Independent Expert Scientific Committee
on Coal Seam Gas and Large Coal Mining Development

Information Guidelines for Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals

Consultation draft

IESC INFORMATION GUIDELINES

The role of the IESC

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (the IESC) is a statutory body under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act).

The IESC's key legislative functions are to:

- provide scientific advice to the Commonwealth Environment Minister and relevant state ministers in relation to coal seam gas (CSG) or large coal mining development proposals that are likely to have a significant impact on water resources
- provide scientific advice to the Commonwealth Environment Minister on bioregional assessments
- provide scientific advice to the Commonwealth Environment Minister on research priorities and projects
- collect, analyse, interpret and disseminate scientific information about the impacts of CSG and large coal mining activities on water resources
- provide scientific advice on other matters in response to a request from the Commonwealth or state ministers.

Further information on the role of the IESC is available on the IESC website[1].

Purpose of these Guidelines

The Information Guidelines (the Guidelines) outline the information considered necessary to enable the IESC to provide robust scientific advice to government regulators on the potential water-related impacts of CSG and large coal mining development proposals.

The Guidelines were initially published in February 2013, reviewed in April 2014 and June 2015, and amended to take account of the IESC's experience and comments from interested parties.

The nature of advice from the IESC

The IESC's advice to Australian government regulators on CSG and large coal mining development proposals is scientific in nature. The IESC does not make regulatory decisions; advice is provided in response to a request from a government regulator. The advice and considerations provided by the IESC are designed to support statutory decision makers in considering the best available science in the regulatory process.

The Commonwealth and declared state regulators (in accordance with section 505E of the EPBC Act) seek advice from

the IESC at appropriate stages in the assessment and approvals process, as outlined in the relevant state protocols. More information on state protocols can be found at:

- http://iesc.environment.gov.au/committee-advice, or
- New South Wales – www.planning.nsw.gov.au/gateway-assessment-and-site-verification
- Queensland – www.ehp.qld.gov.au/management/impact-assessment/national-partnership-agreement.html
- Victoria – http://www.dtpli.vic.gov.au/planning/environmental-assessment
- South Australia – www.waterconnect.sa.gov.au/Industry-and-Mining/CSG-Coal-Mining

In accordance with section 505D of the EPBC Act, the IESC is required to provide advice to the regulator within no more than two months of receiving a request. The IESC's advice will be published on the IESC website no more than ten days after it is provided to the regulator.

The IESC's advice focuses on potential impacts of CSG or large coal mining development on all aspects of water resources including water quantity, water quality, ecosystems and ecological processes that contribute to the state and value of the water resource and water-related assets.

In providing advice, the IESC will consider whether a proponent's environmental assessment documentation has:

- used relevant data and information
- applied appropriate methods and interpreted model outputs in a logical and reasonable way.

The advice of the IESC can include but is not limited to:

- an assessment of the adequacy of models and water and salt balances
- the potential water-related impacts of the proposal and their likely risk and consequence to water resources and water-related assets
- whether the information used and methods applied were the best available at the time, and whether the assessment of risk and uncertainty is appropriate
- critical data and information gaps that need to be addressed to complete an adequate assessment
- the cumulative water-related impact of the proposal in the context of past, present, and/or reasonably foreseeable actions
- the adequacy of proposed environmental objectives, outcomes, and management measures proposed to mitigate risks, and any additional measures to mitigate risks from the proposal.

INFORMATION NEEDS FOR IESC ADVICE

The information available will vary for individual proposals depending on the point in the regulatory assessment process at which the proposal is referred. Whether the project is a new development (greenfield) or an expansion of an existing operation (brownfield) will also affect the type and amount of information provided to the IESC. The documentation provided to the IESC needs to include the most

comprehensive information possible, based on the available data.

Early in the assessment process (e.g. Gateway projects in NSW), preliminary conceptual and numerical/analytical models should consider all available data. Conceptual models should identify water resources and water-related assets within the project area and surrounding areas, including their significance under state and Commonwealth legislation, and identify any potential impacts to water-related assets

For projects at draft EIS and supplementary EIS stages, there is expected to be a clear and evidence-based determination of potential significant impacts to water resources and water-related assets, supported by detailed modelling. Modelling should include detailed conceptual and numerical models at spatial and temporal scales suitable to represent physical processes associated with each identified water resource or water-related asset. The information provided should include an assessment of the risk to water resources and water-related assets resulting from the development proposal, and details of proposed mitigation measures to manage these risks.

Proposals for expansions or modifications to existing mining operations should outline historical and existing operations, existing water-related environmental approval conditions and associated approved monitoring and management plans. Any impacts to water resources and water-related assets from the current project should be clearly stated and supported by existing monitoring data. Project documentation should outline how existing data have been used to assess the potential impacts from the proposal.

It is envisaged that the information needed will be provided by proponents in their project assessment documentation. This information may be augmented by further information required or generated by the relevant regulator.

The text below provides general guidance on IESC information needs. Specific information needed for the IESC to fulfil its role is included in the checklist at **Appendix A.** The checklist will assist proponents and regulators ensure that requests for advice to the IESC are supported by appropriate information.

1. Description of the proposed project

A regional overview of the proposed project area including a description of the geological basin, coal resource, surface water catchments, groundwater systems, water-related assets, and current and reasonably foreseeable coal mining, CSG developments and other water-intensive activities, including irrigation, should be provided. Relevant information generated by a bioregional assessment should be included. Where a bioregional assessment has not been initiated and/or completed, best available information should be used in describing the existing location and condition of water resources and water-related assets in the region.

The description of the proposed project should clearly describe the proposal's location, purpose, scale, duration, disturbance area, and the means by which it is likely to have a significant impact on water resources and water-related assets. For proposals that will use existing approved infrastructure, such as mine extensions, information should clearly identify which components of the proposal are new.

A description of the statutory context, including information on the proposal's status within the regulatory assessment process, and any water management policies or regulations applicable to the

proposal, including state or Commonwealth regulation of potentially impacted water resources, should also be provided.

2. Description of impacts to water resources and water-related assets

For all relevant water resources and water-related assets, a description of existing conditions, conceptual and/or numerical modelling of potential impacts and a description of proposed mitigation and management measures are needed.

For each potential impact to a water resource, the impact to the resource, the resultant impact to any water-related assets dependent on the resource, and the consequence or significance of the impact should be clearly articulated.

Impacts on water-related assets should be compared with project-specific environmental objectives and the legislated environment values and water quality objectives for surface waters and groundwaters under relevant state environmental legislation.

For brownfield projects, the impacts on water resources and water-related assets from the existing project should be described separately from the potential impacts of the project expansion. The potential cumulative impacts of the project in its entirety should also be described.

2.1 Conceptual modelling

Conceptual models must be based on the best available science and should consider relevant field data and investigations, expert advice, relevant scientific literature, and other appropriate information sources. Conceptual models should identify the geological formations, water resources, and water-related assets likely to be impacted by the proposal. They should be developed at appropriate scales which enable clear description of important pathways of cause and effect, how these would be influenced by the proposal, and the expected responses in identified water resources and water-related assets. Reliable conceptual models provide the scientific basis for developing analytical and numerical models and site water and salt balances.

In general terms, a conceptual model can be effectively summarised by pictorial hydrological, hydrogeological and ecological representations of the project site showing the stores, flows and uses of water, including use of water by ecosystems. Conceptual models are also useful in the problem formulation stage of ecological risk assessment to show stressors, sources and cause-effect pathways.

In some cases, it may be necessary to develop conceptual models for different components of the designated region or several models depicting different spatial and/or temporal scales. The level of detail within a conceptual model should be based on the environmental objectives, data availability, and knowledge of the water resources, water-related assets and processes within a designated region.

Further information regarding conceptual modelling, including issues of scale and uncertainty can be found in *Modelling water-related ecological responses to coal seam gas extraction and coal mining* (Commonwealth of Australia, 2015).[2]

2.2 Analytical and numerical modelling

Numerical models can predict potential impacts on water resources and water-related assets from a development proposal and support the exploration of management approaches to mitigate impacts. It is recognised that for projects presented to the IESC early in the assessment process, the data required for detailed modelling may not be available. A detailed description of any methods and

evidence (e.g. expert opinion, analogue sites) used in addition to modelling should also be provided.

Modelling should be undertaken to fulfil a specific purpose such as understanding potential impacts to a water resource or resources. This purpose should inform the model design and assumptions which should be clearly described and justified in the project assessment documentation. The model should be constructed in accordance with the system's conceptualisation, and calibrated and verified with appropriate baseline data.

Results from modelling should be presented to show a range of possible outcomes based on uncertainty analysis.

Impact analysis should be based on modelling results and should clearly articulate the potential impact pathways. Details of the proposed monitoring and management plans should be clearly linked to the impact analysis informed by modelling.

2.3 Water and salt balances

Site-specific salt and water balances, complemented by an understanding of the inputs, outputs and diversions of water in a region, should be provided for both pre- and post-development scenarios under a range of potential climatic conditions, for example guided by the Australian Climate Futures Tool (CSIRO, 2015[3]). The water and salt balances provided should use consistent water metrics and definitions and be accompanied by relevant contextual information and statements of accuracy (for example, see the *Water Accounting Framework for the Minerals Industry* Minerals Council of Australia, 2012[4]).

Information is needed about the set of water and salt stores for the site and the movement of water and salt between stores, tasks (such as coal handling and processing, dust suppression, underground mining), and treatment plants within the site. This should include estimates of water use in transpiration by vegetation and the predicted changes to vegetation water use as a result of the proposal. An assessment of the potential impact of any changes to any store or flow of water and mass or concentration of salt arising from the development proposal on water-related assets is needed.

Estimates of the quality and quantity of external water supply and operational discharges under dry, median and wet conditions and the likely impacts on water-related assets should be provided.

It is noted that for greenfield coal seam gas projects, there is a large degree of uncertainty around produced water volumes and salt loads. Regardless, estimates of water and salt volumes, and the uncertainty associated with these estimates, should be quantified and communicated in the project documentation.

3. Data, management and monitoring

Baseline data provides the foundation for developing environmental objectives and outcomes. Baseline measurements are also required to measure changes to water resources and water-related assets as a result of a development proposal. Baseline data is needed for all water resources, including contextual information such as dates and locations of measurements, sampling protocols, flow conditions and elevations of the reference points from which water levels were measured.

Baseline ecological data should be sufficient to identify all water-related assets dependent on surface water and groundwater resources and include the results of habitat, fauna (including stygofauna) and flora surveys, and the current condition of and stressors on these assets, to inform ecological risk

assessment. Adequate ecological and hydrological (for quick response systems) baseline data would generally be for a period of around two years, at a frequency sufficient to capture likely changes in the system.

Proposed management and mitigation measures should be detailed, and references provided to previous projects, case studies or scientific literature that support the adequacy of the measure in the project context. The monitoring plan should detail how triggers and limits will be measured and how performance of the proposed mitigation measures will be assessed. It should also outline contingency plans if the environmental objectives are not met. If offsets are proposed, the potential management options that were considered and investigated prior to offsetting should be described.

Plans for ongoing monitoring and management are expected where significant impacts to water resources and water-related assets are predicted. Plans should focus on a robust monitoring programme to inform the management and mitigation of likely impacts and to reduce the uncertainty of predicted impacts. The monitoring programme should include groundwater, surface water and associated ecological attributes and be capable of tracking changes from pre-development conditions. This requires a comprehensive baseline monitoring dataset prior to commencement of the development. There may also be a need for concurrent baseline monitoring from unimpacted control and reference sites to distinguish project-induced impacts from background variation (i.e. induced by other water users and climatic variability) in the region (i.e. BACI design).

The rationale and design for monitoring programmes should be provided. These should include the hypotheses to be tested by the monitoring programmes, the temporal and spatial frequency (or resolution) of monitoring, the potential parameters and indicators to be monitored, and the analytical methods to be applied. The monitoring programmes should identify the triggers and thresholds associated with environmental objectives and outcomes and the proposed management measures if those levels are reached or exceeded. Triggers and thresholds should be based on the best available science. Any departures from published monitoring guidelines should be justified based on site-specific data.

Information is needed on findings from monitoring programmes, including raw data, analysis of data, and the performance of mitigation measures against the environmental objectives. The monitoring and management programmes should be robust and provide for an adaptive management approach to predicted impacts to water resources and water-related assets.

4. Cumulative impacts

An assessment of cumulative impacts is needed to determine the risks posed by the development proposal within the region. The assessment of cumulative impacts needs to consider all relevant past, present and reasonably foreseeable actions, programmes and policies that are likely to impact on water resources. The scale of a cumulative impact assessment needs to cover spatial and temporal boundaries large enough to include all potential significant impacts on water resources from the proposed project and other activities within the region.

In addition to the proponent's assessment of cumulative impacts, advice may be provided by relevant Australian government regulators.

A quantitative assessment of cumulative impacts is preferred. However, a qualitative or semi-quantitative approach may be used if data are lacking. Assessments may also require consideration of interactive or synergistic impacts in addition to a summation of individual proposals or impacts.

There may be a need to further develop groundwater and surface water models to enable the prediction of cumulative impacts. Local-scale cumulative impact assessments should be undertaken by the proponent. These would ideally be informed by regional assessments such as strategic assessments, Cumulative Management Area models and/or completed Bioregional Assessments.

5. Risk assessment

The IESC will review and evaluate the proponent's assessment of risk in conjunction with any information provided by relevant Australian government regulators in their requests for IESC advice.

Where a proposal referred to the IESC could have a significant impact on water resources and water-related assets, the proponent will need to determine the scope of potential impacts and their likelihood and consequence. The risk assessment should address the potential impact of the proposed project as well as the potential cumulative impact of all past, present and reasonably foreseeable actions that are likely to impact on water resources and water-related assets. The IESC will also consider whether the proponent has demonstrated that the risk can be either avoided or suitably mitigated and may suggest further actions to mitigate or manage residual risks.

Available bioregional assessments will assist in the risk analyses by identifying possible risks and consequences of impacts to water resources and water-related assets from CSG and large coal mining development proposals within specific bioregions. Where a development proposal occurs within an area subject to a bioregional assessment, the IESC will consider the bioregional assessment in its review of the proponent's risk assessment.

GLOSSARY

For the purpose of the Information Guidelines:

Analytical models make simplifying assumptions (e.g. properties of the aquifer are considered to be constant in space and time) to enable solution of a given problem. Analytical models are usually solved rapidly, sometimes using a computer but sometimes by hand.

Assessment documentation is all documentation required by the relevant state regulator to fulfil the requirements of the environmental assessment process at the relevant stage for the proposed project.

BACI design refers to impact assessment using the Before-After-Control-Impact model. At a minimum, a BACI design requires data from two sites, corresponding to a control site and an impact site. Data are collected a number of times before and after the impact occurs.

Bioregional assessment is a scientific analysis of the ecology, hydrology, geology and hydrogeology of a bioregion, with explicit assessment of the potential direct, indirect and cumulative impacts of CSG and coal mining development on water resources. The central purpose of bioregional assessments is to identify areas of likely impact and analyse the impacts and risks associated with changes to water-related assets that arise in response to current and future pathways of CSG and large coal mining development.

Coal seam gas development is defined under the EPBC Act as any activity involving CSG extraction that has, or is likely to have, a significant impact on water resources (including any impacts of associated salt production and/or salinity), either in its own right or when considered with other developments, whether past, present or reasonably foreseeable.

Conceptual model is a descriptive and/or schematic hydrological, hydrogeological and ecological representation of the site showing the stores, flows and uses of water, which illustrates the geological formations, water resources and water-related assets, and provides the basis for developing water and salt balances and inferring water-related ecological responses to changes in hydrology, hydrogeology and water quality.

Cumulative impact is defined as the total impact of a CSG and/or large coal mining development on water resources when all past, present and/or reasonably foreseeable actions that are likely to impact on water resources are considered.

Ecological processes are part of the components that contribute to the physical state and environmental value of a water resource and can include processes such as nutrient cycling, eutrophication and carbon metabolism.

Environmental objective for each water resource or water-related asset is the desired goal that, if met, will indicate that the proposal is not expected to have an unacceptable impact on the environment (amended from definition in EAG 8, WA EPA 2013[5]).

Environmental outcome is a statement of an acceptable level of impact to a water resource or water-related asset that must not be exceeded, or a level of protection that must be achieved. The outcome will be aligned with an environmental objective and must be quantitatively measureable and achievable (amended from EAG 11, WA EPA 2013[6]).

Groundwater-dependent ecosystems (GDEs) are ecosystems that require access to groundwater on a permanent or intermittent basis to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services. GDEs include terrestrial vegetation, wetlands (swamps, lakes and rivers) and ecosystems in aquifers and caves.

Large coal mining development is defined under the EPBC Act as any coal mining activity that has, or is likely to have, a significant impact on water resources (including any impacts of associated salt production and/or salinity), either in its own right or when considered with other developments, whether past, present or reasonably foreseeable.

Numerical models divide space and/or time into discrete pieces. Features of the governing equations and boundary conditions (e.g. aquifer geometry, hydrogeological properties, pumping rates or sources of solute) can be specified as varying over space and time. This enables more complex, and potentially more realistic, representation of a groundwater system than could be achieved with an analytical model.

Significant impact is defined by the *Significant Impact Guidelines (2013)*[7] as an impact which is important, notable or of consequence, having regard to its context or intensity. Whether or not an action is likely to have a significant impact depends upon the sensitivity, value and quality of the water resource which is impacted, and upon the intensity, duration, magnitude and geographic extent of the impacts.

Water balance is a mathematical expression of water flows and exchanges, described as inputs, outputs and changes in storage. Surface water, groundwater and atmospheric components should be included.

Water-dependent ecosystems are defined by the *Water Act 2007* (Cth) as a surface water ecosystem or a groundwater ecosystem, and its natural components and processes, that depends on periodic or sustained inundation, waterlogging or significant inputs of water for its ecological integrity and includes an ecosystem associated with a wetland, stream, lake or waterbody, salt marsh, estuary, karst system or groundwater system. A reference to a water-dependent ecosystem includes a reference to the biodiversity of the ecosystem.

Water-related asset is defined by the *Water Act 2007* (Cth) as a defined value or public benefit with a dependence on surface water or groundwater, including water-dependent ecosystems, drinking water, public health, recreation and amenity, Indigenous and cultural values, fisheries, tourism, navigation, agriculture and industry values.

Water resources are defined by the *Water Act 2007* (Cth) as “surface water or groundwater or a watercourse, lake, wetland or aquifer (whether or not it currently has water in it); and includes all aspects of the water resource, including water, organisms and other components and ecosystems that contribute to the physical state and environmental value of the water resource.” Broadly, a water resource encompasses the water body itself and all aspects that contribute to its physical state and environmental value, such as the associated water quality and any associated organisms, ecological processes and ecosystems.

CHECKLIST OF SPECIFIC INFORMATION NEEDS

Specific guidance on IESC information needs is provided below. This checklist reflects the approach taken by the IESC when assessing project documentation. The checklist should be considered in addition to the general guidance provided in the main body of the Guidelines.

The IESC recognises that at the early assessment stage project, documentation will not contain the level of analysis expected for a subsequent development application and accompanying environmental assessment. Where data and analyses are lacking, a sound conceptualisation of the system is needed, with explicit explanations of underlying assumptions. Plans to improve the understanding of the system over time, including details of when and how data to support assumptions will be gathered, must also be provided.

<table>
<tr><th colspan="2">Description of the proposal</th></tr>
<tr><td>☐ A regional overview of the proposed project area including a description of the geological basin, coal resource, surface water catchments, groundwater systems, water-related assets, and past, current and reasonably foreseeable coal mining and CSG developments.</td><td>☐ A description of the proposal's location, purpose, scale, duration, disturbance area, and the means by which it is likely to have a significant impact on water resources and water-related assets.</td></tr>
<tr><td>☐ A description of the statutory context, including information on the proposal's status within the regulatory assessment process and on any water management policies or regulations applicable to the proposal.</td><td>☐ A description of how impacted water resources are currently being regulated under state or Commonwealth law, including whether there are any applicable standard conditions.</td></tr>
<tr><th colspan="2">Groundwater</th></tr>
<tr><td colspan="2">Context and conceptualisation</td></tr>
<tr><td rowspan="2">☐ Descriptions and mapping of geology at an appropriate level of horizontal and vertical resolution including:
definition of the geological sequence/s in the area, with names and descriptions of the formations with accompanying surface geology and cross-sections.
definitions of any significant geological structures (e.g. faults) in the area and their influence on groundwater, in particular, groundwater flow, discharge or recharge.</td><td>☐ Data to demonstrate the varying depths to the hydrogeological units and associated standing water levels or potentiometric heads, including direction of groundwater flow, contour maps, hydrographs and hydrochemical characteristics (e.g. acidity/alkalinity, electrical conductivity, metals, major ions). Time series data representative of seasonal and climatic cycles.</td></tr>
<tr><td>☐ Description of the likely recharge, discharge and flow pathways for all hydrogeological units likely to be impacted by the proposed development.</td></tr>
<tr><td>☐ Values for hydraulic parameters (e.g. vertical and horizontal hydraulic conductivity and storage characteristics) for each hydrogeological unit.</td><td>☐ Assessment of the frequency, location, volume and direction of interactions between water resources, including surface water/groundwater connectivity, inter-aquifer connectivity and connectivity with sea water.</td></tr>
</table>

Analytical and numerical modelling	
☐ A detailed description of all analytical and/or numerical models used, and any methods and evidence (e.g. expert opinion, analogue sites) employed in addition to modelling.	☐ Identification of the volumes of water predicted to be taken annually with an indication of the proportion supplied from each hydrogeological unit.
☐ Undertaken in accordance with the Australian Groundwater Modelling Guidelines[8], including peer review.	☐ An explanation of the model conceptualisation of the hydrogeological system or systems, including key assumptions and model limitations, with any consequences described.
☐ Calibration with adequate monitoring data, ideally with calibration targets related to model prediction (e.g. use baseflow calibration targets where predicting changes to baseflow).	☐ Consideration of a variety of boundary conditions across the model domain, including constant head or general head boundaries, river cells and drains, to enable a comparison of groundwater model outputs to seasonal field observations.
☐ Representations of each hydrogeological unit, the thickness, storage and hydraulic characteristics of each unit, and linkages between units, if any.	☐ Sensitivity analysis of boundary conditions and hydraulic and storage parameters, and justification for the conditions applied in the final groundwater model.
☐ Representation of the existing recharge/discharge pathways of the units and the changes that are predicted to occur upon commencement, throughout, and after completion of the development activities.	☐ An assessment of the quality of, and risks and uncertainty inherent in, the data used to establish baseline conditions and in modelling, particularly with respect to predicted potential impact scenarios.
☐ Incorporation of the various stages of the proposed development (construction, operation and rehabilitation) with predictions of water level and/or pressure declines and recovery in each hydrogeological unit for the life of the project and beyond, including surface contour maps.	☐ A programme for review and update of the models as more data and information become available, including reporting requirements.
☐ Information on the time for maximum drawdown and post-development drawdown equilibrium to be reached.	
Impacts to water resources and water-related assets	
☐ An assessment of the potential impacts of the proposal, including how impacts are predicted to change over time and any residual long-term impacts: • Description of any hydrogeological units that will be directly or indirectly dewatered or depressurised, including the extent of impact on hydrological interactions between water resources, surface water/groundwater connectivity, inter-aquifer connectivity and connectivity with	☐ Description of the water resources and water-related assets that will be directly impacted by mining or CSG operations, including hydrogeological units that will be exposed/partially removed by open cut mining and/or underground mining. ☐ For each potentially impacted water resource, a clear description of the impact to the resource, the resultant impact to any water-related assets dependent on the resource, and the consequence or significance of the impact.

sea water. • The effects of dewatering and depressurisation (including lateral effects) on water resources, water-related assets, groundwater, flow direction and surface topography, including resultant impacts on the groundwater balance. • Description of potential impacts on hydraulic and storage properties of hydrogeological units, including changes in storage, potential for physical transmission of water within and between units, and estimates of likelihood of leakage of contaminants through hydrogeological units. • Consideration of possible fracturing of and other damage to confining layers. • For each relevant hydrogeological unit, the proportional increase in groundwater use and impacts as a consequence of the development proposal, including an assessment of any consequential increase in demand for groundwater from towns or other industries resulting from associated population or economic growth due to the proposal.	☐ Description of existing water quality guidelines and targets, environmental flow objectives and other requirements (e.g. water planning rules) for the groundwater basin(s) within which the development proposal is based. ☐ An assessment of the cumulative impact of the proposal on groundwater when all developments (past, present and/or reasonably foreseeable) are considered in combination. ☐ Proposed mitigation and management actions for each significant impact identified, including any proposed mitigation or offset measures for long-term impacts post mining. ☐ Description and assessment of the adequacy of proposed measures to prevent/minimise impacts on water resources and water-related assets.
Data and monitoring	
☐ Sufficient physical aquifer parameters and hydrogeochemical data to establish pre-development conditions, including fluctuations in groundwater levels at time intervals relevant to aquifer processes.	☐ Long-term groundwater monitoring, including a comprehensive assessment of all relevant chemical parameters to inform changes in groundwater quality and detect potential contamination events.
☐ A robust groundwater monitoring programme, utilising dedicated groundwater monitoring wells and targeting specific aquifers, providing an understanding of the groundwater regime, recharge and discharge processes and identifying changes over time.	☐ Water quality monitoring complying with relevant National Water Quality Management Strategy (NWQMS) guidelines[9] and relevant legislated state protocols[10].
Surface water	
Context and conceptualisation	
☐ A description of the hydrological regime of all watercourses, standing waters and springs across the site including: • Geomorphology, including drainage patterns, sediment regime and floodplain features. • Spatial, temporal and seasonal trends in streamflow and/or standing water levels.	☐ A description of the existing flood regime, including flood volume, depth, duration, extent and velocity for a range of annual exceedance probabilities, and flood hydrographs and maps identifying peak flood extent, depth and velocity. ☐ Assessments of the frequency, volume and

<table>
<tr><td>• Spatial, temporal and seasonal trends in water quality data (such as turbidity, acidity, salinity, relevant organic chemicals, metals and metalloids and radionuclides).
• Current stressors on watercourses, including impacts from any currently approved projects.</td><td>direction of interactions between water resources, including surface water/ groundwater connectivity and connectivity with sea water.</td></tr>
<tr><td colspan="2">Analytical and numerical modelling</td></tr>
<tr><td>☐ Conceptual models at an appropriate scale, including water quality, stores, flows and use of water by ecosystems.</td><td>☐ Description and justification of model assumptions and limitations, and calibration with appropriate surface water monitoring data.</td></tr>
<tr><td>☐ Methods in accordance with the most recent publication of Australian Rainfall and Runoff.</td><td>☐ An assessment of the risks and uncertainty inherent in the data used in the modelling, particularly with respect to predicted scenarios.</td></tr>
<tr><td>☐ A programme for review and update of the models as more data and information becomes available.</td><td>☐ A detailed description of any methods and evidence (e.g. expert opinion, analogue sites) employed in addition to modelling.</td></tr>
<tr><td colspan="2">Impacts to water resources and water-related assets</td></tr>
<tr><td rowspan="5">☐ Description of all potential impacts of the proposed project on surface waters, including a clear description of the impact to the resource, the resultant impact to any water-related assets dependent on the resource, and the consequence or significance of the impact, including:
• Impacts on streamflow under different flow conditions.
• Impacts associated with surface water diversions.
• Impacts to water quality, including consideration of mixing zones.
• Estimates of the quality, quantity and ecotoxicological effects of operational discharges of water (including saline water), including potential emergency discharges, and the likely impacts on water resources and water-related assets
• Identification and consideration of landscape modifications, for example,</td><td>☐ Existing water quality guidelines and targets, environmental flow objectives and requirements for the surface water catchment(s) within which the development proposal is based.</td></tr>
<tr><td>☐ Identified processes to determine surface water quality and quantity triggers which incorporate seasonal variation but provide early indication of potential impacts to assets.</td></tr>
<tr><td>☐ Proposed mitigation actions for each trigger and identified significant impact.</td></tr>
<tr><td>☐ Description and adequacy of proposed measures to prevent/minimise impacts on water resources and water-related assets.</td></tr>
<tr><td>☐ Description of the cumulative impact of the proposal on surface water resources and water-related assets when all developments (past, present and/or reasonably foreseeable) are considered in combination.</td></tr>
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subsidence, voids, onsite earthworks including disturbance of acid-forming or sodic soils, roadway and pipeline networks through effects on surface water flow, surface water quality, erosion and habitat fragmentation of water-dependent species and communities.	☐ An assessment of the risks of flooding, including channel form and stability, water level, depth, extent, velocity, shear stress and stream power, and impacts to ecosystems, project infrastructure and the final project landform.
Data and monitoring	
☐ Water quality monitoring complying with relevant National Water Quality Management Strategy (NWQMS) guidelines[5] and relevant legislated state protocols[8].	☐ Monitoring sites representative of the diversity of potentially affected water-related assets and the nature and scale of potential impacts, and matched with suitable replicated control and reference sites (i.e. BACI design) to enable detection and monitoring of potential impacts.
☐ A surface water monitoring programme collecting sufficient data to detect and identify the cause of any changes from established baseline conditions, and assessing the effectiveness of mitigation and management measures.	☐ The rationale for selected monitoring variables, duration, frequency and methods, including the use of satellite or aerial imagery to identify and monitor large-scale impacts.
☐ Identification of dedicated sites to monitor hydrology, water quality, and channel and floodplain geomorphology throughout the life of the development proposal and beyond.	☐ Ongoing ecotoxicological monitoring, including direct toxicity assessment of discharges to surface waters where appropriate.
☐ Specified data sources, including streamflow data, proximity to rainfall stations, data record duration and a description of data methods, including whether missing data has been patched.	
Water-related assets	
Context and conceptualisation	
☐ Identification of water-related assets, including: • Water-dependent fauna and flora supported by habitat, flora and fauna (including stygofauna) surveys. • Public health, recreation, amenity, Indigenous, tourism or agricultural values for each water resource.	☐ Identification of GDEs in accordance with the method outlined by Eamus et al. (2006)[11]. Information from the GDE Toolbox[12] and GDE Atlas[13] may assist in identification of GDEs.
	☐ Identification of the hydrogeological units on which any identified GDEs are dependent.
	☐ An estimation of the ecological water requirements of identified GDEs and other water-dependent assets.
☐ An outline of the water-related assets and associated environmental objectives and the modelling approach to assess impacts to the assets.	☐ Conceptualisation and rationale for likely water-dependence, impact pathways, tolerance and resilience of water-related assets. Examples of ecological conceptual models can be found in Commonwealth of

	Australia (2015)[2].
☐ A description of the process employed to determine water quality and quantity triggers and impact thresholds for water-related assets (e.g. threshold at which a significant impact on an asset may occur).	
Impacts, risk assessment and management of risks	
☐ An assessment of direct and indirect impacts on water-related assets, including ecological assets such as flora and fauna dependent on surface water and groundwater, springs and other GDEs.	☐ A description of the potential range of drawdown at each affected bore, and a clear articulation of the scale of impacts to other water users.
☐ Estimates of the impact of operational discharges of water (particularly saline water), including potential emergency discharges due to unusual events, on water-related assets and ecological processes.	☐ An assessment of the overall level of risk to water-related assets that combines probability of occurrence with severity of impact.
☐ Indication of the vulnerability to contamination (for example, from salt production and salinity) and the likely impacts of contamination on the identified water-related assets and ecological processes.	☐ The proposed acceptable level of impact for each water-related asset based on the best available science and site-specific data, and ideally developed in conjunction with stakeholders.
☐ Identification and consideration of landscape modifications (for example, voids, onsite earthworks, roadway and pipeline networks) and their potential effects on surface water flow, erosion and habitat fragmentation of water-dependent species and communities.	☐ Proposed mitigation actions for each identified impact, including a description of the adequacy of the proposed measures and how these will be assessed.
Data and monitoring	
☐ Ecological monitoring complying with relevant state or national monitoring guidelines.	☐ Monitoring that identifies impacts, evaluates the effectiveness of impact prevention or mitigation strategies, measures trends in ecological responses and detects whether ecological responses are within identified thresholds of acceptable change.
☐ Sampling sites at an appropriate frequency and spatial coverage to establish pre-development (baseline) conditions, and test hypothesised responses to impacts of the proposal.	☐ Regular reporting, review and revisions to the monitoring programme.
☐ Concurrent baseline monitoring from unimpacted control and reference sites to distinguish impacts from background variation in the region (e.g. BACI design).	
Water and salt balance and water management strategy	
☐ Quantitative site water balance model	☐ Estimates of the quality and quantity of

describing the total water supply and demand under a range of rainfall conditions and allocation of water for mining activities (e.g. dust suppression, coal washing etc), including all sources and uses.	operational discharges under dry, median and wet conditions, potential emergency discharges due to unusual events and the likely impacts on water-related assets.
☐ Description of water requirements and onsite water management infrastructure, including modelling to demonstrate adequacy under a range of potential climatic conditions.	☐ Salt balance modelling, including stores and the movement of salt between stores taking into account seasonal and long-term variation.
Subsidence – underground coal mines and coal seam gas	
☐ Consideration of geological layers and their properties (strength/hardness/fracture propagation) in subsidence modelling.	☐ Description of subsidence monitoring methods, including use of remote or on-ground techniques and explanation of predicted accuracy of such techniques.
☐ Predictions of subsidence impact on surface topography, water-related assets, groundwater (including enhanced connectivity between aquifers) and movement of water across the landscape[14,15]	
Final landform and voids – coal mines	
☐ Identification and consideration of landscape modifications (for example, voids, onsite earthworks, roadway and pipeline networks) and their potential effects on surface water flow, erosion and habitat fragmentation of water-dependent species and communities.	☐ An assessment of the long-term impacts to water resources posed by various options for the final landform design, including complete or partial backfilling of mining voids, which considers: • Groundwater behaviour – sink or lateral flow from void. • Water level recovery – rate, depth, and stabilisation point (e.g. timeframe and level in relation to existing groundwater level, surface elevation). • Seepage – geochemistry and potential impacts. • Long-term water quality, including salinity, pH, metals and toxicity. • Measures to prevent migration of void water off-site.
☐ An assessment of the adequacy of modelling, including surface water and groundwater quantity and quality, lake behaviour, timeframes and calibration.	
Acid-forming materials and other contaminants of concern	
☐ Identification of the presence and potential exposure of acid-sulphate soils (including oxidation from groundwater drawdown).	☐ Handling and storage plans for acid-forming material (co-disposal, tailings dam, encapsulation).
☐ Identification of the presence and volume of potentially acid-forming waste rock and coal reject/tailings material and exposure pathways.	☐ Assessment of the potential impact to water-related assets, taking into account dilution factors, and including solute transport modelling where relevant, representative and statistically valid sampling, and appropriate

	analytical techniques.
☐ Identification of other sources of contaminants, such as high metal concentrations in groundwater, leachate generation potential and seepage paths.	☐ Description of proposed measures to prevent/minimise impacts on water resources, water users and water-dependent ecosystems and species.
Hydraulic stimulation – coal seam gas projects	
☐ A description of the scale of fracturing (number of wells, number of fracturing events per well), types of wells to be stimulated (vertical versus horizontal), and other forms of well stimulation (cavitation, acid flushing).	☐ A list of chemicals proposed for use in hydraulic fracturing including: • names of the companies producing fracturing fluids and associated products • proprietary names (trade names) of compounds (fracturing fluid additives) being produced • chemical names of each additive used in each of the fluids • Chemical Abstract Service (CAS) numbers of each of the chemical components used in each of the fluids • general purpose and function of each of the chemicals used • mass or volume proposed for use • maximum concentration (mg / L or g / kg) of the chemicals used • chemical half-life data, partitioning data, and volatilisation data • excotoxicology • any material safety data sheets for the chemicals or chemical products used.
☐ Measuring and monitoring of fracture propagation.	
☐ A description of the water source for hydraulic stimulation, volume of fluid and mass balance (quantities/volumes).	
☐ A description of the rules (e.g. water sharing plans) covering access to each water source for hydraulic stimulation and how the project proposes to comply with them.	
☐ Quantification of flowback water and a description of how it will be managed.	☐ Chemicals for use in hydraulic fracturing must be identified as being approved for import, manufacture or use in Australia (that is, confirmed by NICNAS as being listed in the Australian Inventory of Chemical Substances[16]).
☐ Potential for inter-aquifer leakage or contamination.	☐ The use of chemicals should be informed by appropriately tiered deterministic and/or probabilistic hazard and risk assessments, based on ecotoxicological testing consistent with Australian Government testing guidelines[5, 17, 18.]
Cumulative Impacts	
Context and conceptualisation	
☐ Cumulative impact analysis with sufficient geographic and time boundaries to include all potentially significant water-related impacts.	☐ Cumulative impact analysis identifies all past, present, and reasonably foreseeable actions, including development proposals, programs and policies that are likely to impact on the water resources of concern.

Impacts	
☐ An assessment of the condition of affected water resources which includes: • Identification of all water resources likely to be cumulatively impacted by the proposed development. • A description of the current condition and quality of water resources and information on condition trends. • Identification of ecological characteristics, processes, conditions, trends and values of water resources. • Adequate water and salt balances. • Identification of potential thresholds for each water resource and its likely response to change and capacity to withstand adverse impacts (e.g. altered water quality, drawdown).	☐ An assessment of cumulative impacts to water resources which considers: • The full extent of potential impacts from the proposed development, including alternatives, and encompassing all linkages include both direct and indirect links, operating upstream, downstream, vertically and laterally. • An assessment of impacts considered at all stages of the development, including exploration, operations and post closure / decommissioning. • An assessment of impacts, utilising appropriately robust, repeatable and transparent methods. • Identification of the likely spatial magnitude and timeframe over which impacts will occur, and significance of cumulative impacts. • Identification of opportunities to work with others to avoid, minimise or mitigate potential cumulative impacts.
Mitigation, monitoring and management	
☐ Identification of modifications or alternatives to avoid, minimise or mitigate potential cumulative impacts	☐ Identification of cumulative impact environmental objectives
☐ Identification of measures to detect and monitor cumulative impacts, pre and post development, and assess the success of mitigation strategies	☐ Appropriate reporting mechanisms
☐ Proposed adaptive management measures and management responses	

SUPPORTING DOCUMENTS

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[3] Commonwealth Scientific and Industrial Research Organisation 2015, Australian Climate Futures, *Climate Change in Australia Projections for Australia's NRM Regions,* http://www.climatechangeinaustralia.gov.au/en/climate-projections/climate-futures-tool/introduction-climate-futures/

[4] Minerals Council of Australia 2012, *Water Accounting Framework for the Minerals Industry User Guide*, http://www.minerals.org.au/file_upload/files/resources/water_accounting/WAF_UserGuide_v1.2.pdf

[5] Environmental Protection Authority (2013) *Environmental assessment guideline for environmental principles, factors and objectives (EAG 8).* Environmental Protection Authority, Perth, Western Australia. http://edit.epa.wa.gov.au/EPADocLib/EAG8-Principles-factors-objectives-RevJan2015.pdf

[6] Environmental Protection Authority (2013) *Environmental assessment guideline for recommending environmental conditions (EAG 11)*. Environmental Protection Authority, Perth, Western Australia. http://edit.epa.wa.gov.au/EPADocLib/EAG%2011%20Recommending%20environmental%20conditions%20130913.pdf

[7] Commonwealth of Australia 2013, *Significant Impact Guidelines1.3: Coal seam gas and large coal mining developments - impacts on water resources,* http://www.environment.gov.au/system/files/resources/42f84df4-720b-4dcf-b262-48679a3aba58/files/nes-guidelines_1.pdf

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[9] Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand, 2000. *Australian and New Zealand guidelines for fresh and marine water quality volume 1*, http://www.environment.gov.au/system/files/resources/53cda9ea-7ec2-49d4-af29-d1dde09e96ef/files/nwqms-guidelines-4-vol1.pdf

[10] Department of Environment and Heritage Protection (2009) Monitoring and Sampling Manual 2009, Version 2, July 2013 format edits, https://www.ehp.qld.gov.au/water/pdf/monitoring-man-2009-v2.pdf

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[12] Richardson S, et al 2011, *Australian groundwater-dependent ecosystem toolbox part 1: assessment framework*, Waterlines report, National Water Commission, Canberra, http://archive.nwc.gov.au/__data/assets/pdf_file/0006/19905/GDE-toolbox-part-1.pdf

[13] Bureau of Meteorology, 2015, *Atlas of Groundwater Dependent Ecosystems*, http://www.bom.gov.au/water/groundwater/gde/map.shtml

[14] Commonwealth of Australia, 2014, *Subsidence from coal seam gas in Australia, Background review,* http://www.environment.gov.au/water/publications/background-review-subsidence-coal-seam-gas-extraction-australia

[15] Commonwealth of Australia, 2014, *Subsidence from coal mining activities, Background review,* http://www.environment.gov.au/water/publications/background-review-subsidence-from-coal-mining-activities

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