	5.87%	2.07%	4.88%
Mine / (L1 + L2 + L3)	3.69%	na	4.13%	0.84	2.09%
Mine / (L1 + L2 + L3 + L4)	2.11%	na	na	na	na
Mine / (L1 + L2 + L3 + L4+L5)	1.22%	na	na	na	na

'na' means not applicable as not all mines required analysis to the fifth level. The mines are reported from north to south. Locations of subcatchments for each mine are shown in Figure 10.

The analysis for the Tahmoor mine was slightly greater than the 5% threshold and required further investigation. To ensure that the mine-catchment contribution was less than 5% of the regional runoff contribution, an additional surface water catchment for the Tahmoor mine needed to be defined. However, the next subcatchment level for the Tahmoor mine includes the Dendrobium mine catchment, so in this additional analysis, the two mine catchments were considered together (Figure 11). Details of the subcatchments are reported in Table 15 and their relative runoff contributions with increasing subcatchment level are provided in Table 16. Results show that at subcatchment level 1, the combined runoff contribution from Tahmoor and Dendrobium mines is below the 5% threshold. This concludes the first step of the analysis, to identify which catchments should be included in the PAE based on considerations of surface water – groundwater connectivity.

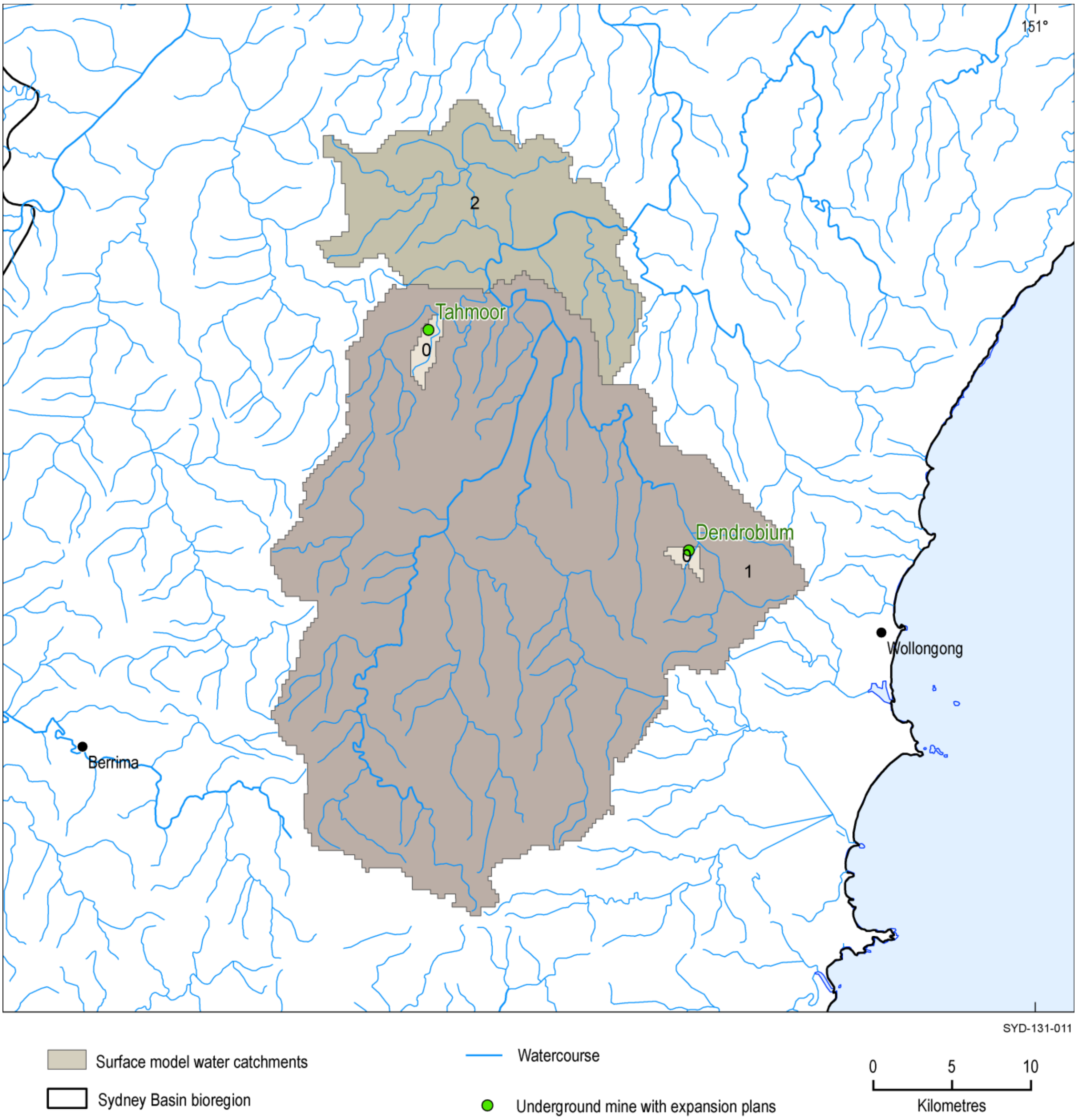

Figure 11 Subcatchments definition for the merged Tahmoor and Dendrobium analysis

Catchments are numbered in order of increasing catchment area, with '0' always assigned to the first order stream catchment in which the mine is located.
Data: Geoscience Australia (Dataset 43); NSW Trade and Investment (Dataset 44); Bioregional Assessment Programme (Dataset 46)

Table 15 Details of subcatchments around the Tahmoor and Dendrobium underground coal mines

Subcatchment level	Subcatchment codes	Area (km²)	Annual average runoff (%)
Containing the Mines	Tahmoor+Dendrobium	7.97	0.93%
First level	TD_1	827.80	92.37%
Second level	TD_2 /	175.22	6.70%

The annual average runoff calculation is relative to the highest level shown for each mine and results are not nested.

Table 16 Relative runoff contributions from Tahmoor and Dendrobium underground coal mines in the wider catchment context

Mine / level(s)	Tahmoor + Dendrobium annual average runoff (%)
Mine / L1	1.00
Mine / (L1 + L2)	0.93

In the second and final step, the distance of the buffer either side of the main channels, in which the groundwater and surface water are likely to be connected, was defined. Most of the main channels defining locations of potential surface water – groundwater connectivity are already contained within the groundwater PAE (Figure 14). Only around the Angus Place mine, and to lesser extents the Clarence, Cullen Valley and Appin-West Cliff mines, is it possible that surface water – groundwater connectivity may extend beyond the groundwater PAE. Thus the valley floor characteristics of the valleys around these mines, using the MrVBF (Multi-resolution Valley Bottom Flatness) terrain analysis product (Gallant and Dowling, 2003), informed the delineation of the buffer. Figure 12 shows flat areas identified along streams around the Angus Place mine. A maximum buffer width of 500 m was determined to be sufficiently wide enough to accommodate the full extent of flat areas. Thus, a 500 m buffer was applied to all main channels in catchments identified in the previously documented Budyko analysis for the longwall mines. The final result is presented in Figure 13.

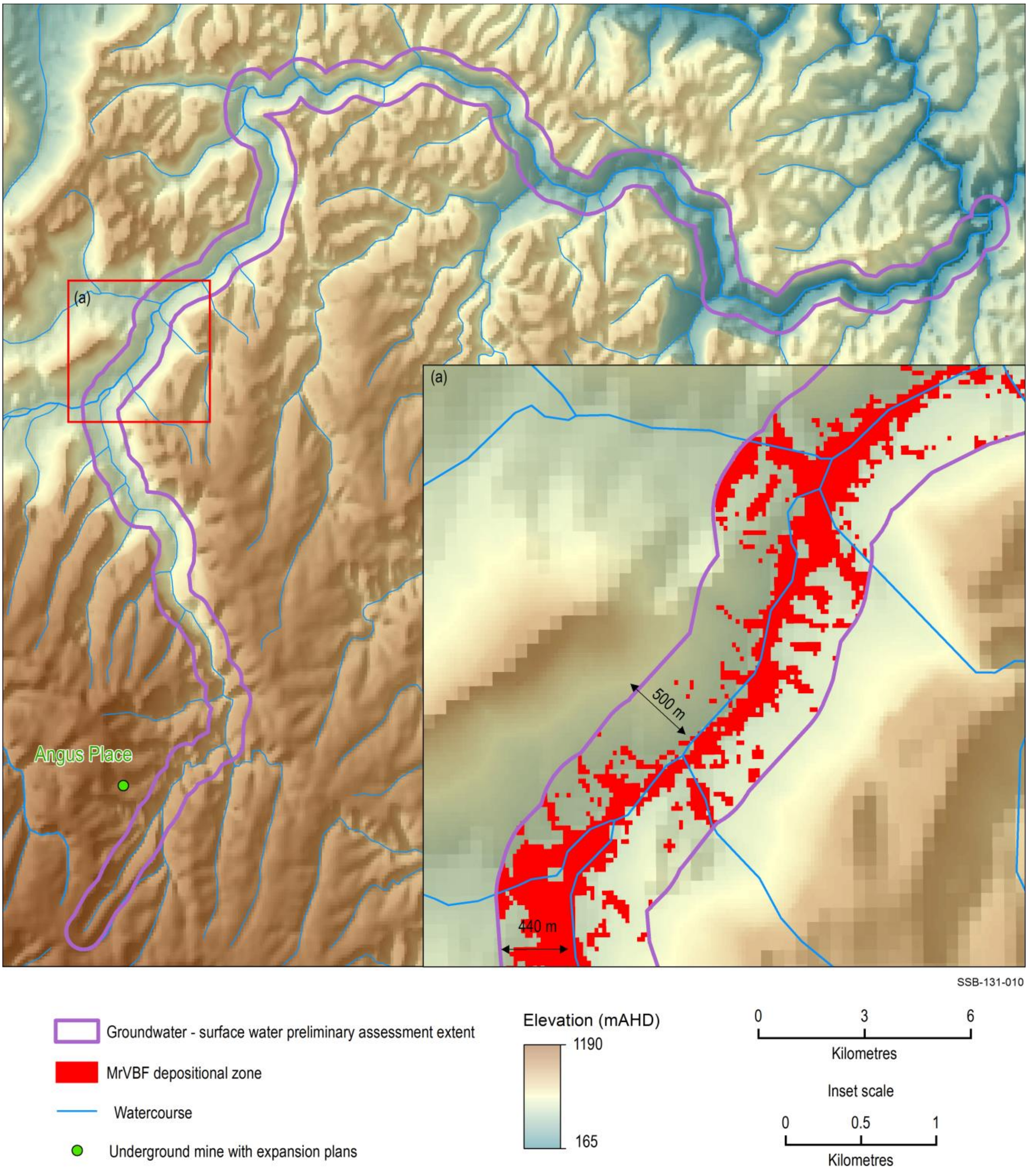

Figure 12 Flat areas from terrain analysis (red) and the 500 m stream buffer (purple) used to define the preliminary assessment extent (PAE) based on surface water – groundwater connectivity in the vicinity of Angus Place

Data: Geoscience Australia (Dataset 43, Dataset 51); NSW Trade and Investment (Dataset 44); Bioregional Assessment Programme (Dataset 46); CSIRO (Dataset 52)

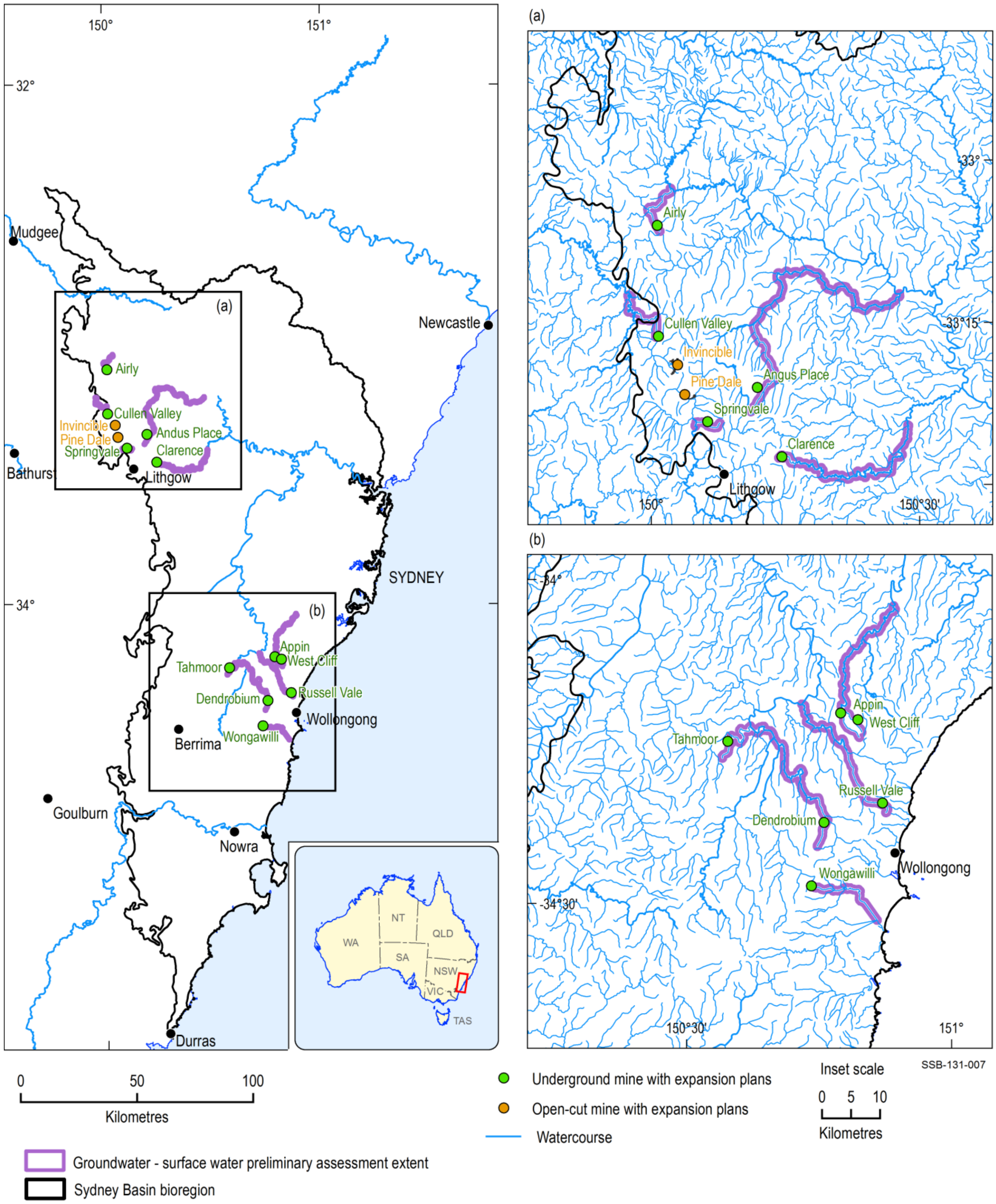

Figure 13 Preliminary assessment extent (PAE) based on surface water – groundwater connectivity in the Sydney Basin bioregion

Data: Geoscience Australia (Dataset 43); NSW Trade and Investment (Dataset 44); Bioregional Assessment Programme (Dataset 46)

1.3.1.3.4 The final preliminary assessment extent

The final PAE of the Sydney Basin bioregion was defined as the union of the groundwater PAE, surface water PAE and surface water – groundwater connectivity PAE. The overlay of these three components is shown in Figure 14 and the unified PAE boundary in Figure 15. The Sydney Basin bioregion covers about 24,606 km^2, of which the PAE covers about 5,398 km^2. The PAE comprises two disconnected components: one in Western Coalfield in the vicinity of Lithgow (2522 km^2); and the second in the Southern Coalfield centred on Wollongong (2876 km^2). It is in the PAE that geospatial referenced lists of water-dependent assets will be identified.

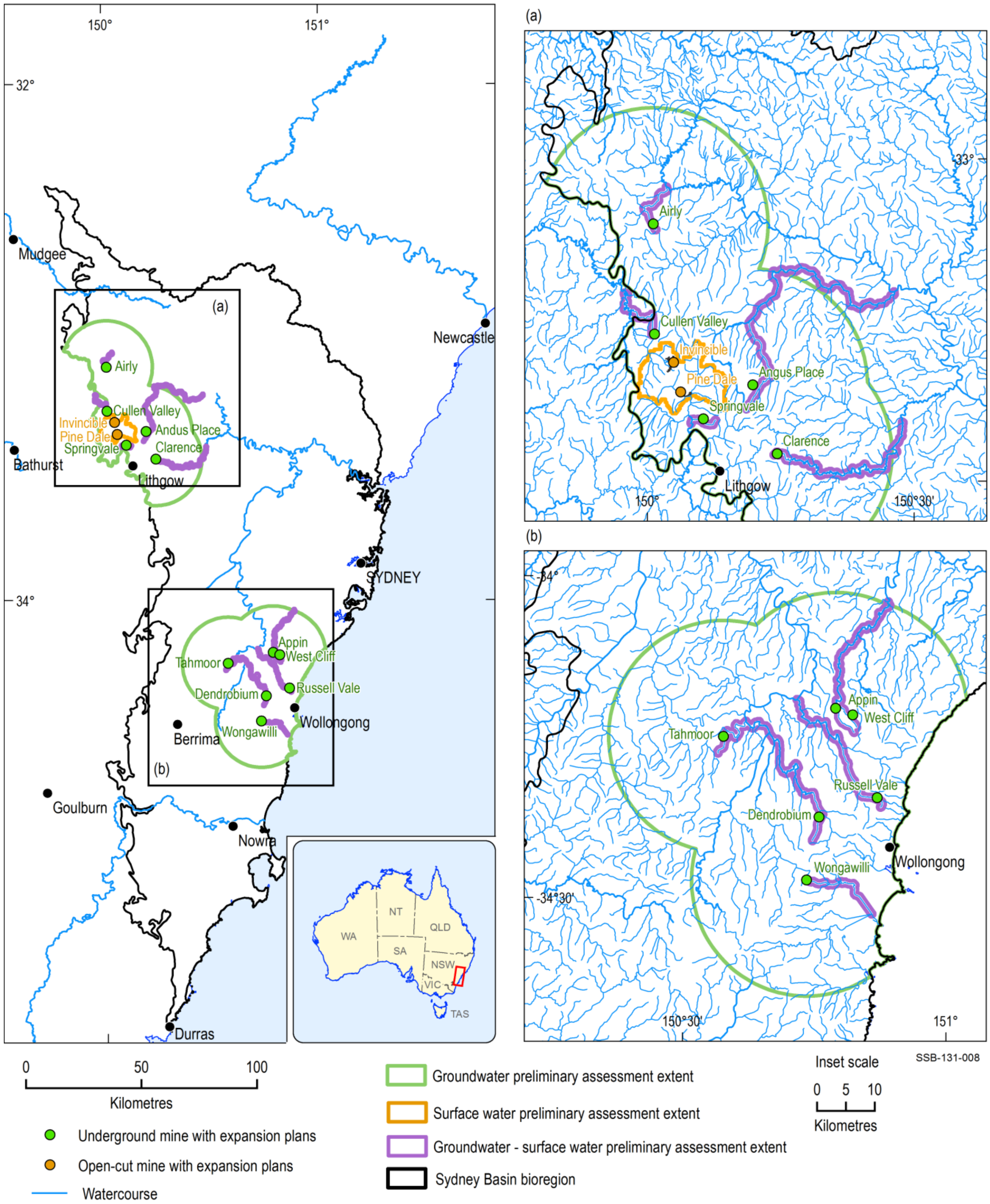

Figure 14 Overlay of the three components (groundwater, surface water and surface water – groundwater connectivity) considered when defining the preliminary assessment extent (PAE) of the Sydney Basin bioregion

Data: Geoscience Australia (Dataset 43); NSW Trade and Investment (Dataset 44); Bioregional Assessment Programme (Dataset 46)

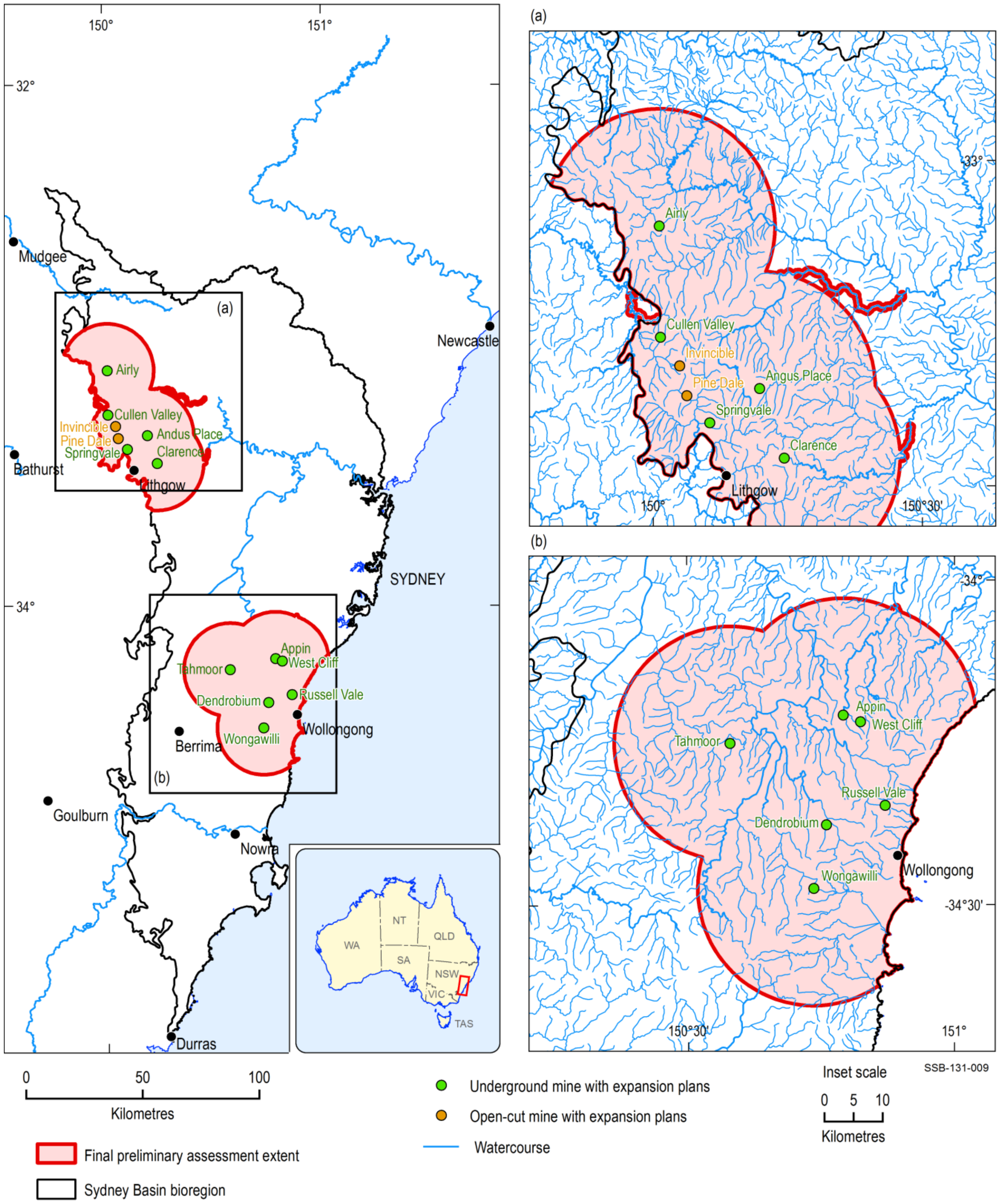

Figure 15 Preliminary assessment extent (PAE) of the Sydney Basin bioregion

Data: Bioregional Assessment Programme (Dataset 53); Geoscience Australia (Dataset 43); NSW Trade and Investment (Dataset 44)

1.3.1.4 Assessing water dependence

Assets in the asset database that intersect the PAE of the Sydney Basin form the asset list for the Sydney Basin bioregion. The water dependency of each asset in the asset list must then be assessed. Only assets that have a water dependency qualify for inclusion in the water-dependent asset register. Thus any asset that might potentially be affected by changes in the groundwater and/or surface water regime due to coal resource development is added to the water-dependent asset register. Many assets are clearly 'water dependent', including all economic assets (i.e. water access entitlements and reservoirs).

For ecological assets, features such as rivers, wetlands, lakes, lagoons and groundwater-dependent ecosystems are clearly water dependent; however, the water dependency of other assets, such as nature reserves and conservation areas, is less certain. The water dependency of nature reserves and conservation areas was determined based on their intersection with obvious surface water and groundwater features. Assets that do not overlap with obvious water features were judged not to be water dependent. The water dependency of threatened species and communities were assessed on a case-by-case basis, based on their profiles in the Species Profile and Threats Database (SPRAT) (Australian Government Department of the Environment, Dataset 10; Bioregional Assessment Programme, Dataset 11) and the NSW BioNet website (NSW Office of Environment and Heritage, 2016).

A similar approach was taken to judge the water dependency of sociocultural assets. The water dependency of sociocultural assets is not always obvious, so it was assumed that within some specified distance of a water feature, there is the potential for changes in groundwater table or streamflow regime to impact the assets. A 500 m buffer (i.e. the same buffer width used to define the area around streams where surface water and groundwater potentially interact (see section 1.3.1.3.3 and Figure 12)) – was put around all rivers and wetlands, and this was intersected with the sociocultural assets to identify those having a potential water dependency.

Water dependence was determined for a preliminary list of assets to produce a preliminary version of the water-dependent asset register. For transparency, decisions about water dependency are recorded in the asset database. The preliminary version of the water-dependent asset register, with associated maps and data, was presented to experts and organisations with local knowledge at the Sydney Basin asset workshop in Penrith (NSW) in August 2015 for comment and feedback. There were 14 participants from state and local governments and 10 participants from Commonwealth agencies and the Assessment team (Table 17). The participants demonstrated an enormous willingness to provide additional or better data to improve the water-dependent asset register for the subregion.

Most participants had seen the preliminary list of assets prior to the workshop and had already identified missing datasets. There were very few issues raised on the day and the discussions were mostly around additional data that could be made available. They are summarised in Table 18, together with the BA response to these issues.

Following the workshop, three weeks was allowed to follow up additional datasets from the local government and state agencies. Where datasets were deemed fit-for-BA purpose and the assets were within the PAE, they were added to the water-dependent asset register.

More details about the ecological, economic and sociocultural water-dependent assets identified in the Sydney Basin bioregion, and the reasons for their inclusion or exclusion from the water-dependent asset register, are described in Section 1.3.2, Section 1.3.3 and Section 1.3.4 respectively.

The water-dependent asset register is an authoritative listing of the assets that will be included in other components of the BA; all spatial data and other data associated with each asset are stored in the asset database.

Table 17 Organisations represented at the Sydney Basin bioregion asset workshop held in Penrith on 24 August 2015

Organisation	Number of participants
CSIRO	5
Department of the Environment – Environmental Resources Information Network	2
Department of the Environment – Office of Water Science	2
Bureau of Meteorology	1
NSW Office of Environment and Heritage	2
NSW Department of Primary Industries, Fisheries	1
NSW Department of Primary Industries, Water	1
WaterNSW	2
Greater Sydney Local Land Services	2
Southeast Local Land Services	1
Central Tablelands Local Land Services	1
Wollondilly Shire Council	2
Blue Mountains City Council	1
Campbelltown City Council	1
Total	**24**

Table 18 Issues and comments from the Sydney Basin bioregion asset workshop and actions for the Assessment team

Asset	Issue/comment	Action/response
Economic	WaterNSW: Greater Sydney water supply catchments are not specifically included as an asset.	Four water supply catchments were defined based on water source areas in the Greater Metropolitan Region Unregulated water sources WSP.
Ecological	Greater Sydney LLS: missing some surface water GDEs OEH: NSW Wetlands (2006) layer will not include a lot of upland swamps. Other sources available (Macquarie University; OEH may have data; Centennial Coal mapping)	'National Groundwater Dependent Ecosystems (GDE) Atlas' (Bureau of Meteorology, Dataset 3) includes some upland swamps. No other mapped data obtained. This is potentially a data gap, but some may also be covered by other spatial layers in the asset register.
	Greater Sydney LLS: have vegetation layer that covers all freshwater wetland endangered ecological communities	Two data layers were supplied: OEH (Dataset 22) and NSW Office of Water (Dataset 27).
	OEH: mapping of EPBC Act-listed species is highly uncertain	Noted. This is acknowledged as a data limitation in Section 1.3.2.

Asset	Issue/comment	Action/response
	OEH: individual rivers and creeks are not identified as assets. Grose and Colo are examples of wild rivers. OEH have statewide data layer of Wild Rivers	Geofabric rivers cover river assets, but Colo and Grose have been specifically added as assets (Dataset 33).
	OEH: recharge areas for GDEs (e.g. Birds Rock Flora Reserve; Agnes Banks woodland)	Recharge areas are part of the causal pathway, but not water-dependent assets under the BA definition. If changes occur from mining that affect recharge areas, conceptual and/or numerical modelling will reflect this connectivity.
	OEH: raised question of connectivity between Thirlmere Lakes and groundwater (i.e. should it be listed as a GDE?)	Regardless of the connectivity, it meets BA criteria for water dependence – it is a lake. It is included in five of the asset datasets: DIWA (Dataset 2), CAPAD (Dataset 7), NSW Wetlands (Dataset 4), WAIT database (Dataset 6), Register of the National Estate (Dataset 42).
	DPI: are caves included? Not part of National Atlas Wetlands or NSW wetland mapping	Gardens of Stone National Park is in CAPAD dataset (Dataset 7) and includes Coco Creek, Blue Rock karst systems. They have been added as point features to the water-dependent asset register (NSW Office of Water, Dataset 27)
	DPI Fisheries: threatened fish	Fitzroy Falls spiny crayfish, Macquarie Perch, Purple spotted gudgeon added (DPI, Dataset 23; DPI, Dataset 24; DPI, Dataset 25)
	Platypus should be included	Iconic species. Identified as an asset at Gloucester, Hunter and Sydney Basin workshops. Included in WAIT_ALA_ERIN dataset (Dataset 17)
Sociocultural	Greater Sydney LLS: Brad Moggridge was commissioned by Hawkesbury-Nepean CMA to do a study of Indigenous water assets	Report supplied (Moggridge, 2010) and assets within PAE included in asset list (Bioregional Assessment Programme, Dataset 1)
	OEH: EISs include Indigenous/cultural info (e.g. Russell Vale has some important sites)	Office of Water Science have a process for pursuing Indigenous assets as part of BA. Mining reports have not informed the asset list for sociocultural assets.
	OEH: are rivers with recreational values (e.g. used for canyoning) included?	All Geofabric rivers are included in the water-dependent asset register (Dataset 33). Can have multiple values
	Coco Creek – sociocultural significance	In asset list as a geological feature of significance (karst) (NSW Office of Water, Dataset 27)

BA = bioregional assessment, CAPAD = Collaborative Australian Protected Areas Database, CMA = catchment management authority, DIWA = *A directory of important wetlands in Australia*, DPI = New South Wales Department of Primary Industries, EPBC Act = Commonwealth's *Environment Protection and Biodiversity Conservation 1999*, EIS = environmental impact statement, GDE = groundwater-dependent ecosystems, OEH = Office of Environment and Heritage, PAE = preliminary assessment extent, WAIT = Water Asset Information Tool, WSP = water sharing plan

References

Budyko MI (1974) Climate and Life. Academic, New York.

Bureau of Meteorology (2012) Australian Hydrological Geospatial Fabric (Geofabric) Version 2.1. Viewed 15 February 2016, http://www.bom.gov.au/water/geofabric.

Choudhury BJ (1999) Evaluation of an empirical equation for annual evaporation using field observations and results from a biophysical model. Journal of Hydrology 216(1–2), 99–110.

Donohue R, Roderick M and McVicar T (2012) Roots, storms and soil pores: Incorporating key ecohydrological processes into Budyko's hydrological model. Journal of Hydrology 436, 35–50.

Donohue RJ, Roderick ML and McVicar TR (2007) On the importance of including vegetation dynamics in Budyko's hydrological model. Hydrology and Earth System Sciences 11(2), 983–995.

Donohue RJ, Roderick ML and McVicar TR (2010) Can dynamic vegetation information improve the accuracy of Budyko's hydrological model? Journal of Hydrology 390(1–2), 23–34.

Donohue RJ, Roderick ML and McVicar TR (2011) Assessing the differences in sensitivities of runoff to changes in climatic conditions across a large basin. Journal of Hydrology 406(3–4), 234–244.

DPI (2012) NSW Aquifer Interference Policy: NSW Government policy for the licencing and assessment of aquifer interference activities. New South Wales Department of Primary Industries, Office of Water.

Gallant JC and Dowling TI (2003) A multiresolution index of valley bottom flatness for mapping depositional areas. Water Resources Research 39(12), 1347.

Herron NF, McVicar TR, Rohead-O'Brien H, Rojas R, Rachakonda PK, Zhang YQ, Dawes WR, Macfarlane C, Pritchard J, Doody T, Marvanek SP and Li LT (2018a) Context statement for the Sydney Basin bioregion. Product 1.1 from the Sydney Basin Bioregional Assessment. Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia. http://data.bioregionalassessments.gov.au/product/SSB/SSB/1.1.

Herron NF, Peeters LJM, Crosbie RS, Marvanek SP, Ramage A, Rachkonda PK and Wilkins A (2018b) Groundwater numerical modelling for the Hunter subregion. Product 2.6.2 for the Hunter subregion from the Northern Sydney Basin Bioregional Assessment. Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia. http://data.bioregionalassessments.gov.au/product/NSB/HUN/2.6.2.

Hodgkinson JH, Rohead-O'Brien H, Wilkes PG and Marvanek SP (2018) Coal and coal seam gas resource assessment for the Sydney Basin bioregion. Product 1.2 from the Sydney Basin Bioregional Assessment. Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia. http://data.bioregionalassessments.gov.au/product/SSB/SSB/1.2.

Jankowski J (2007) Surface water-groundwater interactions in a catchment impaired by longwall mining. Proceedings of the 7th Triennial Conference on Mine Subsidence. Mine Subsidence Technological Society, Wollongong, NSW, 253-262.

Jankowski J (2009) Hydrological changes due to longwall mining in the southern coalfield, New South Wales, Australia. Groundwater in the Sydney Basin Symposium. IAH NSW, Sydney, 107-117.

Jones DA, Wang W and Fawcett R (2009) High-quality spatial climate data-sets for Australia. Australian Meteorological and Oceanographic Journal 58(4), 233–248.

Krogh M (2007) Management of longwall coal mining impacts in Sydney's southern drinking water catchments. Australian Journal of Environmental Management 14(3), 155–165.

McNally G and Evans R (2007) Impacts of longwall mining on surface water and groundwater, Southern Coalfield NSW. Report prepared for NSW Department of Environment and Climate Change. eWater Cooperative Research Centre, Canberra. Viewed 15 February, 2016, http://www.ewater.com.au/uploads/files/McNally_Evans-2007-Longwall_mining.pdf.

McVicar TR, Roderick ML, Donohue RJ and Van Niel TG (2012) Less bluster ahead? Ecohydrological implications of global trends of terrestrial near-surface wind speeds. Ecohydrology 5(4), 381–388.

McVicar TR, Van Niel TG, Li LT, Roderick ML, Rayner DP, Ricciardulli L and Donohue RJ (2008) Wind speed climatology and trends for Australia, 1975–2006: Capturing the stilling phenomenon and comparison with near-surface reanalysis output. Geophysical Research Letters 35, L20403, DOI: 10.1029/2008GL035627.

Moggridge B (2010) Identification of culturally significant groundwater dependent ecosystems and identification of reaches within management zones to support Aboriginal Community Development Licenses, Final report for the Hawkesbury-Nepean Catchment Management Authority, November 2010. CSIRO Land and Water, Australia.

Mount RE, Mitchell PJ, Macfarlane C, Marston FM, McNamara JM, Raisbeck-Brown N, O'Grady AP, Moran BT and Wang J (2015) Compiling water-dependent assets. A submethodology from the Bioregional Assessment Technical Programme. Department of the Environment, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia. Viewed 25 July 2016, http://data.bioregionalassessments.gov.au/submethodology/M02.

NSW Office of Environment and Heritage (2016) NSW Bionet. Viewed 12 February 2016, http://www.bionet.nsw.gov.au/.

NSW Planning and Environment (2016) Major Projects website. Viewed 29 March 2016, http://majorprojects.planning.nsw.gov.au/.

Peeters LJM, Dawes WR, Rachakonda PR, Pagendam DE, Singh RM, Pickett TW, Frery E, Marvanek SP and McVicar TR (2018) Groundwater numerical modelling for the Gloucester subregion. Product 2.6.2 for the Gloucester subregion from the Northern Sydney Basin Bioregional Assessment. Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia. http://data.bioregionalassessments.gov.au/product/NSB/GLO/2.6.2.

Wang J, Rachakonda PK, Macfarlane CK, Pritchard J, Guo L, Bell J, Slegers S, Marvanek SP and Herron NF (2018) Water-dependent asset register and asset list for the Sydney Basin bioregion on 29 March 2016. A spreadsheet associated with product 1.3 for the Sydney Basin bioregion from the Sydney Basin Bioregional Assessment. Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia. http://data.bioregionalassessments.gov.au/product/SSB/SSB/1.3.

Datasets

Dataset 1 Bioregional Assessment Programme (2016) Asset database for the Sydney Basin bioregion on 29 March 2016. Bioregional Assessment Derived Dataset. Viewed 29 March 2016, http://data.bioregionalassessments.gov.au/dataset/ae283994-5f14-4442-af0d-8f8c81eb657e.

Dataset 2 Australian Government Department of the Environment (2015) Directory of Important Wetlands in Australia (DIWA) Spatial Database (Public). Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/6636846e-e330-4110-afbb-7b89491fe567.

Dataset 3 Bureau of Meteorology (2012) National Groundwater Dependent Ecosystems (GDE) Atlas. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/e358e0c8-7b83-4179-b321-3b4b70df857d.

Dataset 4 NSW Department of Environment Climate Change and Water (2010) NSW Wetlands. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/90476e12-77a2-4970-a0be-942eeb84e95e.

Dataset 5 Bioregional Assessment Programme (2015) SW Economic Elements Sydney Basin 20150730. Bioregional Assessment Derived Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/4240553d-702c-4fae-b64b-074d611f2a34.

Dataset 6 Australian Government Department of the Environment (2015) New South Wales NSW - Regional - CMA - Water Asset Information Tool - WAIT - databases. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/330532aa-66ba-44f5-984b-8a21a99661a0.

Dataset 7 Australian Government Department of the Environment (2010) Collaborative Australian Protected Areas Database (CAPAD) 2010 - External RESTRICTED (Not current release) - Metadata only. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/7b649c6d-fdbf-40e3-b002-db521665af53.

Dataset 8 Birds Australia (2009) Birds Australia - Important Bird Areas (IBA) 2009. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/5d488350-83b6-4e71-8d17-687ad8ff9941.

Dataset 9 Murray-Darling Basin Authority (2010) Key Environmental Assets - KEA - of the Murray Darling Basin RESTRICTED (Metadata only). Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/9948195e-3d3b-49dc-96d2-ea7765297308.

Dataset 10 Australian Government Department of the Environment (2015) Communities of National Environmental Significance Database - RESTRICTED - Metadata only. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/c01c4693-0a51-4dbc-bbbd-7a07952aa5f6.

Dataset 11 Bioregional Assessment Programme (2013) Species Profile and Threats Database (SPRAT) - Australia - Species of National Environmental Significance Database (BA subset - RESTRICTED - Metadata only). Bioregional Assessment Derived Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/7276dd93-cc8c-4c01-8df0-cef743c72112.

Dataset 12 Department of Primary Industries (2004) Estuarine Macrophytes of Hunter Subregion NSW DPI Hunter 2004. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/fb7bf5a0-f0e3-429b-9b54-0d4b58fb49c2.

Dataset 13 NSW Department of Environment, Climate Change and Water (DECCW) (2010) Travelling Stock Route Conservation Values. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/198900d5-0d06-4bd0-832b-e30a7c4e8873.

Dataset 14 NSW Department of Environment, Climate Change and Water (DECCW) (2012) Native Vegetation Management (NVM) - Manage Benefits. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/b299e256-1d37-4f89-8c51-93567ebf3753.

Dataset 15 NSW Department of Environment, Climate Change and Water (DECCW) (2010) Threatened migratory shorebird habitat mapping DECCW May 2006. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/cc0b62a0-ded7-4c14-b954-1552337b395e.

Dataset 16 Office of Environment and Heritage, Department of Premier and Cabinet (2013) Spatial Threatened Species and Communities (TESC) NSW 20131129. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/a6664894-1489-46d1-a6ca-16f9ab519a28.

Dataset 17 Office of Environment and Heritage (OEH) (2015) Atlas of Living Australia NSW ALA Portal 20140613. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/cb420b33-b828-40fe-a844-7fdbe828d4d6.

Dataset 18 Office of Environment and Heritage (OEH) (2015) Cumberland Subregion BIO Map Core Areas 20150804. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/14bda271-f0e8-4bfb-91dd-865f8b311d29.

Dataset 19 Office of Environment and Heritage (OEH) (2015) Cumberland Subregion BIO Map Biodiversity Corridors of Regional Significance 20150804. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/223e1f69-2da8-40e3-bdb5-433df6de650c.

Dataset 20 Office of Environment and Heritage (OEH) (2015) Illawarra Region BIO Map - Core Areas 20150430. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/523facf7-eacd-42b8-92b3-a01a842b9b75.

Dataset 21 Office of Environment and Heritage (OEH) (2015) Illawarra Region BIO Map Corridors 20150430. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/edd25bee-de70-47ba-a3af-b6f08846fdfa.

Dataset 22 Office of Environment and Heritage (OEH) (2015) Map of Critically Endangered Ecological Communities NSW Version 3 20150925. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/cd7fdee5-1dec-4778-91f7-ddd43eabe8dc.

Dataset 23 Department of Primary Industries, NSW Trade and Investment (2015) Fitzroy Falls Spiny Crayfish NSW DPI Fisheries 20150316. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/fe9241ad-79d6-43bb-922b-cb2fe86fff68.

Dataset 24 Department of Primary Industries, NSW Trade and Investment (2015) Macquarie Perch NSW DPI Fisheries 20150313. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/cd5b1500-f56b-47b0-beff-5f3349493054.

Dataset 25 Department of Primary Industries, NSW Trade and Investment (2015) Purple Spotted Gudgeon NSW DPI Fisheries 20150317. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/8e6e7bce-fce0-4dd0-b5ec-dcf513cf2213.

Dataset 26 NSW Department of Environment, Climate Change and Water (DECCW) (2010) An Estuarine Inventory for New South Wales, Australia VIS_ID 2224 20100723. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/e7d763eb-d6b8-480a-8d9e-3d6e9e0b9bc1.

Dataset 27 NSW Office of Water (2013) NSW Office of Water identified GDEs. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/b6df5934-c978-471c-83a0-c55b5031f79b.

Dataset 28 NSW Department of Environment, Climate Change and Water (DECCW) (2010) Southeast NSW Native Vegetation Classification and Mapping - SCIVI VIS_ID 2230 20030101. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/0f1aeb33-1b49-4839-88fa-8b635cf9d3ab.

Dataset 29 Office of Environment and Heritage (OEH) (2009) NSW Wild Rivers Office of Environment and Heritage (OEH) 20091001. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/817b89f1-36dd-4725-b849-d60fb45d6f31.

Dataset 30 Office of Environment and Heritage (OEH) (2015) Old Growth Forest Mapping Broad, Central, 1996. VIS_ID 4122 2015 20150116. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/85a296b9-0c03-4dec-a0c1-cb22debbdbd1.

Dataset 31 Department of Planning and Infrastructure (2006) State Environmental Planning Policy no. 14 - Coastal Wetlands 19891027. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/d2ec27ef-026b-4cb8-ad12-bd1d638240d0.

Dataset 32 Department of Planning and Infrastructure (1988) State Environmental Planning Policy no. 26 - Littoral Rainforest 19860101. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/c6c20dcc-8f14-44b5-a018-b8865c4193e5.

Dataset 33 Bureau of Meteorology, Water Division, Water Data Services (2011) Geofabric Surface Network - V2.1. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/ed3acf9b-888c-4d53-b376-ecab89781651.

Dataset 34 Bioregional Assessment Programme (2015) GW Economic Elements Sydney Basin 20150730. Bioregional Assessment Derived Dataset. Viewed 04 February 2016, http://data.bioregionalassessments.gov.au/dataset/59c19a78-ee89-4555-a57d-d57bc3c80c28.

Dataset 35 NSW Office of Water (2013) NSW Office of Water combined geodatabase of regulated rivers and water sharing plan regions. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/24157c41-c42f-4e1f-a791-a1ad18c8215d.

Dataset 36 Bureau of Meteorology (2015) National Groundwater Management Zones BOM 20150730. Bioregional Assessment Source Dataset. Viewed 30 March 2016, http://data.bioregionalassessments.gov.au/dataset/1004e325-f94b-44f5-89e2-9402e8f4ad67.

Dataset 37 Australian Government Department of the Environment (2012) Sydney Catchment Authority Water Licences and Approvals Package May 2012. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/a3da31b4-1fca-4d55-addb-05d295c31427.

Dataset 38 CSIRO (2010) Identification of Culturally Significant Groundwater Dependent Ecosystems CSIRO 2010. Bioregional Assessment Source Dataset. Viewed 05 February 2016, http://data.bioregionalassessments.gov.au/dataset/4d0bc9d9-7675-4e57-b0fd-750b323fde95.

Dataset 39 Australian Government Department of the Environment (2013) Australia World Heritage Areas. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/4927789b-7ba7-4a77-b6fc-be1b29b6590c.

Dataset 40 Australian Government Department of the Environment (2014) National Heritage List Spatial Database (NHL) (v2.1). Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/26daa8d7-a90e-47f3-982b-0df362414e65.

Dataset 41 Australian Government Department of the Environment (2014) Commonwealth Heritage List Spatial Database (CHL). Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/57720684-4948-45db-a2c8-37259d531d87.

Dataset 42 Australian Government Department of the Environment (2014) Australia, Register of the National Estate (RNE) - Spatial Database (RNESDB) Internal. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/878f6780-be97-469b-8517-54bd12a407d0.

Dataset 43 Geoscience Australia (2015) Operating Mines OzMin Geoscience Australia National 20150201. Bioregional Assessment Source Dataset. Viewed 03 February 2016, http://data.bioregionalassessments.gov.au/dataset/65c0c042-1ba8-47a8-9793-4363672500b9.

Dataset 44 NSW Trade and Investment (2014) NSW Petroleum Boreholes 20140815. Bioregional Assessment Source Dataset. Viewed 03 February 2016, http://data.bioregionalassessments.gov.au/dataset/7629e8db-b01e-4d6e-b926-a4df07e7eebc.

Dataset 45 DTIRIS (2011) NSW Coalfield boundaries. Bioregional Assessment Source Dataset. Viewed 14 April 2016, http://data.bioregionalassessments.gov.au/dataset/c93d9cbc-22f9-459d-a2d8-e530332393b0.

Dataset 46 Bioregional Assessment Programme (2015) SSB Preliminary Assessment Extent inputs v01. Bioregional Assessment Derived Dataset. Viewed 14 April 2016, http://data.bioregionalassessments.gov.au/dataset/dd30b80e-68da-4fc8-8df7-c126909a2f1a.

Dataset 47 Bioregional Assessment Programme (2016) SSB Landsat processed data v01. Bioregional Assessment Derived Dataset. Viewed 30 March 2016, http://data.bioregionalassessments.gov.au/dataset/46e9abad-16c3-448c-b34d-c25dba10c694.

Dataset 48 Bioregional Assessment Programme (2015) Mean annual climate data clipped to BA_SYD extent. Bioregional Assessment Derived Dataset. Viewed 03 February 2016, http://data.bioregionalassessments.gov.au/dataset/a8393a45-5e86-431b-b504-c0b2953296f4.

Dataset 49 CSIRO (2015) AUS Budyko Runoff 1982 to 2010 v01. Bioregional Assessment Source Dataset. Viewed 03 February 2016, http://data.bioregionalassessments.gov.au/dataset/6e2d4bb1-6902-4243-8be4-eb72dbabcb1b.

Dataset 50 Bioregional Assessment Programme (2015) AUST Choudhury runoff derived annual flow v01. Bioregional Assessment Derived Dataset. Viewed 11 February 2016, http://data.bioregionalassessments.gov.au/dataset/afd66e9f-afca-4008-986b-ba9b06b47e57.

Dataset 51 Geoscience Australia (2011) Geoscience Australia, 1 second SRTM Digital Elevation Model (DEM). Bioregional Assessment Source Dataset. Viewed 03 February 2016, http://data.bioregionalassessments.gov.au/dataset/9a9284b6-eb45-4a13-97d0-91bf25f1187b.

Dataset 52 CSIRO (2016) AUS SRTM 1sec MRVBF mosaic v01. Bioregional Assessment Source Dataset. Viewed 30 March 2016, http://data.bioregionalassessments.gov.au/dataset/79975b4a-1204-4ab1-b02b-0c6fbbbbbcb5.

Dataset 53 Bioregional Assessment Programme (2015) SYD Preliminary Assessment Extent v01. Bioregional Assessment Derived Dataset. Viewed 03 February 2016, http://data.bioregionalassessments.gov.au/dataset/11c2a9c7-aabc-410f-ae4a-1b3305423fab.

1.3.2 Ecological assets

Summary

Of the 1148 ecological assets listed in the asset database for the Sydney Basin bioregion, 751 were deemed to be water dependent for the purposes of the Assessment. The asset list contains 961 assets in the ‘Vegetation’ subgroup, 34 in the ‘Groundwater feature (subsurface)’ subgroup and 153 in the ‘Surface water feature’ subgroup. All assets in the ‘Groundwater feature (subsurface)’ and ‘Surface water feature’ subgroups are water dependent. Of the 961 assets in the ‘Vegetation’ subgroup, 564 assets are water dependent; these assets comprise 200 in the ‘Groundwater-dependent ecosystem’ class and 364 in the ‘Habitat (potential species distribution)’ class.

1.3.2.1 Description

The total number of ecological assets in the asset database for the Sydney Basin bioregion is 1148 (Table 19) (Bioregional Assessment Programme, Dataset 1). These ecological assets fall within three broad subgroups – ‘Groundwater feature (subsurface)’, ‘Surface water feature’ or ‘Vegetation’ – and seven asset classes that are based on the type of water-dependent system within the subgroup (Table 19).

As described in Section 1.3.1.4, all landscape features such as aquifers, rivers, lagoons, lakes, springs and wetlands, and the habitats dependent on them, are inherently water dependent; hence, all assets in the subgroups ‘Surface water feature’ and ‘Groundwater feature (subsurface)’ are included in the water-dependent asset register. Selected ‘Surface water feature’ assets are illustrated in Figure 16 and Figure 17 and ‘Groundwater feature (subsurface)’ assets are illustrated in Figure 18.

Of the 961 assets in the ‘Vegetation’ subgroup, 477 assets are groundwater-dependent ecosystems (GDEs) (Figure 19) derived from the *National atlas of groundwater-dependent ecosystems* (GDE Atlas) (Bioregional Assessment Programme, Dataset 2). Of these, 14 are wetlands and 64 are rivers or creeks, which are by definition water dependent, and are classified as surface GDEs. Many of these are duplicates of assets within the ‘Surface water feature’ subgroup (e.g. Lake Illawarra). Of 397 ‘Vegetation’ assets classified as subsurface GDEs, 120 were included in the water-dependent asset register because they were identified as either ‘known GDEs’ or having a high probability of being a GDE. A further two known GDEs were supplied as assets by the NSW Office of Water based on occurrence of karst features (NSW Office of Water, Dataset 3). All 80 GDEs in the 'Vegetation’ subgroup classified as surface GDEs were determined to be water dependent.

The remaining 484 assets in the ‘Vegetation’ subgroup are classified as ‘Habitat (potential species distribution)’ and were derived from many sources (see Section 1.3.1). Of these, 364 were judged to be water dependent. Based on spatial overlap with other water-dependent landscape features, 24 of the 27 assets from the Collaborative Australian Protected Area Database (CAPAD) (Department of the Environment, Dataset 4) were judged to be water dependent, along with all Important Bird Areas (Birds Australia, Dataset 5) and all but one of the assets derived from NSW

Office of Environment and Heritage (Dataset 6, Dataset 7, Dataset 8, Dataset 9, Dataset 11 and Dataset 15), NSW Department of Environment, Climate Change and Water (Dataset 10, Dataset 12, Dataset 14), and NSW Department of Planning and Infrastructure (Dataset 13). Selected assets are presented in Figure 20.

Four of the threatened ecological communities listed under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (Department of the Environment, Dataset 16) were judged to be water dependent, including the 'Temperate Highland Peat Swamps on Sandstone Threatened Ecological Community'. Of the 144 EPBC Act-listed species, 105 were judged to be water dependent based on their profiles in the Species Profiles and Threats Database (SPRAT) (Bioregional Assessment Programme, Dataset 17) and the NSW BioNet website (OEH, 2016). This included all fish (including sharks), turtles and frogs, 1 of 3 other reptiles (in addition to turtles), 50 of 51 birds, 6 of 8 mammals and 33 of 66 plants. The platypus was also included as a water-dependent asset. Because of the large number of these assets and their overlap, they are not presented in map form.

Of the 43 vegetation communities listed under NSW's *Threatened Species Conservation Act 1995* (TSC Act) (NSW Office of Environment and Heritage, Dataset 18), 21 were judged to be water dependent; of the 202 TSC Act-listed species, 151 were judged to be water dependent. Spatial layers for these assets were not available as of February 2016.

The three protected fish species (NSW Department of Primary Industries, Dataset 19, Dataset 20; Murray-Darling Basin Authority, Dataset 21) are clearly water dependent.

Table 19 Total ecological assets and water-dependent ecological assets in the preliminary assessment extent (PAE) of the Sydney Basin bioregion

Subgroup	Asset class	Total assets (asset list)	In water-dependent asset register
Groundwater feature (subsurface)	Aquifer, geological feature, alluvium or stratum	34	34
	Groundwater feature (subsurface) total	**34**	**34**
Surface water feature	River or stream reach, tributary, anabranch or bend	76	76
	Lake, reservoir, lagoon or estuary	53	53
	Wetland, wetland complex or swamp	16	16
	Floodplain	8	8
	Surface water feature total	**153**	**153**
Vegetation	Groundwater-dependent ecosystem	477	200
	Habitat (potential species distribution)	484	364
	Vegetation total	**961**	**564**
Total		**1148**	**751**

Data: Bioregional Assessment Programme (Dataset 1)

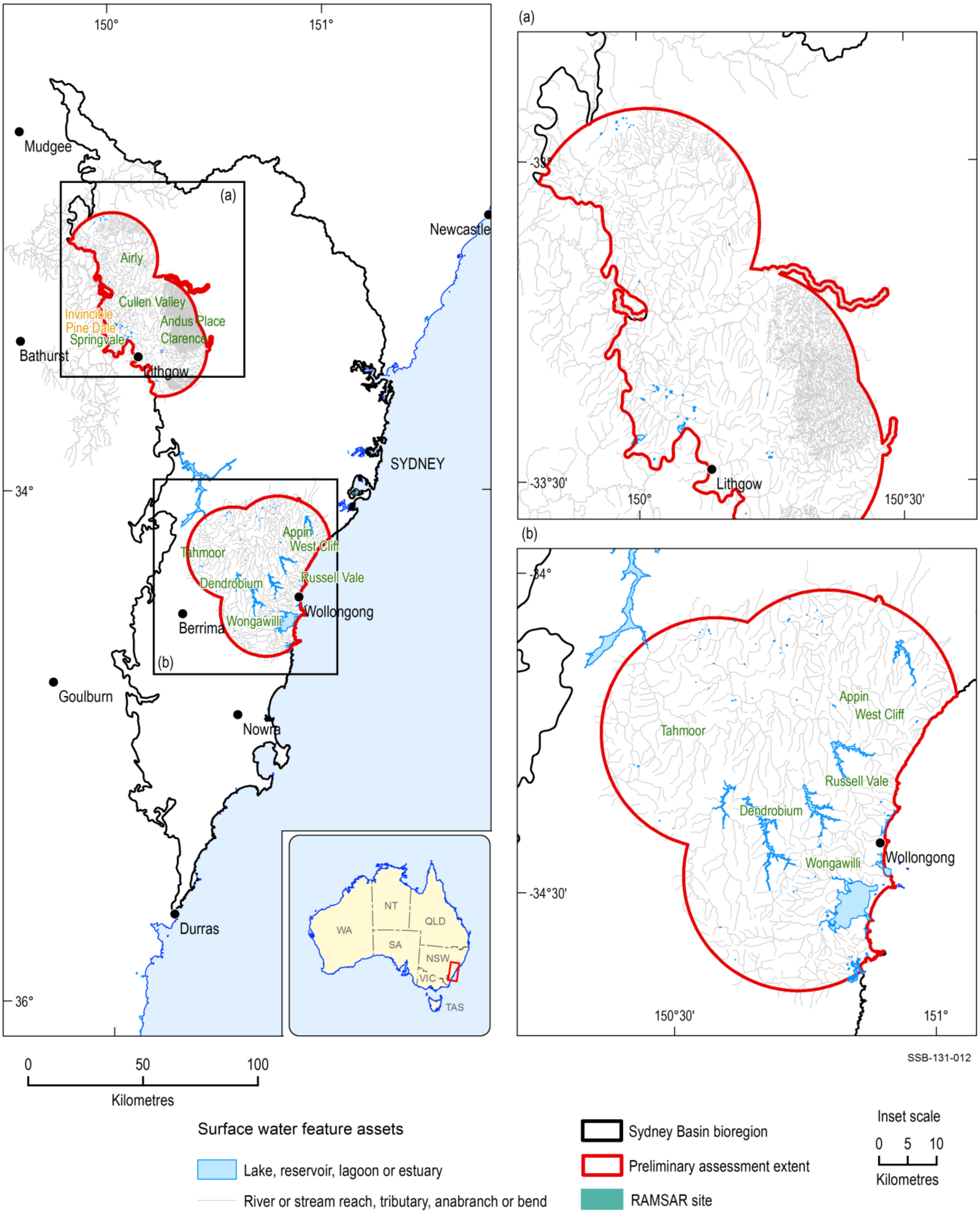

Figure 16 Selected ecological assets in the 'Surface water feature' subgroup in the 'River or stream reach, tributary, anabranch or bend' and 'Lake, reservoir, lagoon or estuary' asset classes of the Sydney Basin bioregion

Data: Bioregional Assessment Programme (Dataset 1)

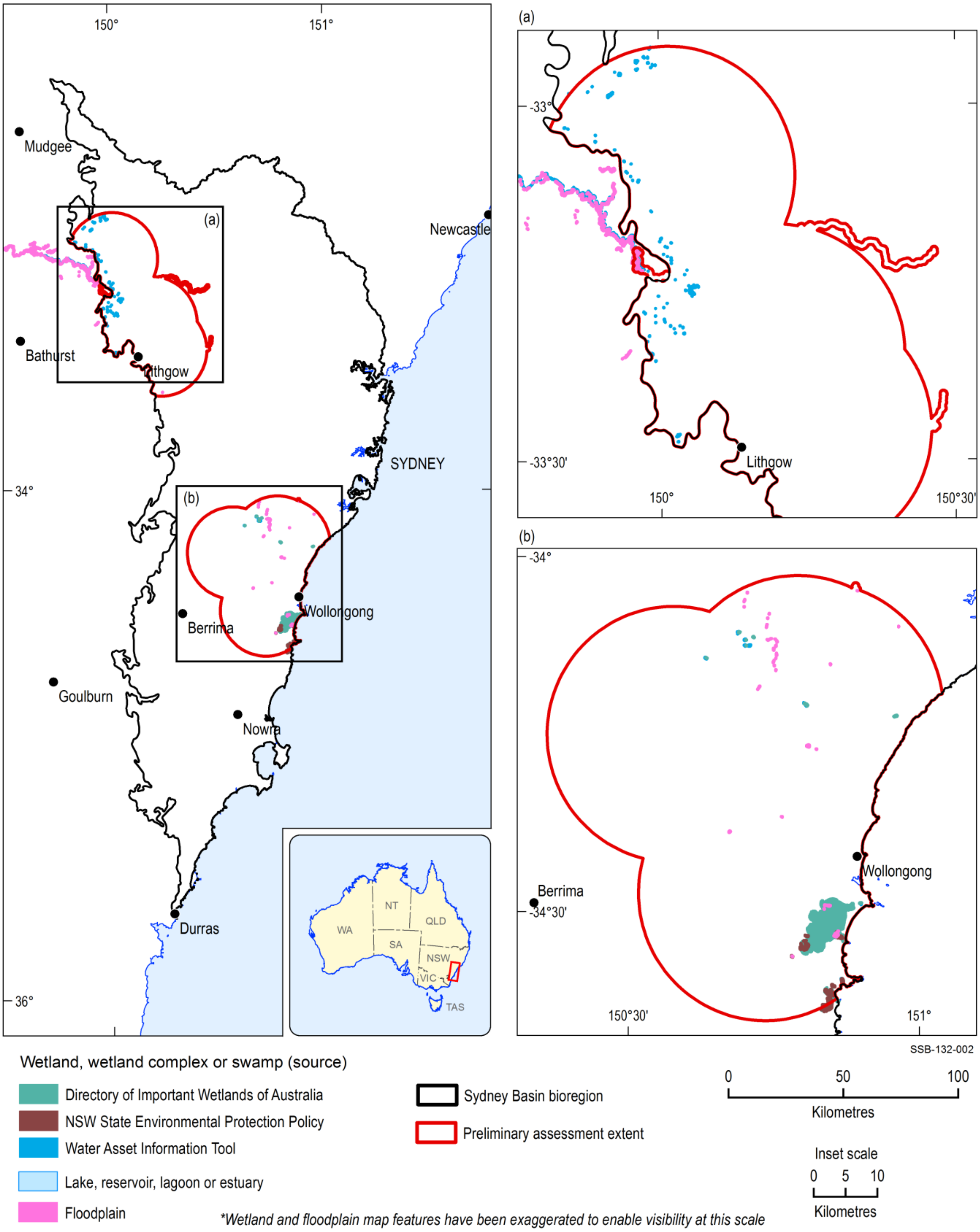

Figure 17 Selected ecological assets in the 'Surface water feature' subgroup in the 'Wetland, wetland complex or swamp' and 'Floodplain' asset classes of the Sydney Basin bioregion

Data: Bioregional Assessment Programme (Dataset 1)

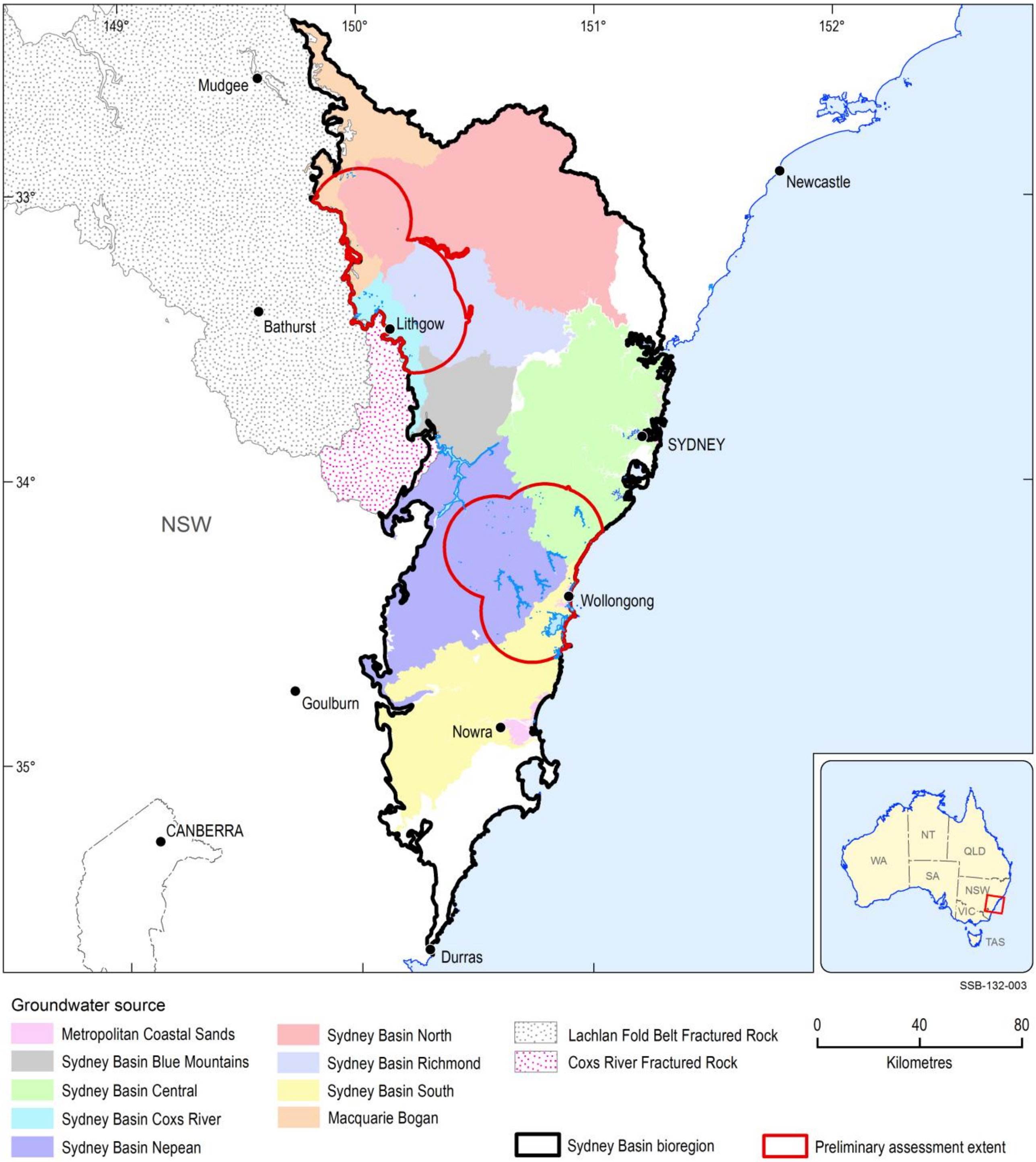

Figure 18 Selected ecological assets in the 'Aquifer, geological feature, alluvium or stratum' asset class of the Sydney Basin bioregion

Data: Bioregional Assessment Programme (Dataset 1)

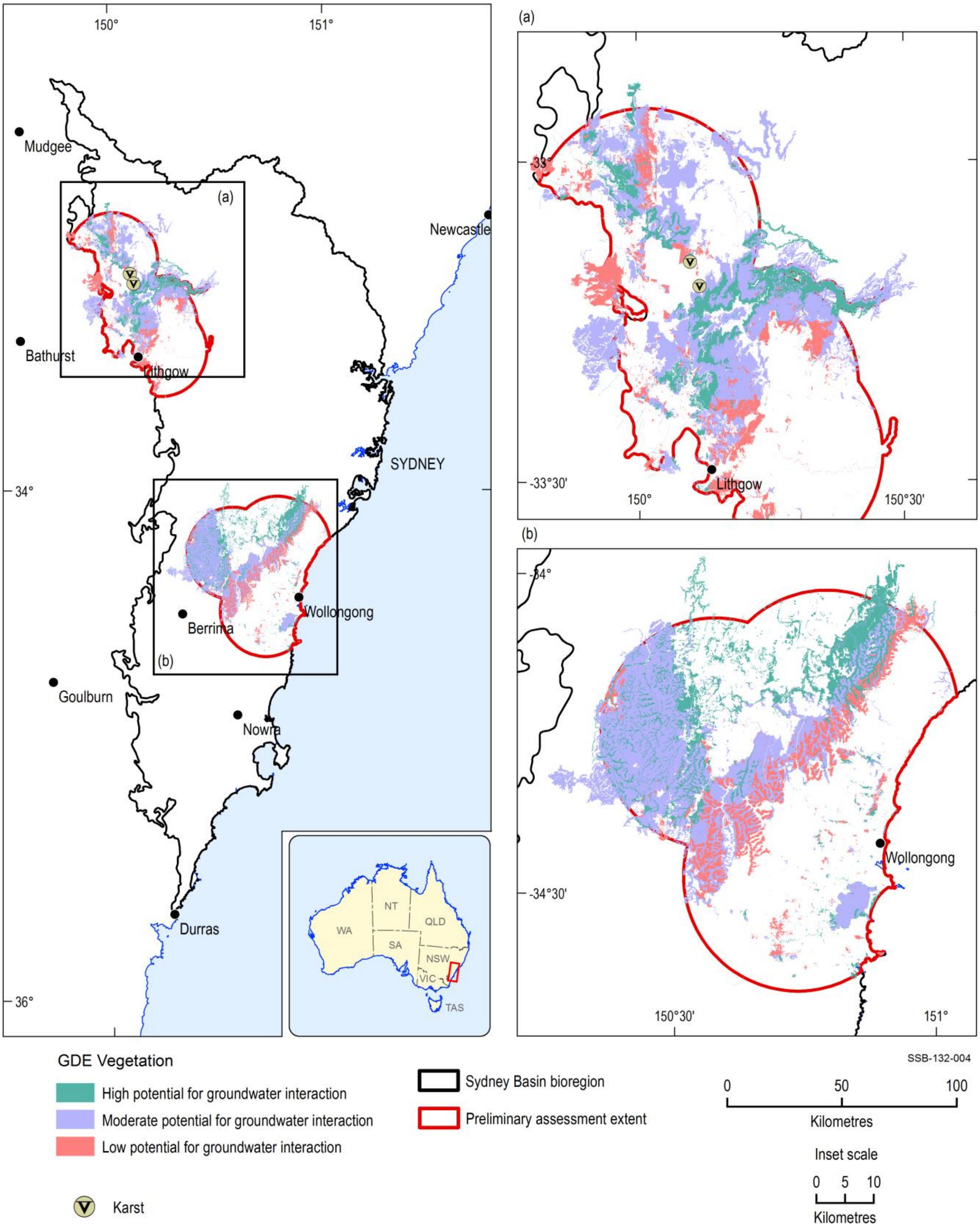

Figure 19 Ecological assets in the 'Vegetation' subgroup in the 'Groundwater-dependent ecosystem' asset class of the Sydney Basin bioregion for (a) Lithgow and (b) Wollongong

GDE = groundwater-dependent ecosystem
Data: Bioregional Assessment Programme (Dataset 1)

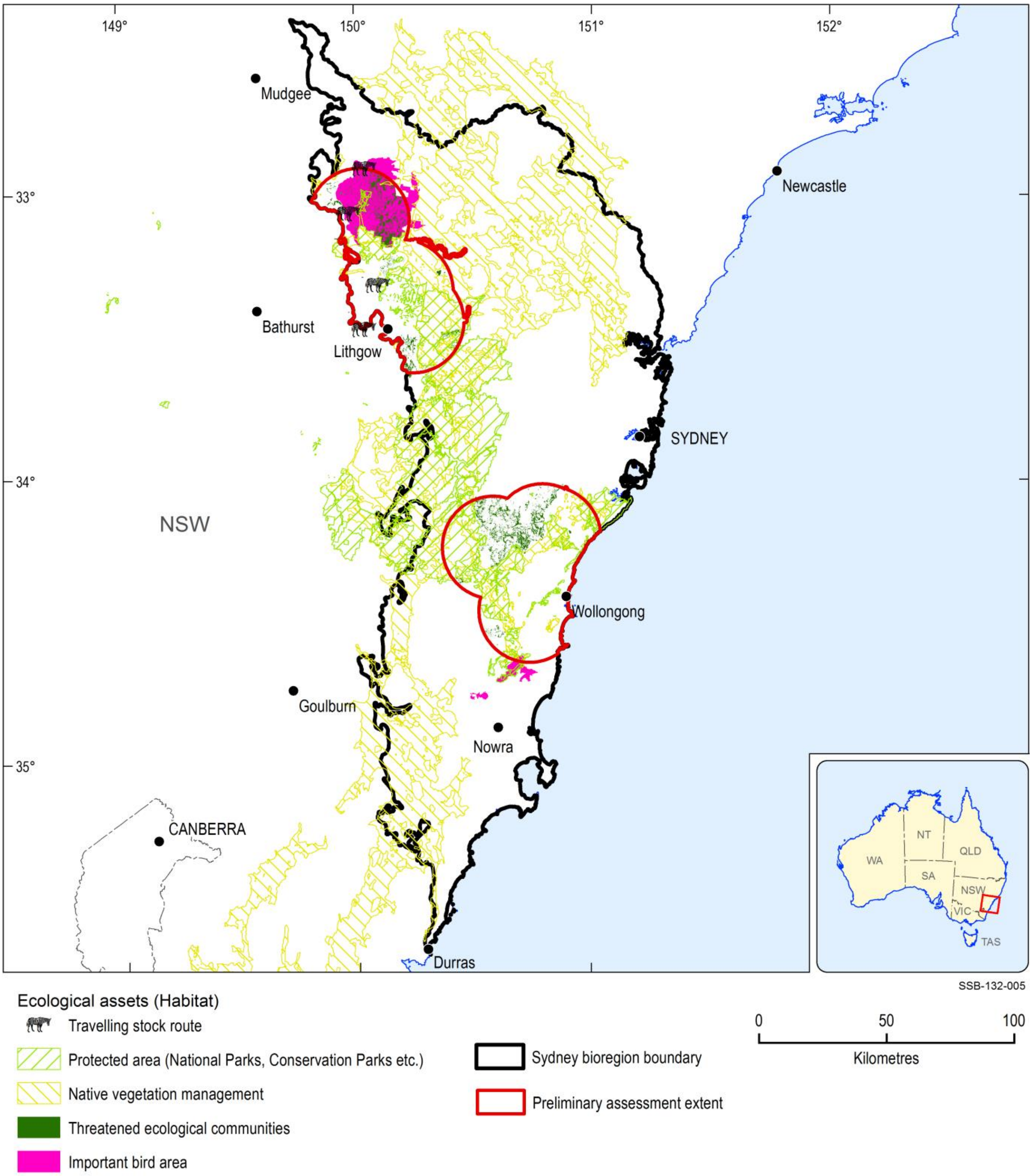

Figure 20 Selected ecological assets in the 'Vegetation' subgroup in the 'Habitat (potential species distribution)' asset class of the Sydney Basin bioregion

Data: Bioregional Assessment Programme (Dataset 1)

1.3.2.2 Gaps

The asset list attempts to present a comprehensive list of assets that are recognised as having ecological value. However, habitat mapping of individual species is sometimes lacking and often imperfect, and not all water-dependent species that might be considered assets are necessarily included in the asset list. Even though habitat mapping of individual species may sometimes be lacking or imperfect, their habitats are represented in the BA in the form of habitat mapping for a wide range of other species with similar habitat requirements.

References

OEH (2016) NSW BioNet. NSW Office of Environment and Heritage. Viewed 11 February 2016, http://www.bionet.nsw.gov.au/.

Datasets

Dataset 1 Bioregional Assessment Programme (2016) Asset database for the Sydney Basin bioregion on 29 March 2016. Bioregional Assessment Derived Dataset. Viewed 29 March 2016, http://data.bioregionalassessments.gov.au/dataset/ae283994-5f14-4442-af0d-8f8c81eb657e.

Dataset 2 Bioregional Assessment Programme (2012) National Groundwater Dependent Ecosystems (GDE) Atlas. Bioregional Assessment Derived Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/e358e0c8-7b83-4179-b321-3b4b70df857d.

Dataset 3 NSW Office of Water (2013) NSW Office of Water identified GDEs. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/b6df5934-c978-471c-83a0-c55b5031f79b.

Dataset 4 Department of the Environment (2010) Collaborative Australian Protected Areas Database (CAPAD) 2010 (Not current release). Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/7b649c6d-fdbf-40e3-b002-db521665af53.

Dataset 5 Birds Australia (2009) Birds Australia - Important Bird Areas (IBA) 2009. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/5d488350-83b6-4e71-8d17-687ad8ff9941.

Dataset 6 NSW Office of Environment and Heritage (2015) Cumberland Subregion BIO Map Core Areas 20150804. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/14bda271-f0e8-4bfb-91dd-865f8b311d29.

Dataset 7 NSW Office of Environment and Heritage (2015) Cumberland Subregion BIO Map Biodiversity Corridors of Regional Significance 20150804. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/223e1f69-2da8-40e3-bdb5-433df6de650c.

Dataset 8 NSW Office of Environment and Heritage (2015) Illawarra Region BIO Map - Core Areas 20150430. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/523facf7-eacd-42b8-92b3-a01a842b9b75.

Dataset 9 NSW Office of Environment and Heritage (2015) Illawarra Region BIO Map Corridors 20150430. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/edd25bee-de70-47ba-a3af-b6f08846fdfa.

Dataset 10 NSW Department of Environment, Climate Change and Water (2012) Native Vegetation Management (NVM) - Manage Benefits. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/b299e256-1d37-4f89-8c51-93567ebf3753.

Dataset 11 NSW Office of Environment and Heritage (2015) Old Growth Forest Mapping Broad, Central, 1996. VIS_ID 4122 2015 20150116. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/85a296b9-0c03-4dec-a0c1-cb22debbdbd1.

Dataset 12 NSW Department of Environment, Climate Change and Water (2010) Southeast NSW Native Vegetation Classification and Mapping - SCIVI VIS_ID 2230 20030101. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/0f1aeb33-1b49-4839-88fa-8b635cf9d3ab.

Dataset 13 NSW Department of Planning and Infrastructure (1988) State Environmental Planning Policy no. 26 - Littoral Rainforest 19860101. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/c6c20dcc-8f14-44b5-a018-b8865c4193e5.

Dataset 14 NSW Department of Environment, Climate Change and Water (2010) Travelling Stock Route Conservation Values. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/198900d5-0d06-4bd0-832b-e30a7c4e8873.

Dataset 15 NSW Office of Environment and Heritage (2015) Map of Critically Endangered Ecological Communities NSW Version 3 20150925. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/cd7fdee5-1dec-4778-91f7-ddd43eabe8dc.

Dataset 16 Department of the Environment (2015) Communities of National Environmental Significance Database - RESTRICTED - Metadata only. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/c01c4693-0a51-4dbc-bbbd-7a07952aa5f6.

Dataset 17 Bioregional Assessment Programme (2013) Species Profile and Threats Database (SPRAT) - Australia - Species of National Environmental Significance Database (BA subset - RESTRICTED - Metadata only). Bioregional Assessment Derived Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/7276dd93-cc8c-4c01-8df0-cef743c72112.

Dataset 18 NSW Office of Environment and Heritage (2013) Spatial Threatened Species and Communities (TESC) NSW 20131129. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/a6664894-1489-46d1-a6ca-16f9ab519a28.

Dataset 19 NSW Department of Primary Industries (2015) Macquarie Perch NSW DPI Fisheries 20150313. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/cd5b1500-f56b-47b0-beff-5f3349493054.

Dataset 20 NSW Department of Primary Industries (2015) Purple Spotted Gudgeon NSW DPI Fisheries 20150317. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/8e6e7bce-fce0-4dd0-b5ec-dcf513cf2213.

Dataset 21 Murray-Darling Basin Authority (2010) Key Environmental Assets - KEA - of the Murray Darling Basin RESTRICTED (Metadata only). Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/9948195e-3d3b-49dc-96d2-ea7765297308.

1.3.3 Economic assets

Summary

The water-dependent asset register for the Sydney Basin bioregion has 61 economic assets, of which 29 are classed as surface water economic assets and 32 as groundwater economic assets.

These assets represent groupings of surface water and groundwater economic elements, including water access licences, basic water rights, water source areas, water supply infrastructure and the regulated river.

1.3.3.1 Description

The total number of economic assets in the water-dependent asset register for the preliminary assessment extent (PAE) of the Sydney Basin bioregion is 61, of which 29 are surface water assets and 32 groundwater assets. All of these are, by their very nature, water dependent.

The economic assets represent groupings of economic elements. Economic elements include water access licences, basic rights to take water (both referred to as water access entitlements), water source areas and water supply infrastructure, which are represented spatially by:

- location of surface water offtake points and groundwater bores (represented as point features)
- water source areas identified within water sharing plans (WSPs) which intersect the PAE (represented as polygon features)
- water supply and monitoring infrastructure (represented as point features).

All economic elements, assets and total share component data were sourced from DPI Water (formerly the NSW Office of Water) including:

- an extract from the Water Licensing System and Surface and Groundwater Approved Work Locations database (Bioregional Assessment Programme, Dataset 1; NSW Office of Water, Dataset 2)
- NSW Water Sharing Plans (NSW Office of Water, Dataset 3, Dataset 4).

Every water access right (licensed entitlement) and basic water right (statutory entitlement) is an element. DPI Water classifies water access entitlements by 'purpose', which records the intended use of that water. Bores that are classified as exploratory or monitoring bores and which generally do not have water access rights associated with them are not included in the asset register. In all, 1995 monitoring groundwater bores were excluded from the water-dependent asset register (Bioregional Assessment Programme, Dataset 5). A number of bores have high-security licences, reflecting their importance for meeting basic community needs; four bores are classified as being for recreation and irrigation. Most other entitlements have a general security classification, which means they are at greater risk of allocation cuts when resource availability is low, such as in times of drought.

In the Sydney Basin PAE, there are 3999 economic elements, of which 627 pertain to surface water resources and 3372 to groundwater resources. Most of these are water access entitlements; eleven are groundwater source areas and seven are surface water source areas, which are contained within or intersect the PAE; ten are water supply dams. Table 20 summarises the breakdown of assets in the water-dependent asset register. Elements have been grouped by type (water access right or basic water right) and spatial location (water source area) to create assets. Not all water sources have both water access and basic water rights extraction points within the PAE.

The PAE for the Sydney Basin bioregion intersects three WSP areas related to surface water resources: (i) the Greater Metropolitan Region Unregulated River Water Sources; (ii) the Kangaroo River Water Source; and (iii) the Macquarie Bogan Unregulated and Alluvial Water Sources. WSPs specify the water sources to which they pertain and can include rivers, aquifers and lakes. Not all the water source areas within these WSP areas intersect the Sydney Basin PAE. Using basic geographic information system (GIS) analysis tools, seven water source areas were found to intersect the PAE and have been included in the asset list for the Sydney Basin bioregion (Bioregional Assessment Programme, Dataset 5). The Greater Metropolitan Region Unregulated River Water Sources plan area is the largest planning area and contains six water source areas, four of which intersect the PAE. The extents of the seven surface water sources in the water-dependent asset register are shown in Figure 21. These seven water source areas were used to group economic elements within the PAE into assets.

Table 20 Summary of the economic assets within the preliminary assessment extent (PAE) of the Sydney Basin bioregion

Subgroup	Class	Total assets (asset list)	Assets in water-dependent asset register
Groundwater management zone or area (surface area)	A groundwater feature used for water supply (groundwater source)	11	11
	Water supply and monitoring infrastructure	0	0
	Water access right	10	10
	Basic water right (stock and domestic)	11	11
	Groundwater total	**32**	**32**
Surface water management zone or area (surface area)	A surface water feature used for water supply (water source)	7	7
	Water supply and monitoring infrastructure	10	10
	Water access right	7	7
	Basic water right (stock and domestic)	5	5
	Surface water total	**29**	**29**
Total		**61**	**61**

Data: Bioregional Assessment Programme (Dataset 1); NSW Office of Water (Dataset 2, Dataset 3, Dataset 4). The asset database (Bioregional Assessment Programme, Dataset 5) is a collation of all these source datasets.

Most of the groundwater in the Sydney Basin bioregion is managed under NSW's *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011*. Other groundwater WSPs that cover parts of the bioregion are NSW's *Water Sharing Plan for the Murray Darling Basin Porous Rock Groundwater Sources 2011* and *Water Sharing Plan for the Murray Darling Basin Fractured Rock Groundwater Sources 2011*. WSPs for the Clyde River Unregulated and Alluvial Water Sources and South Coast Groundwater Sources have been drafted and put out for public exhibition. Their commencement is anticipated sometime after mid-2016 (NSW Department of Primary Industries, 2016). These plans will manage groundwater extracted from alluvial and coastal groundwater sources, parts of which fall within the Sydney Basin bioregion. These WSP areas do not intersect the PAE for the Sydney Basin bioregion.

The groundwater sources to which each WSP applies are specified in each plan. Eleven groundwater source areas were found to intersect the PAE for the Sydney Basin bioregion and are included in the asset list. Figure 22 shows the eleven groundwater sources in the water-dependent asset register (Bioregional Assessment Programme, Dataset 5). Groundwater water access rights have been grouped into assets on the basis of groundwater source areas and use.

The Sydney Basin bioregion WSPs are discussed more in Section 1.1.4.1 and Section 1.1.5.4 of companion product 1.1 for the Sydney Basin bioregion (Herron et al., 2018).

Table 21 shows the share components for the surface water and groundwater resources. Share components are a specified share or volume of water that can be extracted within a specified water management area within a water year. Total share components include basic landholder rights described in WSPs (DPI Water, 2015). For groundwater and surface water, total share components of basic water rights represent the total extraction limits defined under basic landholder rights described in the WSP. Not all the groundwater management areas and water source areas within these WSP areas are contained within the Sydney Basin PAE.

In the Sydney Basin PAE the surface water asset has been defined in terms of licensed water entitlements on issue, plus basic water rights, for surface water sources that significantly intersect (i.e. more than 1% of total water source area defined in the water sharing plan) the PAE. Thus the surface water asset pool is just over 730,000 ML/year, which includes 658,000 ML/year held by WaterNSW (formerly the Sydney Catchment Authority) to take water from upper Nepean and upstream Warragamba rivers, Hawkesbury and lower Nepean rivers and Southern Sydney rivers water sources for Sydney's water supply. These water source areas extend outside the PAE and the entitlements relate to the entire water source area, not just the area within the PAE. WaterNSW also holds an entitlement to 329,000 ML/year of water in the Shoalhaven River water source, which is not included in the 658,000 ML/year because this water source does not intersect the PAE significantly. Figure 21 shows the location of offtake points within the PAE for licence holders other than WaterNSW.

The Sydney Basin bioregion relies almost entirely on surface water sources to meet demand and development of groundwater resources has been minimal. Rights to use groundwater under a water access right or a basic water right have been estimated at 121,876 ML/year for the 11 water sources that intersect the PAE, although actual extractions are likely to be less than this. Figure 22 shows the location of bores within the PAE from where water is licensed to be extracted under a water access right or a basic water right. In defining the groundwater assets, these bores have been grouped by water source area and whether they relate to a water access right or basic water right. Thus all bores that are associated with a single groundwater source and related to a basic water right represent a single asset.

Table 21 Total share components for surface water and groundwater access entitlements within the preliminary assessment extent (PAE) of the Sydney Basin bioregion

Subgroup	Asset class	Total share component (ML/y)
Groundwater management zone or area (surface area)	Water access right	32,722
	Basic water right	89,154
	Groundwater total	**121,876**
Surface water management zone or area (surface area)	Water access right	706,148
	Basic water right	23,971
	Surface water total	**730,119**
Total		**851,995**

Data: NSW Office of Water (Dataset 2, Dataset 3, Dataset 4). The asset database (Bioregional Assessment Programme, Dataset 5) is a collation of these source datasets.

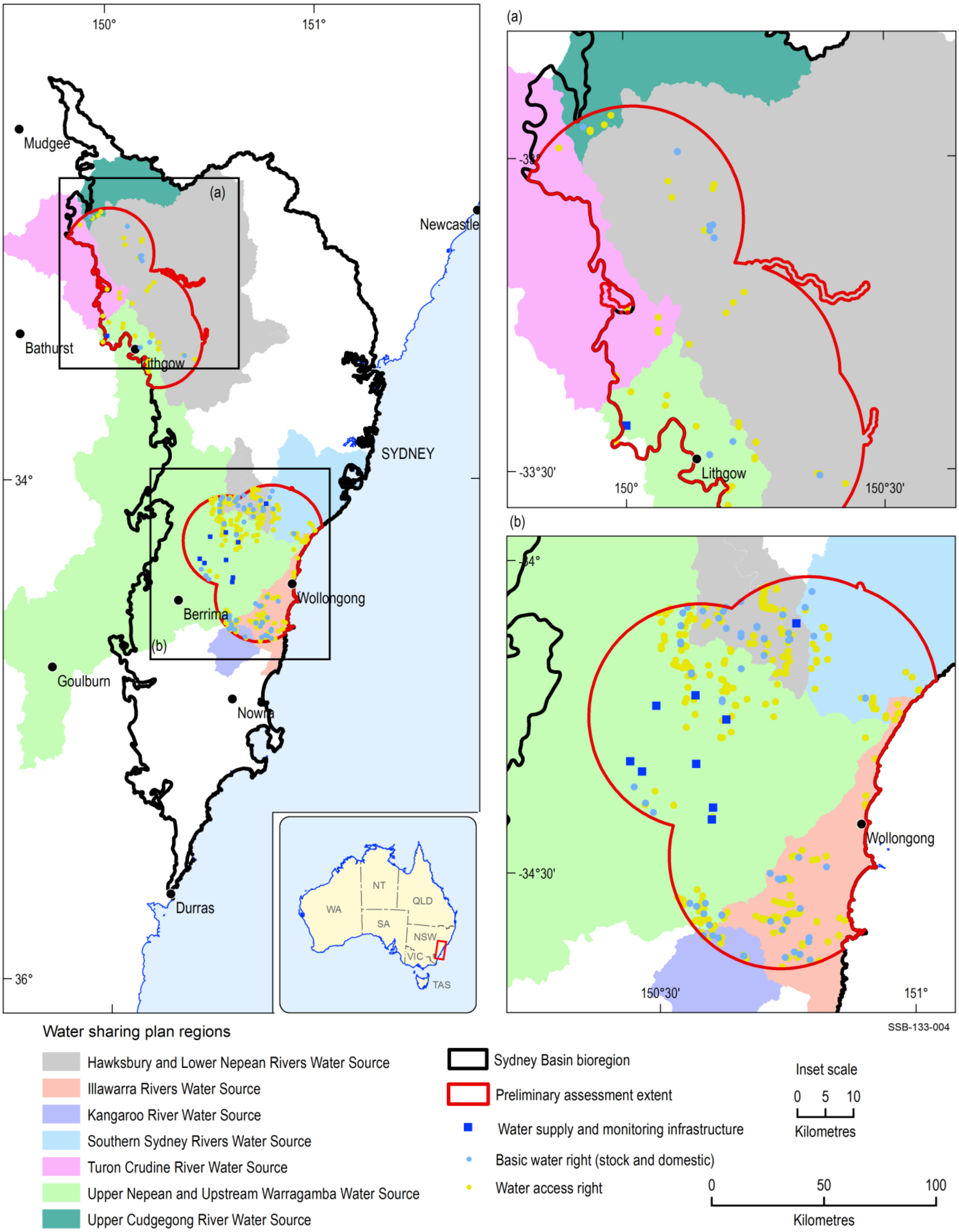

Figure 21 Location of surface water elements within the preliminary assessment extent (PAE) of the Sydney Basin bioregion

Data: NSW Office of Water (Dataset 3, Dataset 4)

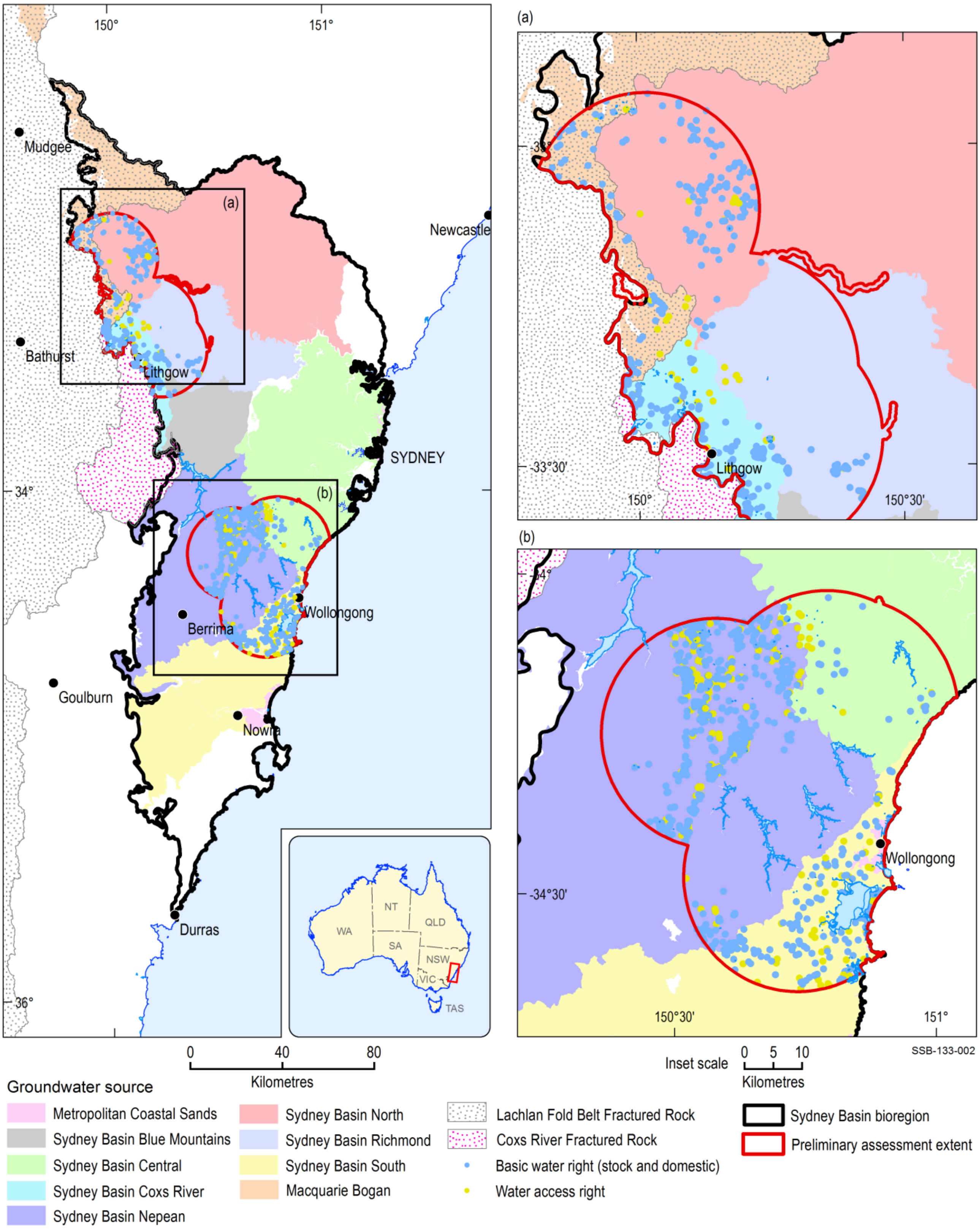

Figure 22 Location of groundwater elements within the preliminary assessment extent (PAE) of the Sydney Basin bioregion

Data: Bioregional Assessment Programme (Dataset 1); NSW Office of Water (Dataset 4)

1.3.3.2 Gaps

The volume of permissible take under a basic water right is not specified under NSW's *Water Act 1912* or *Water Management Act 2000* and volumes of take are generally not metered. Thus the basic water right volumes reported in Table 21 for groundwater and surface water are estimates that have been assumed in the WSPs for those water sources that intersect the PAE for the Sydney Basin bioregion. For estimating annual water use, DPI Water generally assumes an average annual volume of take of 2 ML/year per offtake point (Realica-Turner, *In prep.*).

References

DPI Water (2015) Water sharing plans website. Office of Water, NSW Department of Primary Industries. Viewed 11 November 2015, http://www.water.nsw.gov.au/Water-management/Water-sharing/default.aspx.

Herron NF, McVicar TR, Rohead-O'Brien H, Rojas R, Rachakonda PK, Zhang YQ, Dawes WR, Macfarlane CK, Pritchard J, Doody T, Marvanek SP and Li LT (2018) Context statement for the Sydney Basin bioregion. Product 1.1 from the Sydney Basin Bioregional Assessment. Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia. http://data.bioregionalassessments.gov.au/product/SSB/SSB/1.1.

NSW Department of Primary Industries (2016) Water Sharing Plans under development. New South Wales Department of Primary Industries, Office of Water. Viewed 04 February 2016, http://www.water.nsw.gov.au/Water-management/Water-sharing-plans/plans-on-exhibition/default.aspx.

Realica-Turner S (*In prep*.) Groundwater condition and monitoring report, Porous and fractured groundwater sources in the Hunter Valley. Department of Primary Industries Water, Sydney.

Datasets

Dataset 1 Bioregional Assessment Programme (2015) GW Economic Elements Sydney Basin 20150730. Bioregional Assessment Derived Dataset. Viewed 26 November 2015, http://data.bioregionalassessments.gov.au/dataset/59c19a78-ee89-4555-a57d-d57bc3c80c28.

Dataset 2 NSW Office of Water (2013) NSW Office of Water Surface Water Entitlements Locations v1_Oct2013. Bioregional Assessment Source Dataset. Viewed 26 June 2015, http://data.bioregionalassessments.gov.au/dataset/fc872710-998e-4c76-8b98-1df383c53de6.

Dataset 3 NSW Office of Water (2014) NSW Summary Basic Landholder Rights from Water Sharing Plans v1 20140618. Bioregional Assessment Source Dataset. Viewed 26 June 2015, http://data.bioregionalassessments.gov.au/dataset/d9e3fb05-e35f-4688-a619-495adf9a4a1b.

Dataset 4 NSW Office of Water (2013) NSW Office of Water - Groundwater Management Areas. Bioregional Assessment Source Dataset. Viewed 26 June 2015, http://data.bioregionalassessments.gov.au/dataset/41c28791-77d0-4d1d-b06b-8c9b579b9ab6.

Dataset 5 Bioregional Assessment Programme (2015) Asset database for the Sydney Basin bioregion on 29 March 2016. Bioregional Assessment Derived Dataset. Viewed 30 March 2016, http://data.bioregionalassessments.gov.au/dataset/ae283994-5f14-4442-af0d-8f8c81eb657e.

1.3.4 Sociocultural assets

Summary

The total number of sociocultural assets in the preliminary assessment extent (PAE) for the Sydney Basin bioregion is 251 of which 219 assets are in the 'Cultural' subgroup and 32 assets are in the 'Social' subgroup.

Of these, 190 assets were judged to be water dependent on the basis that they are located in the same area as other surface water or groundwater features. These are included in the water-dependent asset register for the Sydney Basin bioregion.

Where possible and appropriate, and with the agreement of Indigenous knowledge holders, any additional Indigenous water-related values will be published in a separate report.

1.3.4.1 Description

The total number of sociocultural assets identified in the PAE of the Sydney Basin bioregion is 251, of which 219 are classified in the 'Cultural' subgroup and 32 are classified in the 'Social' subgroup. Sources of data are summarised in Table 22. Most assets (243) are derived from the Register of the National Estate (Department of the Environment, Dataset 1). Two assets are Commonwealth heritage-listed (Department of the Environment, Dataset 2), three assets are National heritage-listed (Department of the Environment, Dataset 3) and one World heritage-listed asset (Department of the Environment, Dataset 4) – the Greater Blue Mountains Area World Heritage Area. Also included in the asset list are 25 Indigenous sociocultural assets sourced from Register of the National Estate (RNE; Department of the Environment, Dataset 1). An additional two Indigenous assets were identified from a report prepared by Moggridge (2010), which identified culturally significant groundwater-dependent ecosystems (GDEs) and reaches for the Hawkesbury-Nepean Catchment Management Authority (CSIRO, Dataset 5). Figure 23 and Figure 24 show the location of the cultural and social assets that intersect the PAE.

The total number of assets judged to be water dependent in the PAE of the Sydney Basin bioregion is 190 (Table 22). These are based on their proximity to surface water and/or groundwater features (Section 1.3.1.4). Details can be found in the water-dependent asset register for the Sydney Basin bioregion (Bioregional Assessment Programme, Dataset 6).

Table 22 Summary of sociocultural assets in the preliminary assessment extent (PAE) of the Sydney Basin bioregion

Group	Subgroup	Asset class	Total assets (asset list)	In water-dependent asset register
Sociocultural	Cultural	Heritage site	192	143
	Cultural	Indigenous site	27	23
	Cultural total		**219**	**166**
	Social	Recreation area	32	24
	Social total		**32**	**24**
Total			**251**	**190**

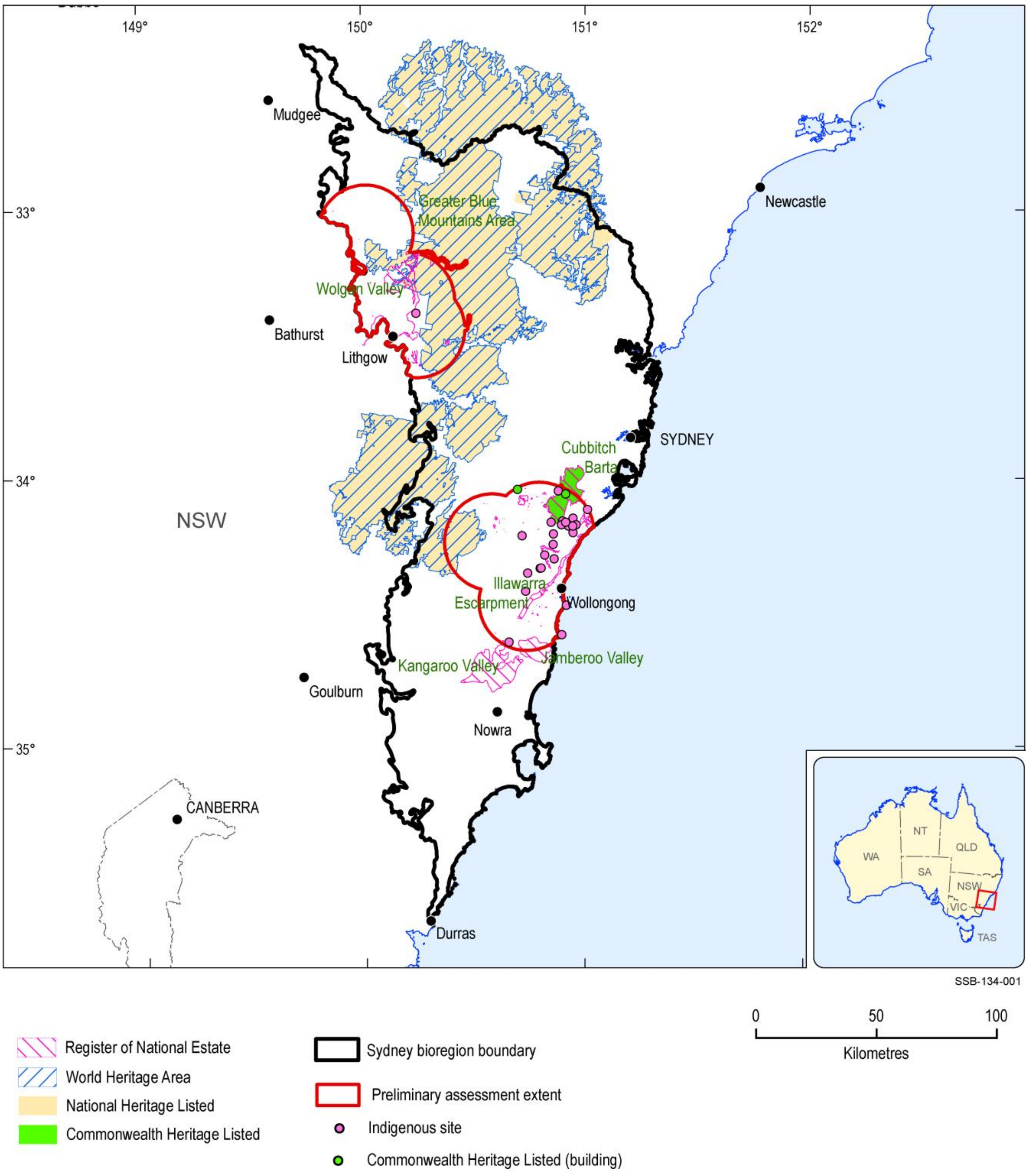

Figure 23 Water-dependent cultural assets of the Sydney Basin bioregion

Data: Bioregional Assessment Programme (Dataset 6)

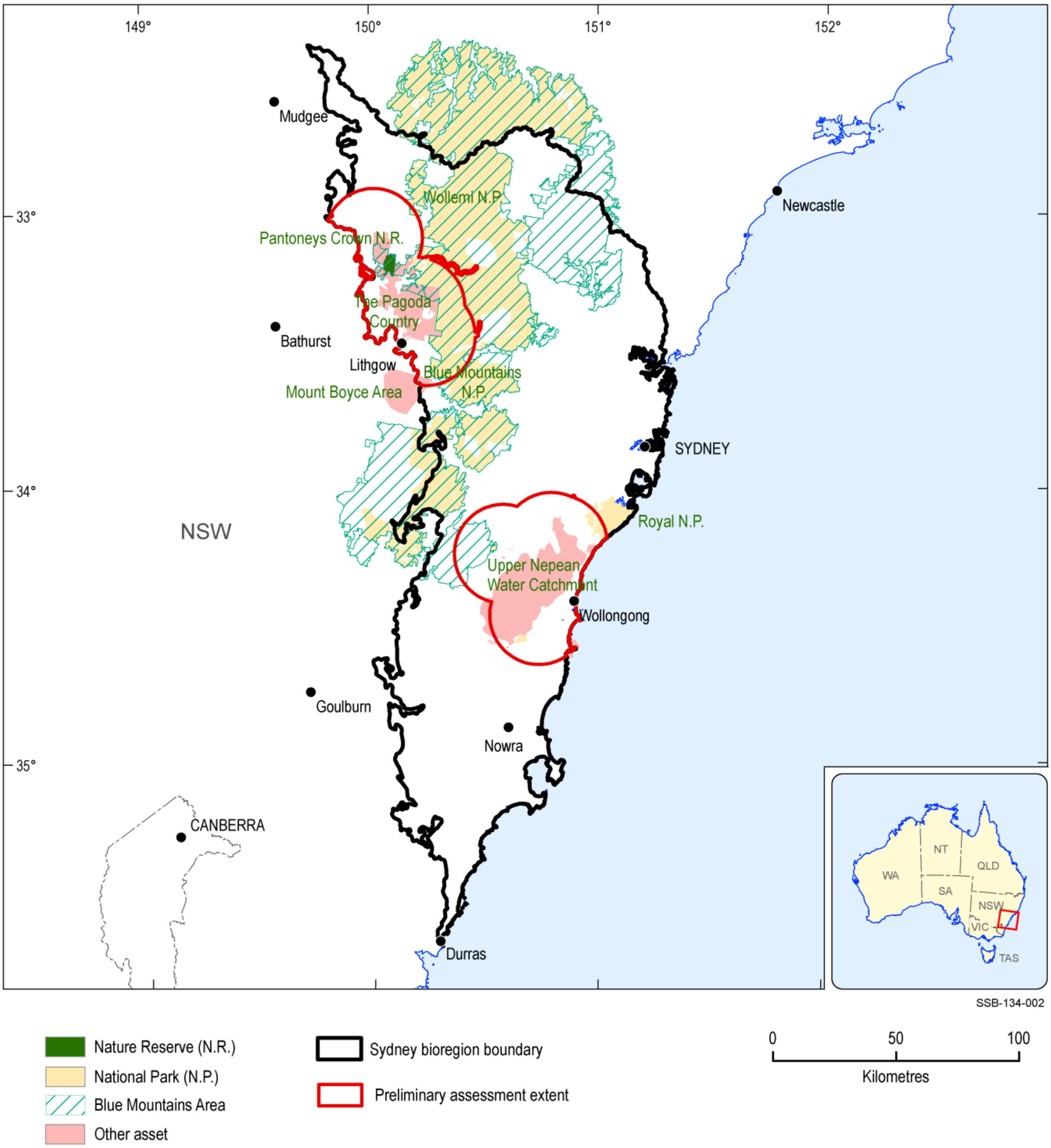

Figure 24 Water-dependent social assets of the Sydney Basin bioregion

Data: Bioregional Assessment Programme (Dataset 6)

1.3.4.2 Gaps

Meetings were not held with Indigenous knowledge holders to identify other Indigenous cultural water-dependent assets in the Sydney Basin bioregion that are not already in the Commonwealth, National or World heritage list. Should additional information on Indigenous water-related values become available to the Programme, it may be incorporated into an updated water-dependent asset register (http://www.bioregionalassessments.gov.au/product/SSB/SSB/1.3) and/or into later technical products. This will only be done if possible and appropriate, and with the agreement of Indigenous knowledge holders.

References

Moggridge B (2010) Identification of culturally significant groundwater dependent ecosystems and identification of reaches within management zones to support Aboriginal Community Development Licenses, Final report for the Hawkesbury-Nepean Catchment Management Authority, November 2010. CSIRO Land and Water, Australia.

Datasets

Dataset 1 Department of the Environment (2014) Australia, Register of the National Estate (RNE) - Spatial Database (RNESDB) Internal. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/878f6780-be97-469b-8517-54bd12a407d0.

Dataset 2 Department of the Environment (2014) Commonwealth Heritage List Spatial Database (CHL). Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/57720684-4948-45db-a2c8-37259d531d87.

Dataset 3 Department of the Environment (2014) National Heritage List Spatial Database (NHL) (v2.1). Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/26daa8d7-a90e-47f3-982b-0df362414e65.

Dataset 4 Department of the Environment (2013) Australia World Heritage Areas. Bioregional Assessment Source Dataset. Viewed 02 February 2016, http://data.bioregionalassessments.gov.au/dataset/4927789b-7ba7-4a77-b6fc-be1b29b6590c.

Dataset 5 CSIRO (2010) Identification of Culturally Significant Groundwater Dependent Ecosystems CSIRO 2010. Bioregional Assessment Source Dataset. Viewed 05 February 2016, http://data.bioregionalassessments.gov.au/dataset/4d0bc9d9-7675-4e57-b0fd-750b323fde95.

Dataset 6 Bioregional Assessment Programme (2015) Asset database for the Sydney Basin bioregion on 29 March 2016. Bioregional Assessment Derived Dataset. Viewed 11 July 2016, http://data.bioregionalassessments.gov.au/dataset/ae283994-5f14-4442-af0d-8f8c81eb657e.

www.bioregionalassessments.gov.au

Australian Government

Department of the Environment and Energy

Bureau of Meteorology

Geoscience Australia

CSIRO