



Information guidelines for proponents preparing coal seam gas and large coal mining development proposals

February 2024



© Commonwealth of Australia, 2024.



Information guidelines for proponents preparing coal seam gas and large coal mining development proposals is licensed by the Commonwealth of Australia for use under a Creative Commons Attribution 4.0 International licence with the exception of the Coat of Arms of the Commonwealth of Australia, the logo of the agency responsible for publishing the report, content supplied by third parties, and any images depicting people. For licence conditions see <https://creativecommons.org/licenses/by/4.0/>

This publication should be attributed as 'IESC 2024. *Information guidelines for proponents preparing coal seam gas and large coal mining development proposals*, Commonwealth of Australia'.

On 15 December 2023, the *Nature Repair (Consequential Amendments) Act 2023* amended the EPBC Act to expand the IESC's remit to all unconventional gas developments. This publication was developed prior to these amendments of the EPBC Act commencing.

This publication is funded by the Australian Government Department of Climate Change, Energy, the Environment and Water. The views and opinions expressed in this publication are those of the authors and do not necessarily reflect those of the Australian Government or the Minister for the Environment and Water.

Contact details

For information about this publication or about the work of the IESC, please contact:

IESC Secretariat
Office of Water Science
Department of Climate Change, Energy, the Environment and Water
GPO Box 3090
CANBERRA ACT 2601

The publication can be accessed at <http://www.iesc.environment.gov.au/>

Images

Front cover: McIntyre River | Location: Condamine catchment area | © Department of Climate Change, Energy, the Environment and Water (taken by staff)

All other images © Department of Climate Change, Energy, the Environment and Water unless specified otherwise.

Information guidelines for proponents preparing coal seam gas and large coal mining development proposals

February 2024





Contents

Background	1
The role of the IESC	1
Purpose and scope of the Information Guidelines	2
Explanatory Notes.....	2
The nature of advice from the IESC	3
Information to provide in the proposal	5
General requirements	5
Specific requirements.....	5
1. Description of the proposed project	7
2. Environmental impact assessment	8
2.1 Risk-based assessments	8
2.2 Impact pathway diagrams and other conceptual models.....	9
2.3 Modelling of water storage and movement	9
2.4 Water and salt balances	11
3. Baseline data	12
4. Monitoring and management.....	14
5. Cumulative impacts.....	16
Glossary.....	17
Supporting documents.....	21
Appendix A – Checklist of specific information needs	24
Description of the proposed project.....	25
Environmental impact assessment.....	26
Baseline data	34
Monitoring and management	35
Cumulative impacts.....	37



Background

The role of the IESC

The Independent Expert Scientific Committee on Unconventional Gas Development and Large Coal Mining Development (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 on unconventional gas and large coal mining development proposals that are likely to have a significant impact on water resources (as defined in Box 1)
- provide scientific advice to the Commonwealth Environment Minister on [bioregional assessments](#) (CoA 2020a) for areas of coal seam gas (CSG) and large coal mining development
- provide scientific advice to the Commonwealth Environment Minister on research priorities and projects
- collect, analyse, interpret and publish scientific information about the impacts of unconventional gas and large coal mining activities on water resources
- provide scientific advice on other matters in response to a request from the Commonwealth or relevant state ministers.

On 15 December 2023, the Nature Repair (Consequential Amendments) Act 2023 amended the EPBC Act to expand the IESC's remit to all unconventional gas developments. This publication was developed prior to these amendments of the EPBC Act commencing.

Further information on the IESC's role is on the [IESC website](#).

Box 1. Definition of 'water resource'

In everyday use, the term 'water resource' usually refers to surface water or groundwater that is or can be exploited for human uses. However, the legislative definition of water resource in the *Water Act 2007* (CoA 2007) and used in these Information Guidelines is much broader:

(a) *surface water or ground water; or*

(b) *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).

The IESC recognises that these 'aspects of the water resource' encompass the biodiversity, ecological condition and biogeochemical processes of all water-dependent ecosystems. As well as aquatic biota, such ecosystems include microbes, plants and animals in the fringing zones of rivers and swamps, groundwater-dependent biota living in aquifers, and vegetation that occasionally or solely relies on groundwater. Furthermore, many of these water-dependent ecosystems are hydrologically linked to each other (e.g., during flooding, via groundwater flowpaths or when ephemeral streams flow). These hydrological linkages are essential to the biodiversity and ecological condition of connected water resources and contribute to their physical state and environmental value.

In these Information Guidelines, the terms ‘water-dependent asset’ and ‘water-dependent ecological asset’ are sometimes used as synonyms for ‘water resource’ as defined above.

Purpose and scope of the Information Guidelines

These Information Guidelines outline what types of information should be included in a proposal for a CSG or large coal mining project. This information is needed for the IESC to provide robust scientific advice to government regulators on the potential impacts of proposed projects on water resources as defined in Box 1. The Information Guidelines could also be used to inform the development of environmental impact assessments for other proposed projects.

The Information Guidelines were first published in February 2013. They were reviewed and amended in April 2014, June 2015, May 2018 and January 2024 to update reference material, cover developments in leading practice and knowledge, take account of the IESC’s recent experience and incorporate comments from users.

Despite these revisions, the scope of the Information Guidelines has remained the same because the role and legislative functions of the IESC (see earlier) have not changed. Therefore, this document does not include guidance on assessment of potential impacts of proposed CSG or large coal mining projects on cultural and spiritual values of water resources to Indigenous and other users or on the water needs of other industries such as forestry or agriculture. It also does not cover potential impacts on particular issues in specific regions (e.g., CSG and subsidence in parts of Queensland). As the IESC’s role is purely scientific and not regulatory (see earlier), these guidelines do not review processes and consultation with regulators and other relevant agencies. Finally, this document also does not cover aspects of economics or social licence for proposed projects – again, these topics are beyond the IESC’s remit.

Explanatory Notes

For some topics, Explanatory Notes supplement the Information Guidelines by giving detailed guidance to help proponents prepare their environmental impact assessments. Topics are chosen based on the IESC’s experience of providing advice on over 150 development proposals.

Explanatory Notes are available (or soon will be) for the following topics:

- [Uncertainty analysis – Guidance for groundwater modelling within a risk management framework](#)
- [Assessing groundwater-dependent ecosystems](#)
- [Deriving site-specific guideline values for physico-chemical parameters and toxicants](#)
- [Characterisation and modelling of geological fault zones](#)
- [Subsidence associated with underground coal mining](#)
- [Subsidence associated with coal seam gas production](#)
- [Using impact pathway diagrams based on ecohydrological conceptualisation in environmental impact](#)

Explanatory Notes describe up-to-date robust scientific methods and tools for specific components of environmental impact assessment. Case studies and practical examples of how to present certain information are also discussed. Proponents are encouraged to refer to issues of relevance to their particular project, recognising that the Explanatory Notes provide detailed guidance rather than mandatory requirements.

The IESC acknowledges that approaches, methods, tools and software will continue to develop. The Information Guidelines, Explanatory Notes and Fact Sheets will be reviewed and updated as needed. New Explanatory Notes will be prepared as needed.

The [IESC website](#) also provides links to reports from commissioned studies and reviews that may be useful for proponents.

The nature of advice from the IESC

The IESC provides scientific advice to regulators on potential direct, indirect and cumulative impacts of unconventional gas and large coal mining development proposals on water resources (as defined in Box 1). The IESC can also provide scientific advice to the Environment Minister in relation to a matter that is protected by a provision of Part 3 of the EPBC Act, or to an appropriate state or territory minister in relation to matters specified in a request, where the IESC has sufficient scientific expertise (section 505D of the EPBC Act). The IESC does not make regulatory decisions. Advice is provided in response to a request from the Australian Government or from a declared state or territory government (i.e., New South Wales, Queensland, South Australia or Victoria). The science-based advice and consideration provided by the IESC are designed to support regulators in their decision-making.

Commonwealth and relevant state regulators (in accordance with section 505D of the EPBC Act) seek advice from the IESC at appropriate stages in the assessment and approval process as per the relevant protocols. In accordance with section 505D(1) of the EPBC Act, the IESC is required to provide advice to the regulator within two months of accepting a request for advice. This advice must be published no later than 10 days after it is provided to the regulator. Regulators can request advice on a project multiple times during the assessment process.

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

- used suitable data, information and modelling to identify and characterise all relevant water resources as defined in the Commonwealth *Water Act 2007* (see Box 1)
- applied appropriate methods in a logical and reasonable way to investigate the risks to those water resources from the proposed project, including using impact pathway diagrams developed from evidence-based conceptualisations
- addressed the inevitable uncertainties in predictions of potential impacts on water resources through appropriate data collection, analysis and discussion
- adequately described appropriate avoidance or mitigation strategies to prevent or reduce potential impacts on water resources
- specified and justified rehabilitation strategies for water resources affected by the project
- proposed effective monitoring and management procedures to detect and ameliorate the risk of potential impacts on water resources, and to assess the effectiveness of proposed mitigation strategies and other management measures
- considered potential cumulative impacts from past, present and reasonably foreseeable actions.

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

- the likely risks to water resources as defined in Box 1

- the adequacy of water and salt balances and of local- and regional-scale groundwater and surface water models, and any implications for water quantity and quality
- whether the information used and methods applied are fit for purpose, and whether the assessment of risk and uncertainty is appropriate
- the residual risks that need to be addressed
- the adequacy of proposed environmental management measures for mitigating residual risks, including for legacy issues such as groundwater level and water-table recovery, rehabilitation and restoration, final land use, closure, residual voids and brine management
- the potential cumulative water-related impacts of the proposed project in the context of past, present and reasonably foreseeable actions.

Information to provide in the proposal

General requirements

The proposal should present sufficient evidence for independent verification of:

- the processes of cause and effect between the project's proposed activities and water resources (as defined in Box 1)
- the materiality and likelihood of the potential impacts on and risks to water resources.

Sufficient information should be provided to allow an independent reviewer, such as the IESC, to consider the appropriateness of assertions made in the environmental assessment documentation. For example, these would include assumptions underlying conceptual and numerical models, claims about why an activity would not significantly affect the physical state or environmental value of a water resource, and justification of proposed mitigation strategies to minimise potential environmental impacts of the project. If any potential impacts are considered to not require further assessment – for example, due to demonstrable lack of materiality of the risk – proponents should clearly document these decisions and provide appropriate scientific evidence.

In short, the environmental assessment documents should provide enough credible evidence for an independent reader to be able to verify all significant conclusions made by the proponent.

Specific requirements

Available information will vary for individual proposals, depending on the point in the regulatory assessment process at which the proposal is referred. The type and amount of information provided to the IESC will also vary depending on whether the project is a new development or an expansion of an existing operation.

Documentation provided to the IESC must contain the most comprehensive information possible and include all relevant data. For example, this could include historical water quality data to demonstrate compliance with existing conditions, bore logs to support geological conceptualisations, and results of pump tests to support model parameterisation. This is particularly relevant for existing mines undergoing modification/extension or in regions where there are abundant historical data.

Early in the assessment process (e.g., for Gateway projects in New South Wales), preliminary conceptual and numerical or analytical models should consider all available data and be used to identify further data that may be needed. Conceptual models should identify all water resources and their associated water-dependent ecosystems in the project area and surrounding areas, specifying their significance under state and Commonwealth legislation. Impact pathway diagrams based on ecohydrological conceptualisation (see Box 2) are needed to help identify and portray potential stressors and exposure pathways by which the proposed project may impact these water resources.

At the assessment stage, there is expected to be clear and evidence-based determination of potential significant impacts on water resources within and near the project area, supported by detailed conceptual models and, where needed, analytical and numerical models. Modelling should be at spatial and temporal scales suitable to represent physical, chemical and ecological processes associated with each identified water resource and its associated water-dependent ecosystems (as defined in Box 1). The information provided should include a comprehensive assessment of the risks to each water resource from the proposed project at all phases (i.e., construction, operation and post-closure), and details of proposed mitigation measures to manage these risks.

Box 2. Using impact pathway diagrams based on ecohydrological conceptualisation in environmental impact assessment

Impact pathway diagrams (IPDs) illustrate how impacts of a proposed project are predicted to affect water resources (receptors), what the potential pathways of the impacts from sources to receptors are, and how these pathways might interact with each other. When superimposed on maps of the project area, IPDs also indicate where such impacts might occur. As most impact pathways affecting water resources are ecohydrological, IPDs are usually based on an initial ecohydrological conceptualisation that integrates hydrological (surface water and groundwater) components and processes with ecological components (e.g., specific taxa, communities and ecosystems) in the project area.

IPDs should be drawn up early in the assessment process, following conceptualisation, and refined as more data become available. The process of generating these diagrams helps the team of consultant experts who are doing the assessment to share their understanding and knowledge, discuss where and how pathways might operate, and agree on what site-specific baseline data are needed.

The products provide effective visual summaries of potential impact pathways. They can be presented at multiple levels (as ‘sub-models’) and superimposed on maps of the project area. They indicate pathways where mitigation is feasible and can guide project-specific monitoring (e.g., relevant parameters and sampling locations) to assess the effectiveness of proposed mitigation strategies.

More details and examples are provided in the [Explanatory Note on IPDs](#).

Proposals for expanding or modifying existing mining operations should outline historical and existing activities, current water-related environmental approval conditions, and associated monitoring data and management plans.

These proposals should:

- clearly identify any potential impacts on water resources from existing actions, the proposed expansion or modification (and multiple stressors associated with it) and cumulative impacts from other actions in the area
- use and present current and historical monitoring data to justify assertions about impacts
- use and present existing project data to verify model predictions
- outline how existing data have been used to assess the potential impacts of the proposed project.

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

The text below provides general guidance on information needed by the IESC. A checklist of specific information requirements is provided at **Appendix A – Checklist of specific information needs**. This will assist proponents and regulators to provide appropriate information to support their requests to the IESC for advice.

1. Description of the proposed project

The proposal should provide a regional overview of the project area, including descriptions and appropriately scaled presentations of the geological basin, coal resource, surface water catchments, groundwater systems and all water resources (as defined in Box 1) that need to be considered in the assessment. It should also describe historical, current and reasonably foreseeable coal mines, CSG developments and other water-intensive activities, including water storages and irrigation.

The proposal should clearly describe the project's location, purpose, scale, duration, disturbance area and water supply, and the means by which the project is likely to have an impact on the quantity and quality of each water resource in and near the project area. For a mine expansion that will use existing approved infrastructure, the proposal should clearly identify which components are new and which components are to be modified (e.g., residual void relocated).

The proposal should also describe the statutory context, including information on the proposal's status within the regulatory assessment process, and any applicable water management policies or regulations, including state or Commonwealth regulation of potentially impacted water resources.

2. Environmental impact assessment

The fundamental goal of environmental impact assessment is to evaluate the risks of impacts of a proposed project on environmental assets, including water resources (as defined in Box 1). Such risk-based assessments should address the likelihood and consequences (risk) of impacts and their potential cause–effect pathways for each phase (i.e., pre-development activities where relevant, development, production, closure and rehabilitation) of the project.

The intensity, duration, magnitude, timing and geographic extent of each potential impact should be described in the environmental impact assessment. This description should specify the impact’s significance and consequences, especially for the environmental condition and human values of each water resource. For proposed expansions or modifications, the description should distinguish potential new impacts, or increases in magnitude of existing impacts, from those arising from existing approved projects. For all proposals the likely contribution of the proposed project to potential cumulative impacts must be clearly identified. Ideally, the significance of the impacts should be assessed with reference to the range of system behaviour found under pre-development conditions and natural environmental and climatic variability.

Where relevant, potential impacts on water resources should be compared with project-specific environmental objectives and the legislated objectives for surface waters and groundwaters under relevant state and national environmental legislation – for example, the ANZG (2018) guidelines and regional water quality guidelines developed by state agencies.

2.1 Risk-based assessments

Risk-based assessments should commence with the proponent consulting relevant stakeholders and regulators to determine the nature of the action and which assets, including water resources, may be impacted. This initial engagement should include agreement about the likely sources of impacts and the receptors that may be affected – the start and end points of the IPDs that will be developed by the team of experts who are doing the assessment to infer likely impact pathways and their associated risks (see Box 2 and Section 2.2).

Modelling and uncertainty analyses are also useful to investigate risks and assess the value of collecting additional data to reduce uncertainties associated with the key risks (see Section 2.3). Risk assessment is iterative: as new information (e.g., from baseline surveys; see Section 3) becomes available, models and risk assessments can be refined to reduce the remaining uncertainty. This also applies to the development of site-specific water and salt balances for both pre- and post-development scenarios under a range of potential climatic conditions (see Section 2.4).

Effort should focus on the aspects of water resources that are at greatest risk. To do this, the proponent will need to determine the scale, likelihood and consequences of all potential impacts that might arise from the project. Examples of impacts include uncontrolled discharges, containment failure, drilling and hydraulic stimulation chemicals, altered surface drainage, and potential waste contaminants (e.g., brines).

Having identified potential risks of the project to water resources and other receptors, the proponent must specify where these risks can be either avoided or mitigated, and describe how monitoring will be able to demonstrate the effectiveness of the mitigation measures (see Section 4). In particular, risk-based assessments should consider potential cumulative impacts of all past, present and reasonably foreseeable actions and activities that are likely to impact on water resources, including from multiple stressors arising from the proposed action (see Section 5).

The IESC will evaluate the proponent's assessments of risk and uncertainty, in conjunction with information provided by the regulator's request for advice. Contextual information relevant to the risk assessment may include bioregional assessments, Commonwealth and state water resource plans (e.g., Murray–Darling Basin Plan, Hunter River Salinity Trading Scheme) and state processes such as those that apply in the Surat Cumulative Management Area and the Commonwealth's Joint Industry Framework on Coal Seam Gas.

2.2 Impact pathway diagrams and other conceptual models

IPDs (see Box 2) are a fundamental tool in risk-based assessment to conceptualise the risks and likely mechanisms by which a proposed project might adversely affect water resources and other receptors. As most of these mechanisms are ecohydrological, generating IPDs usually begins with an initial ecohydrological conceptualisation to integrate hydrological (surface water and groundwater) components and processes with ecological components (e.g., specific taxa, communities and ecosystems) in the project area.

Superimposing IPDs on maps, or 3D cross-sections, of the project area helps show where such impacts might occur and reveals potential high-risk 'hot spots' where monitoring and mitigation measures are most likely to be needed. This mapping of areas of high risk, along with suitable supporting information and evidence to justify the risk-based assessment, is an important part of risk-based assessment.

IPDs and other conceptual models used in risk-based assessments usually draw on multiple information sources. For example, geological conceptual models typically use relevant maps, field data, expert knowledge and scientific information to identify the geological formations in and near the project area, water resources that may be impacted by the proposed project, and how geological features such as faults, fractures and aquitards could respond to or affect potential impact pathways. The models should be developed at appropriate scales to capture inherent variability within measured parameters (e.g., within geological formations), how these may be influenced by the proposal, and the expected impacts on water resources in and near the project area.

Combining conceptual models with appropriate risk analyses may be sufficient to express the level of uncertainty so that analytical and numerical models are not required or may only need to be developed to test a particular impact pathway. Proponents should assess uncertainty to a level of detail commensurate with the potential risks and consequences of the project.

Further information regarding conceptual modelling can be found in CoA (2015) and DCCEEW (2023). Research reports commissioned by the IESC (see the [IESC website](#)) may also be helpful in preparing project-specific conceptualisations.

2.3 Modelling of water storage and movement

Often key site characteristics and potential impacts are assessed using analytical or numerical models. Prior to modelling, a clear list of objectives is required. This specifies the quantities of interest to be assessed, the spatial extent and duration of the assessment, the key processes to be included, suitable spatial and temporal resolutions, and the data required (see sections 3 and 4 also). Site-specific data should be obtained to parameterise numerical models whenever possible. More than one model or a combination of analytical and numerical models may be required to model the behaviour of groundwater, surface water and the interaction between the two, especially if the objectives require sharply differing scales and levels of detail. Conceptual models (see Section 2.2) and the objectives should inform the design of the model (e.g., the level of model complexity needed to achieve its purpose). Assumptions should be clearly described and justified in the project assessment documentation.

The model design should incorporate climate scenarios appropriate to the project area and proposed duration, including recovery of groundwater levels post-closure. New or refined models may be needed after approval of the project. There is unequivocal evidence that greenhouse gas emissions have caused global warming (IPCC 2023), and accordingly all climate scenarios need to account for global warming that may have occurred since historical observations were collected, and for warming that will occur in the future. Guidance on the broad approach to be taken with climate risk assessment can be found in DCCEEW (2023). Specific guidance on climate projections can be obtained from CSIRO and the Bureau of Meteorology (see the [Climate Change in Australia website](#)) – noting that more localised projections have been produced for some areas of Australia by state and territory agencies, as summarised under [Future climate change](#) on the DCCEEW website.

Results from modelling should show the range and likelihood of possible outcomes, based on sensitivity and uncertainty analysis. These predictions should be sufficiently robust to support risk analysis and regulatory decision-making. Peeters and Middlemis (2023) provide further discussion of sensitivity and uncertainty analysis in relation to groundwater modelling and the IESC’s information needs.

Water storage and movement models support decision-making by the regulator. They should therefore:

- incorporate all pertinent data, assimilating new data during model updates
- characterise uncertainties of predictions and assess sensitivity of predictions to key assumptions so that risks can be associated with intended management actions
- consider model simplifications and abstractions when assessing these uncertainties
- ensure that possible structural variability is adequately captured, which may require multiple conceptualisations with associated numerical models
- ensure that parameter and other variability is represented in the range of outputs through uncertainty analysis so that the uncertainties of decision-critical model predictions are not underestimated and management of risks is not understated.

The IESC appreciates that this last point may be difficult to achieve. However, this issue can be addressed if the models are seen as a structured repository for environmental data and a means of analysing these data. When data are limited and/or probabilities are not initially quantified, it is sometimes possible to develop a set of suitably conservative modelling scenarios which can provide information on the risk level and may indicate whether a quantitative uncertainty analysis is needed.

The proponent should also consider how models will be used to inform monitoring and management (see Section 5) during the project. For example, the model may identify knowledge gaps, where uncertainty can be reduced through additional strategic data collection. Structural and parameterisation complexity must be considered in the design of a decision-support model; a model’s parameters are as important as its structure (Peeters and Middlemis 2023).

For projects presented to the IESC early in the assessment process (e.g., Gateway projects in New South Wales), the data needed for detailed modelling may not yet be available. Analytical models assessing potential impact pathways derived from the initial conceptual modelling and risk assessment will often be sufficient at this stage of the process.

In some circumstances, it may be appropriate for uncalibrated models to be used. This does not preclude a proponent from acquiring baseline data (see Section 3), but it does heighten the need to carefully justify the adopted parameterisation with reference to physical reasoning, other modelling and regional information.

2.4 Water and salt balances

The proposal should provide site-specific water and salt balances for both pre- and post-development scenarios under a range of potential climatic conditions (guided by, for example, the [Australian Climate Futures Tool](#) developed by CSIRO). These balances should illustrate all surface water and groundwater inputs, outputs and diversions in and near the project area.

The water and salt balances should use consistent water metrics and definitions and be accompanied by relevant contextual information and statements of accuracy. The assessment documentation should provide a water-accounting framework (Minerals Council of Australia 2022) that describes an input-output statement for each site, including an accuracy table which provides information on the accuracy of the data and whether the data used were measured, estimated or simulated.

Information is needed about water and salt stores for the site and the movement of water and salt between stores, tasks (e.g., coal handling and processing, dust suppression, underground mining) and treatment plants within the site. This should include discussion on the implications for water resources regarding:

- estimates of water use in open-water evaporation and evapotranspiration, including seasonal and interannual variations
- predicted changes to vegetation water use and access as a result of the proposed project
- assessment of the potential impact of any changes to any take, store or flow of water and mass or concentration of salt, including long-term storage, arising from the proposed project.

Estimates of the quality and quantity of external water supply and operational discharges under dry, median and wet conditions should be provided. Volumes and quality of operational discharges and beneficial uses during and after the project should be described and predicted.

For new CSG projects, there is a large degree of uncertainty around produced water volumes and salt loads. Despite this, estimates of water and salt volumes are required, and the uncertainty associated with these estimates should be quantified in the assessment documentation. Proposed management options for flowback and produced waters are required. In addition, management options for waste salt and brines, including associated contaminants in the brines, should be specified over short- and long-term time scales and after project closure.

3. Baseline data

Before a development begins, baseline data, also called pre-operational data, are collected to establish conditions against which impacts can be identified after activities commence. These data must reliably capture the state of all potentially impacted water resources (as defined in Box 1) and other relevant environmental components and processes. Therefore, they need to be collected from all areas of the likely footprint of the development, including downstream and along relevant groundwater gradients, at sufficient spatial resolution and for an adequate time period to capture natural background variability and the effects of existing activities.

Baseline data also need to be concurrently collected from comparable areas where impacts are not predicted. These ‘control’ areas (Downes et al. 2002) are chosen to be as similar as possible to the potentially impacted areas so that after the development begins, conditions in the control areas can be compared with those in impacted areas (discussed further in Section 4). Ideally, baseline data should also be collected from ‘reference’ areas where human disturbance is minimal (Downes et al. 2002). However, suitable reference sites are not always available and it is more realistic to compare baseline data between control and potentially impacted areas, because pre-existing human influences are captured in the control areas.

Reliable baseline data are essential for all proposed projects. They should span all key parameters that may be potentially affected by the development, as indicated by appropriate IPDs (see Box 2). Each parameter must be rigorously measured and presented with all requisite technical information. For example:

- baseline monitoring data for contaminants (e.g., metals and metalloids) in surface waters and groundwaters should be compared to the national/regional guidelines or to site-specific guidelines (Huynh and Hobbs 2019)
- baseline hydrochemical data from surface waters and groundwaters should be provided
- baseline groundwater data should be presented from representative monitoring bores, with full details on bore characteristics such as depth and lithology
- surface flow data, ideally from stream gauges in or near the project area, should be provided as hydrographs that illustrate ecologically relevant flow components (e.g., timing and durations of low- and zero-flow periods)
- ecological baseline data should be sufficient to describe habitat conditions, biodiversity and distributions of plants and animals, as well as likely stressors (e.g., Doody et al. 2019) in potentially impacted water resources and suitable control areas
- information from bioregional assessments or previous site-specific monitoring (e.g., for an existing project) should be included where applicable.

Importantly, baseline data should be collected at suitable spatial and temporal resolutions for each parameter so that significant changes can be detected when the development commences (see Section 4). Sufficient data are needed to underpin robust statistical assessment of baseline conditions to ensure that the natural variability of the system is fully quantified. Data adequacy depends heavily on the specific processes being assessed. Sampling intensity may therefore need to be specific for each parameter and should be justified based on insights from the project’s risk-based assessment (see Section 2).

Baseline groundwater and ecological data may need a longer collection period compared to surface water data because these systems typically respond more slowly to change than surface water systems. As a minimum, ecological

and hydrological baseline data for the project and control areas should be collected for at least two years before development begins, sampling at a frequency sufficient to capture likely variability in the system (e.g., seasonal changes). Given the natural variability in large-scale climate patterns in Australia (such as the El Niño-Southern Oscillation), it would be desirable to have 10 or more years of baseline data. Where necessary, short periods of data can be extended using regression relationships with longer records collected at nearby sites (and with other physically informed statistical or process modelling techniques where justified), but such analyses must ensure that the sites used are not impacted by factors unrelated to climate. The period of baseline data obtained from observations and/or reconstructions through statistical and other modelling techniques should be selected to provide an understanding of system behaviour over extended periods of wet and dry sequences, consistent with the wide range of natural variability of Australia's climate.

During baseline data collection and synthesis, key areas of uncertainty identified in conceptual models and risk-based assessments should be considered and field programs targeted to reduce these uncertainties where possible. Common areas of uncertainty in CSG and coal mining developments include connectivity between geological formations and water-dependent assets, source water for groundwater-dependent ecosystems (GDEs), and the hydraulic properties of faults and aquitards.

Baseline data should be provided and presented clearly (e.g., in graphs, maps and tables) and subject to appropriate analysis. Data should be presented in full to show the ranges of values, ensuring that extremes are not disguised by only presenting means. Proponents should specify how the baseline data have been used in the proposed project's risk assessment (e.g., assessing 10th and 90th percentiles of these data to explore potential consequences of impacts), the design of the monitoring program, and the intended evaluation of the effectiveness of mitigation and management strategies. Choice of parameters and sampling methods for these baseline data must be justified, especially where they are likely to be used in surveillance monitoring if the project goes ahead (see Section 4). Integration of physical, chemical and ecological baseline data is crucial to present a coherent understanding of pre-development conditions in and near the project area.

4. Monitoring and management

Appropriate monitoring is essential so that the proponent can (1) detect any impacts of the project on water resources (as defined in Box 1) and other valued assets, and (2) assess the effectiveness of mitigation measures used to minimise impacts. Typically the same parameters and methods used to collect baseline data (see Section 3) are monitored in control and potentially impacted areas. As before, spatial coverage and temporal sampling frequency for each parameter should be sufficient to detect changes that may be associated with the project's activities.

Detailed monitoring and management plans are expected where significant impacts on water resources are predicted. These plans should describe how the project-specific monitoring program will guide the management and mitigation of likely impacts. In particular, the monitoring plan should explain how the effectiveness of mitigation strategies will be measured. The plans should be flexible enough to capture unexpected or emerging issues, including extreme weather events such as the effects of floods or drought.

Integration of physical, chemical and ecological data with relevant processes is important. For example, the likelihood, severity and materiality of impacts on a specific GDE from drawdown in a particular aquifer could inform the design of the project's environmental monitoring program. Depending on the outcomes of the risk-based assessment, additional investigation may be required to address gaps in knowledge and data about potential impacts on specific water resources and their environmental values. Monitoring intensity is usually commensurate with the value of the water resource and its vulnerability to project-specific impacts.

The monitoring program for water resources should assess all potentially impacted surface waters and groundwaters for their water quality, hydrological regime and ecological attributes, particularly the implications of hydrological connectivity between water resources within and near the project area. The proposal should explain how baseline data from control and impacted sites will be used to identify potential impacts and separate these from background variations (e.g., climatic variability). This can be done using a before-after-control-impact (BACI) model design, preferably with multiple control and impacted sites to capture background variability (reviewed in Downes et al. 2002).

The rationale and design for the monitoring program should be clearly articulated. The questions to be addressed by the monitoring program must be clearly stated, specifying and justifying the spatial resolution and temporal frequency of monitoring, the parameters to be monitored, appropriate quality assurance/control, and intended analytical methods. Where methods vary from standard ones, the reasons for these differences should be explained. Choice of monitoring parameters and sampling regime will be informed by the risk-based assessment (see Section 2) and baseline data collection (see Section 3).

The project-specific monitoring program should complement other monitoring requirements imposed by state regulation of water resources and project approvals. Where possible, the monitoring plan should specify thresholds associated with local- and regional-scale environmental objectives and describe the proposed management and mitigation measures if those thresholds are exceeded. Guideline values should be based on leading-practice science (as outlined by Huynh and Hobbs 2019). Planned departures from published guidelines should be justified in the proposal (e.g., using site-specific data). Based on water quality guidelines currently being developed that incorporate water chemistry influences on metal bioavailability, it is also recommended that pH, water hardness (calcium and magnesium), alkalinity and dissolved organic carbon (DOC) concentrations are measured in matched samples when collecting data on total and dissolved metals. This is because these water chemistry parameters, particularly DOC, influence metal bioavailability and potential toxicity.

Groundwater models developed for the approval process may not be appropriate to guide monitoring of impacts. New models may need to be developed for the post-approval phase, especially if further data are needed to improve predictions and reduce uncertainty. Management plans should explain how these new models will improve the effectiveness of the proposed monitoring and mitigation measures, and what options exist for updating models and plans as new information becomes available.

Many plans include trigger action response plans (TARPs). These define the required actions if a threshold is, or is about to be, exceeded. TARPs should be robust, logical and explicitly linked to environmental objectives and the monitoring program's design. For timely responses, monitoring should be sensitive enough to detect impacts either just before they occur or soon afterwards. In this way, mitigation measures are more likely to be effective at preventing or minimising damage.

Proposed management and mitigation measures should be explained in detail and justified by reference to previous studies and scientific literature that support the success and feasibility of the measures in the project's context. The proposal should specify contingency plans if the environmental objectives are not met. If offsets are proposed, the potential management options, including avoidance and mitigation, that were considered prior to proposing offsets should be described. The proponent should also explain how the proposed management strategies will address long-term risks and legacy impacts that may persist after rehabilitation and relinquishment of the site.

There is a statutory requirement for land disturbed by mining activities to be progressively rehabilitated as a safe and stable landform that does not cause environmental harm and is able to sustain one or more approved post-mining land uses (PMLUs). In addition to describing the consultation with regulators and the community about the intended PMLUs, ideally these plans should specify and justify the methods and techniques proposed to achieve particular rehabilitation milestones for protection or restoration of water resources, and how their effectiveness will be monitored. In some cases, the methods may be limited by project-specific features (e.g., topography, climate, geology and hydrology); these constraints must be fully explained. For example, the geochemistry of waste rock might constrain the types of vegetation that can be established.

Ideally the effectiveness of the proposed rehabilitation methods can be illustrated with reference to examples of their successful application in equivalent locations nearby. Where such examples are unavailable, the rehabilitation plan must use relevant literature to support the choice of rehabilitation techniques and describe a targeted monitoring program that specifies parameters, sampling frequency and methods for demonstrating successful achievement of the targeted PMLUs across the project area after mining or CSG extraction has finished. These monitoring programs should be linked to explicit milestones for completion of progressive stages of rehabilitation, and should include appropriate baseline data against which to judge the effectiveness of the rehabilitation of water resources.

5. Cumulative impacts

Cumulative impacts typically result from the collective and interacting effects of multiple stressors that arise from multiple sources and/or activities. For example, the collective impacts of stressors such as surface water extraction, native vegetation clearance and groundwater drawdown from several adjacent mines may combine with these and other stressors arising from nearby activities such as agriculture and urbanisation to cumulatively impact on water resources (as defined in Box 1). These collective impacts often interact (synergistically, additively or antagonistically) in ways that can be hard to predict.

A proposal must include an assessment of potential cumulative impacts of the planned development and its activities, particularly focusing on how these impacts may interact with each other and with existing and potential impacts of other developments within the region. Interactions with broader-scale drivers such as climate change also need to be evaluated.

This assessment needs to consider all relevant past, present and reasonably foreseeable activities, including the potential impacts from water-intensive activities other than mining and CSG development. Even if potential impacts from a proposed project are small, the cumulative impacts on water resources may be substantial when combined with the impacts from existing developments. This is especially true if a threshold or ‘tipping point’ is exceeded that leads to a severe impact on a water resource (e.g., exceeding the salinity tolerance of key species). Monitoring programs (see Section 4) should explicitly specify how data will be collected to indicate that these thresholds are being approached. TARPs must be presented that describe the intended management response and justify its feasibility.

The spatial and temporal scale of a cumulative impact assessment must be large enough to include all potential impacts on water resources from the proposed project when considered with likely impacts from other activities within the region (CoA 2014a; Kaveney et al. 2015). For example, where predicted impacts from the proposed development (e.g., groundwater drawdown and impacts on GDEs) may overlap with those from another activity, then that activity must be evaluated in the cumulative impact assessment. Where data are not publicly available, the assumptions used to estimate impacts should be provided in sufficient detail to allow uncertainties to be identified. Cumulative impact assessment also includes post-closure impacts, acknowledging that some impacts (e.g., movement of saline groundwater) may occur after mining ceases.

Although a proponent’s cumulative impact assessment will focus on the project area, the regional context is relevant because cumulative impacts often extend well beyond the development footprint. Therefore, a proposal should seek information from regional assessments such as strategic assessments, bioregional assessments and Cumulative Management Area models such as that developed by the [Office of Groundwater Impact Assessment](#) in Queensland.

There may be a need to further develop groundwater and surface water models to enable the prediction of cumulative impacts (i.e., model outcome transferability). Compatibility of model assumptions (e.g., boundaries and parameters, at least) may need to be reviewed for a regional analysis, along with resultant uncertainty metrics.

A quantitative assessment of cumulative impacts is preferred. However, a qualitative or semi-quantitative approach may be used if data for other developments or activities are not publicly available and cannot be estimated. Cumulative impact assessment is a key opportunity for stakeholder engagement and input, especially given the shared concern about managing cumulative impacts of multiple developments in an area. Predicted outcomes of the cumulative impact assessment should also be discussed in the context of broader drivers such as climate change.

Glossary

The definitions that follow are for the purposes of these Information Guidelines.

Term	Description
Analytical models	make simplifying assumptions (for example, properties of the aquifer are considered to be constant in space and time) to enable an exact mathematical solution of a given problem.
Assessment documentation	is all documentation required by the relevant 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 (see Downes et al. 2002). At a minimum, a BACI design requires data from two sites: a control site and an impact site. Data are collected from both sites a number of times before and after the impact occurs.
Baseline data	also called pre-operational data, are collected before a development begins, to establish conditions against which impacts can be identified when developments commence.
Bioregional assessments	are 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 (see the Bioregional Assessments website).
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 simplified representation of a system of interacting components and their linkages, widely used in many disciplines as a powerful tool for developing understanding and communicating relationships among components in complex systems. In hydrology, for example, a conceptual model is usually represented as a set of equations or functional relationships that describe the major processes and variables involved in the movement of water and/or materials through the system.
Control sites	are sites outside the predicted footprint of the project that are chosen to be as similar as possible to potentially impacted areas so that after the project begins, conditions sampled in the control sites can be compared with those from sites in impacted areas to detect any effects of the project (Downes et al. 2002).

Term	Description
Cumulative impacts	typically result from the collective and interacting effects of multiple stressors that arise from multiple sources and/or multiple activities. For example, collective impacts of stressors such as surface water extraction, native vegetation clearance and groundwater drawdown from several adjacent mines may combine with these and other stressors arising from nearby activities such as agriculture and urbanisation to cumulatively impact on water resources (as defined in Box 1).
Ecohydrological conceptualisation	is a conceptualisation that integrates hydrological (surface and groundwater) components and processes with ecological components (e.g., specific taxa, communities and ecosystems) in an area to show the likely pathways by which water resources are linked. This conceptualisation is a crucial initial step in generating IPDs (see Box 2).
Ecological processes	are interactions between the environment and organisms that contribute to the physical state and environmental value of a water resource (as defined in Box 1). Examples include nutrient cycling and carbon metabolism.
Environmental objectives	for each water resource (as defined in Box 1) are the desired goals that, if met, indicate that the project is not expected to have an unacceptable impact on the environment.
Environmental outcomes	are statements of an acceptable level of impact on a water resource (as defined in Box 1) that must not be exceeded, or a level of protection that must be achieved. The outcomes will be aligned with an environmental objective and must be quantitatively measurable, auditable and achievable.
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 groundwater-dependent terrestrial vegetation, wetlands (swamps, lakes and rivers) and ecosystems in aquifers and caves.
Guidelines	with reference to water quality are a numerical concentration limit or narrative statement recommended to support and maintain a designated water use (ANZG 2018).
Impact pathway diagram (IPD)	is a conceptual model, often presented as a box-and-arrow diagram, that is used specifically to understand and communicate potential impact pathways between sources and receptors in an environmental impact assessment (see Box 2)
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.

Term	Description
Numerical models	are computer codes that enable simulation of physical systems and processes such as groundwater or surface water flow and can be applied to assess the potential impacts of a proposed project. They are similar to analytical models as they make simplifying assumptions; however, features of the governing equations and boundary conditions (for example, 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 or surface water system than could be achieved with an analytical model.
Pre-development	refers to the conditions prior to the commencement of the proposed activity. The pre-development conditions may include impacts from currently approved activities (e.g., where the proposal is for an extension of an existing mining operation).
Receptor	is the ecological entity exposed to one or more stressors in an impact pathway diagram.
Significant impact	is defined by the Significant Impact Guidelines (CoA 2022) as ‘an impact which is important, notable, or of consequence, having regard to its context or intensity’.
Subsidence	usually refers to deformation of the surface (and underlying sub-surface strata) as a result of underlying mining extraction. ‘Subsidence’ is primarily used to describe vertical deformation (and related strains) but also includes a component of horizontal deformation, away from the centreline of the extraction area.
Stressor	is any natural or anthropogenic physical, chemical or biological entity that can cause an impact.
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 assets	are entities whose characteristics have value and which can be linked directly or indirectly to a dependency on water quantity and/or quality (amended from Barrett et al. 2013). Examples include habitat for threatened species and rights to water access. Value includes drinking water, public health, recreation and amenity, Indigenous and cultural values, fisheries, tourism, navigation, agriculture and industry values.
Water-dependent ecosystems	are defined by the <i>Water Act 2007</i> (Cth) as surface water ecosystems or groundwater ecosystems, and their natural components and processes, that depend on periodic or sustained inundation, waterlogging or significant inputs of water for their ecological integrity; they include ecosystems associated with a wetland, stream, lake or waterbody, salt marsh, estuary, karst system or groundwater system. A reference to a water-dependent ecosystem includes the biodiversity of the ecosystem. The IESC recognises that water-dependent ecosystems are captured under the definition of water resource (see below and Box 1) but sees the value of retaining the term ‘water-dependent ecosystem’ because everyday usage of the term ‘water resource’ typically refers only to surface water or groundwater that is or can be exploited for human uses.

Term	Description
Water resources	<p>are defined by the <i>Water Act 2007</i> (Cth) as:</p> <p><i>(a) surface water or groundwater; or</i></p> <p><i>(b) a watercourse, lake, wetland or aquifer (whether or not it currently has water in it);</i></p> <p><i>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.</i></p> <p>Box 1 discusses this definition in the context of the IESC's legislative role and information requirements.</p>

Supporting documents

- ANZG 2018. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand governments and Australian state and territory governments, Canberra ACT, Australia. Available [online]: <https://www.waterquality.gov.au/anz-guidelines> accessed December 2023.
- Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M and Testoni I (eds) 2019. *Australian rainfall and runoff: A guide to flood estimation*. Geoscience Australia, Commonwealth of Australia. Available [online]: <https://arr.ga.gov.au/arr-guideline> accessed December 2023.
- Barnett B, Townley LR, Post V, Evans RE, Hunt RJ, Peeters L, Richardson S, Werner AD, Knapton A and Boronkay A 2012. *Australian groundwater modelling guidelines*. Waterlines report. National Water Commission, Canberra. Available [online]: <https://groundwater.com.au/resources> accessed December 2023.
- 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*. Report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of Sustainability, Environment, Water, Population and Communities, Commonwealth of Australia. Available [online]: <http://www.bioregionalassessments.gov.au/methods/bioregional-assessment-methodology> accessed December 2023.
- Commonwealth of Australia (CoA) 2007. *Water Act 2007*. Available [online]: <https://www.legislation.gov.au/Series/C2007A00137> accessed December 2023.
- Commonwealth of Australia (CoA) 2012. *Environmental health risk assessment: Guidelines for assessing human health risks from environmental hazards*. Department of Health and Ageing, Canberra. Available [online]: <https://www.health.gov.au/resources/publications/enhealth-guidance-guidelines-for-assessing-human-health-risks-from-environmental-hazards> accessed December 2023.
- Commonwealth of Australia (CoA) 2014a. *Coal seam gas extraction: Modelling the groundwater impacts*. Knowledge report, prepared by Coffey Geotechnics for the Department of the Environment, Commonwealth of Australia. Available [online]: <https://environment.gov.au/system/files/resources/ee38b672-6faa-452e-979f-d97b7d425333/files/csg-modelling-groundwater-impacts.pdf> accessed December 2023.
- Commonwealth of Australia (CoA) 2014b. *Subsidence from coal seam gas in Australia: Background review*. Available [online]: <http://www.environment.gov.au/water/publications/background-review-subsidence-coal-seam-gas-extraction-australia> accessed December 2023.
- Commonwealth of Australia (CoA) 2014c. *Subsidence from coal mining activities: Background review*. Available [online]: <http://www.environment.gov.au/water/publications/background-review-subsidence-from-coal-mining-activities> accessed December 2023.
- Commonwealth of Australia (CoA) 2015. *Modelling water-related ecological responses to coal seam gas extraction and coal mining*. Prepared by Auricht Projects and the Commonwealth Scientific and Industrial Research Organisation for the Department of the Environment, Commonwealth of Australia. Available [online]: <https://www.dceew.gov.au/water/coal-and-coal-seam-gas/resources/modelling-water-related-ecological-responses-csg-extraction> accessed December 2023.
- Commonwealth of Australia (CoA) 2020a. *Bioregional assessments*. Available [online]: <https://www.bioregionalassessments.gov.au/bioregional-assessment-program> accessed December 2023.
- Commonwealth of Australia (CoA) 2020b. *Australian Industrial Chemicals Introduction Scheme*. Available [online]: <http://www.industrialchemicals.gov.au> accessed December 2023.
- Commonwealth of Australia (CoA) 2022. *Significant Impact Guidelines 1.3: Coal seam gas and large coal mining developments – Impacts on water resources*. Available [online]: <https://www.dceew.gov.au/environment/epbc/publications/significant-impact-guidelines-13-coal-seam-gas-and-large-coal-mining-developments-impacts> accessed December 2023.

- Commonwealth of Australia (CoA) 2023. *Atlas of groundwater dependent ecosystems*. Bureau of Meteorology. Available [online]: <http://www.bom.gov.au/water/groundwater/gde> accessed December 2023.
- Commonwealth of Australia 2024. *Information Guidelines Explanatory Note: Using impact pathway diagrams based on ecohydrological conceptualisation in environmental impact assessment*. Report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of Climate Change, Energy, the Environment and Water, Commonwealth of Australia, Canberra. Available [online]: <https://www.iesc.gov.au/publications/information-guidelines-explanatory-note-using-impact-pathway-diagrams-based-ecohydrological-conceptualisation-environmental-impact-assessment>
- Commonwealth Scientific and Industrial Research Organisation (CSIRO) 2015. *Australian climate futures: Climate change in Australia – Projections for Australia’s NRM regions*. Available [online]: <https://www.climatechangeinaustralia.gov.au/en/projections-tools/climate-futures-tool/introduction-climate-futures> accessed December 2023.
- Department of Climate Change, Energy, the Environment and Water (DCCEEW) 2023. *National climate risk assessment methodology*. Commonwealth of Australia, 2023. Available [online]: <https://www.dcceew.gov.au/climate-change/publications/national-climate-risk-assessment> accessed December 2023.
- Doody TM, Hancock PJ and Pritchard JL 2019. *Assessing groundwater-dependent ecosystems: IESC Information Guidelines Explanatory Note*. A report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of the Environment and Energy, Commonwealth of Australia. Available [online]: <https://www.iesc.gov.au/publications/information-guidelines-explanatory-note-assessing-groundwater-dependent-ecosystems> accessed December 2023.
- Downes BJ, Barmuta LA, Fairweather PG, Faith DP, Keough J, Lake PS, Mapstone BD and Quinn GP 2002. *Monitoring ecological impacts: Concepts and practice in flowing waters*. Cambridge University Press, Cambridge.
- Eamus D, Friend R, Loomes R, Hose G and Murray B 2006. A functional methodology for determining the groundwater regime needed to maintain the health of groundwater-dependent vegetation. *Australian Journal of Botany*, 54: 97–114.
- Huynh T and Hobbs D 2019. *Deriving site-specific guideline values for physico-chemical parameters and toxicants*. Report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of the Environment and Energy. Available [online]: <https://www.iesc.gov.au/publications/information-guidelines-explanatory-note-deriving-site-specific-guidelines-values> accessed December 2023.
- IPCC 2023. *Climate change 2023: Synthesis report. Contribution of Working Groups I, II, and III to the sixth assessment report of the Intergovernmental Panel on Climate Change* [Core writing team H Lee and J Romero (eds)]. IPCC, Geneva. Available [online]: <https://doi.org/10.59327/IPCC/AR6-9789291691647> accessed December 2023.
- Kaveney T, Kerswell A and Buick A 2015. *Cumulative environmental impact assessment industry guide: Adaptive strategies*. Report prepared for the Minerals Council of Australia.
- Kurukulasuriya D, Howcroft W, Moon, E, Meredith K and Timms W 2022. Selecting environmental water tracers to understand groundwater around mines: Opportunities and limitations. *Mine Water and the Environment*, 41: 257–369. Available [online]: <https://doi.org/10.1007/s10230-022-00845-y> accessed December 2023.
- Minerals Council of Australia 2022. *Minerals industry water accounting framework: User guide version 2.0*. Available [online]: <https://minerals.org.au/policies/sustainability/land-use-and-water-stewardship> accessed December 2023.
- Murray TA and Power WL 2021. *Information Guidelines Explanatory Note: Characterisation and modelling of geological fault zones*. Report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of Agriculture, Water and the Environment, Commonwealth of Australia. Available [online]: <https://www.iesc.gov.au/publications/information-guidelines-explanatory-note-characterisation-modelling-geological-fault-zones> accessed December 2023.
- Nathan RJ and McMahon TA 2017. Recommended practice for hydrologic investigations and reporting. *Australasian Journal of Water Resources*, 21(1): 3–19.
- NRMMC-EPHC-NHMRC 2009. *Australian guidelines for water recycling (Phase 2): Managed aquifer recharge*. Natural Resource Ministerial Management Council, Environmental Protection and Heritage Council and National

- Health and Medical Research Council, Canberra. Available [online]: <https://www.waterquality.gov.au/guidelines/recycled-water> accessed December 2023.
- Office of Water Science (OWS) 2020. *Environmental water tracers in environmental impact assessments for coal seam gas and large coal mining developments: Fact sheet*. Prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development, Canberra. Available [online]: <https://www.iesc.gov.au/publications/environmental-water-tracers> accessed December 2023.
- Peeters LJM and Middlemis H 2023. *Information Guidelines Explanatory Note: Uncertainty analysis for groundwater modelling*. Report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of Climate Change, Energy, the Environment and Water, Commonwealth of Australia. Available [online]: <https://www.iesc.gov.au/publications/information-guidelines-explanatory-note-uncertainty-analysis> accessed December 2023.
- Queensland Government 2015. *Guideline for the environmental assessment of subterranean aquatic fauna: Sampling methods and survey considerations*. Department of Science, Information Technology and Innovation. Available [online]: <https://www.publications.qld.gov.au/dataset/subterranean-aquatic-fauna/resource/ba880910-5117-433a-b90d-2c131874a8e6> accessed December 2023.
- Queensland Government 2018. *Monitoring and sampling manual: Environmental protection (water) policy 2009*. Department of Environment and Science. Available [online]: <https://environment.des.qld.gov.au/management/water/quality-guidelines/sampling-manual> accessed December 2023.
- Richardson S, Irvine E, Froend R, Boon P, Barber S and Bonneville B 2011. *Australian groundwater-dependent ecosystem toolbox part 1: Assessment framework*. Waterlines report. National Water Commission, Canberra. Available [online]: www.bom.gov.au/water/groundwater/gde/GDETtoolbox_PartOne_Assessment-Framework.pdf accessed December 2023.
- Vaze J, Jordan P, Beecham R, Frost A and Summerell G 2012. *Guidelines for rainfall-runoff modelling: Towards best practice model applications*. eWater Cooperative Research Centre.

Appendix A – Checklist of specific information needs

The following checklist provides specific guidance on IESC information needs, and reflects the approach taken by the IESC when assessing project documentation.

The checklist does not stand alone. It should be considered in addition to the general guidance provided in the main body of the Information Guidelines and any Explanatory Notes available on the IESC website.

A project may not need to address all items included in the checklist. For example, a coal mining proposal will not need to address the parts of the checklist related to CSG well construction and operation. Proponents should provide justification and supporting data and information if not addressing any sections of the checklist.

The IESC recognises that at the early assessment stage – for example, Gateway projects in New South Wales – project documentation may not contain enough data to allow a robust environmental impact assessment. In cases where data and analyses are lacking, it is essential to present a sound conceptualisation of the system, with explicit explanations of underlying assumptions. The proposal must also provide plans to improve understanding of the system over time, including details of when and how data to support assumptions will be gathered.

Description of the proposed project

General

- Provide a regional overview of the proposed project area, including a description of the geological basin, coal resource, surface water catchments, groundwater systems, water-dependent assets (including terrestrial and aquatic GDEs), and past, present and reasonably foreseeable coal mining and CSG developments.
- Describe the proposal's location, purpose, scale, duration and disturbance area, and the means by which it is likely to have a significant impact on water resources and water-dependent assets.
- Assess the frequency (and time lags, if any), location, volume and direction of interactions between water resources, including surface water/groundwater connectivity, inter-aquifer connectivity and connectivity with sea water.

Regulatory context

- Describe the statutory context, including information on the proposal's status within the regulatory assessment process and any applicable water management policies or regulations.
- Describe how potentially impacted water resources are currently being regulated under state or Commonwealth law, including whether there are any applicable standard conditions.
- Describe existing water quality guidelines, environmental flow objectives and other requirements (e.g., water planning rules) for the surface water catchments and groundwater basins within which the development proposal is based.
- Describe public health, recreation, amenity, Indigenous, tourism and/or agricultural values for each water resource, and the plans relevant to their management and protection.

Groundwater context

- Describe and map the 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 and accompanying surface geology, cross-sections and any relevant field data
 - identification of hydrogeological sequences and characteristics.
- Define and describe or characterise significant geological structures (e.g., faults, folds, intrusives) and associated fracturing in the area and their influence on groundwater – particularly groundwater flow, discharge or recharge.
 - Provide geological maps appropriately annotated with symbols that denote fault type, throw and the parts of sequences the faults intersect or displace (e.g., Murray and Power 2021).
 - Include discussion of how the faults potentially influence regional-scale groundwater conditions.
- Describe the likely recharge, discharge and flow pathways for all hydrogeological units likely to be impacted by the proposed development.
 - Identify current stressors, including impacts from any currently approved projects.

- Describe the existing water quality of all aquifers in the project area.
 - Where groundwater is to be used for a given purpose such as irrigation, compare the data with relevant guideline values (ANZG 2018) and regional and local water quality objectives.

Surface water context

- Describe the watercourses, standing waters and springs across the site, including:
 - drainage patterns and key surface water and floodplain features
 - hydrological regimes (especially ecologically relevant components such as durations, timing and frequency of periods when no surface water is present)
 - current stressors, including impacts from any currently approved projects.
- Describe the existing water quality of surface waters potentially impacted by the proposed development.
 - Include comparison to relevant default guideline values (ANZG 2018) and regional and local (or site-specific) water quality objectives.

Ecological context

- Describe the ecological water-dependent assets in and near the proposed development area, including:
 - water-dependent fauna and flora and their habitats, including GDEs (see Doody et al. 2019)
 - their current condition and environmental values
 - stressors that currently affect each ecological water-dependent asset, including stressors that alter the quantity and/or quality of water required by each asset in and near the proposed development area.

Environmental impact assessment

General

- Describe the intensity, duration, magnitude, timing and geographic extent of each potential impact, specifying the impact's significance and consequences, especially on the environmental condition and human values of each water resource.
- For proposed expansions or modifications, distinguish potential impacts from those of the existing project, and include the likely contribution of the proposed expansion to potential cumulative impacts.
- Assess the significance of each impact with reference to the range of system behaviour found under pre-development conditions and natural environmental and climatic variability.

Risk-based assessment

- Identify and assess all potential environmental risks to water resources and water-related assets, and their possible impacts. In selecting a risk-assessment approach, consideration should be given to the complexity of the project and the probability and potential consequences of the project's impacts.
- Describe the consultation with relevant stakeholders and regulators about the likely risks to water resources and water-related assets. This initial engagement should include agreement about the nature of the action,

which assets (including water resources) may be impacted, and the likely sources of impacts and the receptors that may be affected.

- The risk assessment should include a systematic and evidence-based assessment of:
 - the sources of environmental impacts in the project area
 - the exposure pathways by which impacts may be transferred from these sources to water resources (receptors), presented as one or more IPDs based on ecohydrological conceptualisation (see Box 2)
 - the likely response of each receptor, especially when the impact(s) may be severe and likely to cause irreversible damage (posing a high risk)
 - ‘hot spots’, or areas in the project area (e.g., where vulnerable receptors occur close to impact sources) where risks are especially high
 - ‘hot moments’, or periods during and after the project (e.g., when activities are likely to generate major impact) when risks are especially high.
- Specify where and how each risk can be avoided or mitigated (or, as a last resort, requires appropriate offsets and/or a conservation payment), and:
 - provide evidence (preferably from equivalent activities and regions) for the feasibility and effectiveness of mitigation or offset methods
 - describe how monitoring will be able to demonstrate the effectiveness of the mitigation measures.
- Describe the risks of potential cumulative impacts of all past, present and reasonably foreseeable actions and activities that are likely to impact on water resources, including from multiple stressors arising from the proposed action.
- Specify all sources of uncertainty in the assessments of each risk and describe how information has been and will be collected to reduce this uncertainty.
- Investigate relevant context for the risk assessment, such as bioregional assessments, Commonwealth and state water resource plans (e.g., Murray–Darling Basin Plan, Hunter River Salinity Trading Scheme) and state processes such as those that apply in the Surat Cumulative Management Area and the Commonwealth’s Joint Industry Framework on Coal Seam Gas.
- Assess residual risks remaining after the implementation of the proposed mitigation and management options, to determine whether these effectively reduce risks to an acceptable level based on the identified environmental objectives.

Modelling of water storage and movement

- Incorporate causal mechanisms and pathways identified in the risk assessment (e.g., IPDs) in conceptual and numerical modelling. Use the results of these models to update the risk assessment.
- Provide a detailed description of all analytical, numerical and conceptual models used, and any methods and evidence (e.g., expert opinion, analogue sites) employed in addition to modelling.
- Explain the conceptualisation of the system(s), including multiple conceptual models if appropriate. Describe the data and information, including field data, on which the models are based; all key assumptions; and model limitations and their consequences.

- Calibrated models require adequate monitoring data from either the project area or sites representative of local conditions, ideally with calibration targets related to model predictions. Summarise the extent to which parameterisation is consistent with expectations based on literature values, outcomes of field or laboratory investigations, or with values obtained by calibration in similar nearby applications.
- Where possible, verify models by using past and/or existing site monitoring data that were not used for calibration.
- Assess 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. Identify key gaps in data and knowledge and describe how they can be addressed.
- Describe the various stages of the proposed project (construction, operation and rehabilitation) and their incorporation into the model. Provide predictions of changes and recovery in each water resource for the life of the project and beyond, including an assessment of the impacts of climate change where applicable, and cumulative impacts.
- Provide a program for reviewing and updating models as more data and information become available, including reporting requirements.

Groundwater

- Undertake groundwater modelling in accordance with the *Australian groundwater modelling guidelines* (Barnett et al. 2012), including independent peer review.
- Describe each hydrogeological unit as incorporated in the groundwater model, including the thickness, storage and hydraulic characteristics, and hydraulic linkages between units, if any.
- Describe the existing recharge/discharge pathways of the units and the changes that are predicted to occur upon commencement, throughout, and after completion of the proposed project.
- Select and justify appropriate boundary conditions across the model domain to enable a comparison of groundwater model outputs to seasonal field observations.
- Where possible, calibration should incorporate measurements of both potentiometric head (or pressure) and flux, such as measured mine inflows or measured discharges to streams or springs.
- Undertake sensitivity analysis of boundary conditions and hydraulic and storage parameters, and justify the conditions applied in the final groundwater model. Where the interaction between surface water and groundwater is important, parameters describing their connectivity, such as riverbed conductance, should be assessed.
- Assess the potential impacts of the proposal, including how impacts are predicted to change over time and any residual long-term impacts. Consider and describe:
 - any hydrogeological units that will be directly or indirectly dewatered or depressurised (including lateral effects), interactions between water resources (inter-aquifer connectivity), and connectivity with sea water
 - the magnitude, extent and change over time of drawdown/mounding, including the time for post-development equilibrium to be reached
 - the extent of impacts on surface water/groundwater connectivity, water-dependent assets, flow direction and surface topography, including resultant impacts on the groundwater balance

- the potential range of drawdown at each affected bore, and clearly articulate the spatial and temporal scales of impacts on other water users
- the 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
- the possible fracturing of and other damage to confining layers.
- Undertake an uncertainty analysis of key predictive outputs (i.e., quantities of interest as per Peeters and Middlemis 2023).
- For each relevant hydrogeological unit, describe the proportional increase in groundwater use and impacts as a consequence of the proposed project, 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.

Surface water

- For flood estimation, use methods in accordance with the most recent publication of *Australian rainfall and runoff* (Ball et al. 2019); for rainfall-runoff modelling, use methods as outlined by Vaze et al. (2012); and for the modelling of water and salt balances related to mine water management, refer to the water accounting framework (Minerals Council of Australia 2022). Consider the relevance of regional information (see Nathan and McMahon 2017). It is expected that flood risks are assessed for annual exceedance probabilities of at least 1% (i.e., 1 in 100); however, in many instances it may be necessary to estimate floods with rarer annual exceedance probabilities, such as 0.1% (i.e., 1 in 1,000), or events which have a negligible chance of being exceeded (the probable maximum flood).
- Describe all potential impacts of the proposed project on surface waters. Include a clear description of the impact on the resource and the likelihood and consequences of the impact. Consider:
 - impacts on streamflow under the full range of flow conditions, focusing on metrics that are most relevant to ecologically important flow components (e.g., the timing, frequency and variability of zero- and low-flow days, low flows exceeded 90% of the time, flow pulses related to ecological processes such as spawning and migration) as well as those relevant to water supply reliability
 - impacts associated with surface water diversions
 - impacts on water quality, including consideration of mixing zones (i.e., areas downstream of discharges where water quality objectives do not apply) if applicable
 - the quality, quantity and ecotoxicological effects of operational and emergency discharges of water (including saline water) at different flows, and the likely impacts on water resources and water-dependent assets
 - landscape modifications such as subsidence, voids, post-rehabilitation landform collapses and on-site earthworks (including disturbance of acid-forming or sodic soils, roadway and pipeline networks), and describe how these could affect surface water flow, surface water quality, erosion and sedimentation within and downstream of the project area.
- Identify processes to determine surface water quality guidelines and quantity thresholds which incorporate seasonal variation but provide early indication of potential impacts on assets.

- Assess the risks of flooding (including channel form and stability, water level, depth, extent, velocity, shear stress and stream power) and the impacts of flooding on water-dependent assets, project infrastructure and the final project landform.
- Identify and evaluate the quality (including uncertainty) and other aspects of streamflow and other hydrological data, such as proximity to rainfall stations and stream gauges, duration of data records, and whether missing data have been patched.
- Develop and describe a plan for ongoing ecotoxicological monitoring, including direct toxicity assessment of discharges to surface waters where appropriate.

Ecology

- Assess direct and indirect impacts of the proposed project (e.g., landscape modifications such as voids, on-site earthworks, roads, pipelines and stream-channel diversions, mine dewatering, operational releases of water affected by mining or CSG activities) on water-dependent ecological assets such as flora and fauna dependent on surface water and groundwater, including springs and other GDEs.
- Using suitable IPDs based on an initial ecohydrological conceptualisation, describe the likely cause–effect mechanism(s) from impact sources to each receptor. Consider:
 - direct and indirect impacts on aquatic and water-dependent terrestrial populations, species and communities, including those whose water dependence may not yet be demonstrated (e.g., terrestrial GDEs)
 - how predicted alterations of the hydrological regime (especially ecologically relevant components such as durations, timing and frequency of periods when no surface water is present; and timing and duration of overbank flooding) in standing and flowing waters might affect each water-dependent ecological asset in and near the project area at a range of temporal scales (e.g., seasonal, annual, decadal)
 - how predicted alterations of water quality (including water temperature and salinity) might affect each water-dependent ecological asset in and near the project area at a range of temporal scales (e.g., seasonal, annual, decadal)
 - how interactions of predicted alterations of quantities and quality of surface water and/or groundwater might affect each water-dependent ecological asset in and near the project area at a range of temporal scales (e.g., seasonal, annual, decadal)
 - the likely cumulative impacts of the proposed development with those of pre-existing water-intensive activities and other drivers such as climate change.
- For ecological risk-based assessment, evaluate the likelihood and consequences of the impacts and their pathways based on the impact assessment and IPDs (outlined above), particularly for highly valued receptors and in ‘hot spots’ where impacts are especially likely. Consider that some impacts may be especially likely during particular phases of the proposed development, and describe these ‘hot moments’ and their associated risks to water-dependent ecological assets.

Water and salt balances

- Describe the proposed development’s water requirements and on-site water management infrastructure, including modelling to demonstrate the infrastructure’s adequacy under a range of potential climatic conditions, including extremes associated with predicted climate change.

- Provide salt balance modelling that includes stores and the movement of salt between stores, and takes into account seasonal and long-term variation.
- Indicate the vulnerability to contamination (e.g., from salt production and salinity) of, and the likely impacts of contamination on, the identified water-dependent ecological assets.
- Identify how produced water, brine and waste from water treatment plants that are stored on site during operations will be managed and disposed of after operations cease, where applicable.
- Provide a quantitative site-level water balance model describing the total water supply and demand under a range of rainfall conditions and allocations of water for mining activities (e.g., dust suppression, coal washing), including all sources and uses.
- Provide estimates of the quality and quantities of operational discharges under dry, median and wet conditions, potential emergency discharges due to unusual events, and the likely impacts on water-dependent ecological assets.

Geochemistry (e.g., acid-sulfate soils)

- Identify the presence and potential exposure of acid-sulfate soils (including from oxidation arising during groundwater drawdown) and other geochemical sources of contaminants and extreme pH.
- Identify the presence and volume of potentially acid-forming waste rock and fine-grained amorphous sulfide minerals and describe coal reject/tailings material and potential exposure pathways.
- Identify other sources of contaminants, such as high metal concentrations in groundwater, leachate generation potential and seepage paths. Where identified, quantify potential contaminants in coal rejects and leachate with appropriate testing methods.
- Assess the potential impacts on and risks to water-dependent ecological assets, taking into account dilution factors and including solute transport modelling where relevant; representative and statistically valid sampling; and appropriate analytical techniques.
- Describe proposed measures to avoid or mitigate risks of impacts on water resources, water users and water-dependent ecosystems and species, and provide evidence for the likely feasibility and effectiveness of these measures. Specify handling and storage plans for acid-forming materials (e.g., co-disposal, tailings dam, encapsulation) to reduce their risks to water-dependent ecological assets.

Subsidence

- Provide predictions of subsidence impacts on surface topography, water-dependent assets, groundwater (including enhanced connectivity between aquifers) and the movement of water across the landscape (see CoA 2014b; CoA 2014c).
 - Consider multiple methods of prediction and apply the most appropriate method.
 - Consider the limitations of the applied method, including the adequacy of empirical data and site-specific geological conditions, and justify the selected method.
 - Consider the timing of subsidence impacts, identifying whether impacts will occur rapidly or develop over the longer term.
- Describe subsidence monitoring methods, including the use of remote or on-ground techniques, and explain the predicted accuracy of such techniques.

- Assess both conventional and unconventional subsidence. For project expansions, provide an evaluation of past or current effects of geological structures on subsidence and the implications for water resources and water-dependent assets.
- Consider geological strata and their properties (strength/hardness/fracture propagation) in the subsidence analysis and/or modelling. Anomalous and near-surface ground movements with implications for water resources and compaction of unconsolidated sediment should also be considered.

Chemicals

- List the chemicals proposed for use in drilling and hydraulic stimulation of CSG production bores, including:
 - proprietary names (trade names) of compounds (e.g., fracturing fluid additives) being produced
 - chemical names and CAS numbers of each additive used in each of the fluids
 - general purpose and function of each of the chemicals used
 - mass or volume of each of the chemicals proposed for use and its maximum concentration (mg/L or g/kg)
 - ecotoxicology
 - any material safety data sheets for the chemicals or chemical products used.
- The use of drilling and hydraulic fracturing 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 (see CoA 2012; NRMMC-EPHC-NHMRC 2009).
- Chemicals for use in drilling and hydraulic fracturing must be identified as being approved for import, manufacture or use in Australia (i.e., listed on the Australian Inventory of Industrial Chemicals; see CoA 2020b).
- Propose waste management measures (including salt and brines) during both operations and legacy after closure.

Drilling and hydraulic stimulation

- Describe 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 (e.g., cavitation, acid flushing).
- Describe proposed measurement and monitoring of fracture propagation, and specify associated uncertainties and challenges.
- Identify water source(s) for drilling and hydraulic stimulation, and specify the volumes of fluid and mass balance (quantities/volumes).
- Describe the rules (e.g., water sharing plans) covering access to each water source to be used for drilling and hydraulic stimulation, and how the project proposes to comply with them.
- Quantify and describe the quality and toxicity of flowback and produced water and how it will be treated and managed.
- Assess the potential for inter-aquifer leakage or contamination, and describe the risks to water-dependent assets if such leakage or contamination occurs.

Closure, rehabilitation and post-development final landforms and voids

- Describe the timing and processes planned for cessation of operations and the closure of the development, particularly any risks of impacts on water-dependent assets that may arise during this phase (e.g., when dismantling and removing infrastructure). Explain how such risks will be avoided or mitigated.
- If appropriate, qualitatively describe the various final landform options that were considered and their likely legacy impacts on water resources. This context will be useful for justifying the choice of the proposed final landform and how it avoids or mitigates risks of legacy impacts on water resources.
- Ideally, describe how land disturbed by mining activities will be progressively rehabilitated to a safe and stable landform that does not cause environmental harm to water resources and is able to sustain one or more approved post-mining land uses (PMLUs). Give details of the consultation with regulators and the community about the intended PMLUs, the targets associated with their achievement, and how achievement of these targets may be hampered by, for example, site geology and climatic extremes.
- If requested by regulators, specify and justify the methods and techniques that will be used to achieve particular rehabilitation targets and milestones. Explain how these methods may be constrained by project-specific features (e.g., topography, climate, geology and hydrology).
- If appropriate, describe how the effectiveness of the proposed rehabilitation methods and techniques for protecting or restoring water resources will be monitored, and present details (e.g., parameters, sampling frequency) of a monitoring program for demonstrating successful achievement of the targeted PMLUs across the project area after mining or CSG extraction has finished. These monitoring programs should be linked to explicit milestones for completion of progressive stages of rehabilitation, and should include appropriate baseline data against which to judge the effectiveness of the rehabilitation.
- Describe the final landform and any voids that may remain after closure, and specify the predicted legacy impacts that may persist, such as ongoing effects on surface water and groundwater movements and water quality, erosion and sedimentation, and habitat fragmentation of water-dependent species and communities. Evaluate the adequacy of the modelling underlying these predictions, especially all sources of uncertainty.
- Assess qualitatively the likely long-term risks of impacts on water resources and water-dependent assets posed by various options for the final landform design, including complete or partial backfilling of mining voids. Assessment of the final landform for which approval is being sought should consider:
 - stability (e.g., resistance to erosion and slumping), soil geochemistry and quality (relevant for post-closure establishment of vegetation) and the likely effects of the final landform on long-term surface water and groundwater behaviour (e.g., fluxes and runoff) and on water quality, including salinity, pH, toxicity and concentrations of contaminants
 - geochemistry and its potential effects on seepage through waste rock (e.g., fully or partially refilled voids, remnant rock dumps) and on the quality of water exiting from mine adits and other post-closure sources
 - groundwater behaviour and rate and depths of water table recovery, including timeframe and final levels of stabilisation
 - available measures (and their likely effectiveness and feasibility) to avoid or mitigate legacy impacts from the final landform and any voids on water resources and water-dependent assets.

Baseline data

- For groundwaters, surface waters and ecological water-dependent assets that have been identified in the risk-based assessment, present data that are sufficient to establish pre-development (baseline) conditions and that have been collected at an appropriate sampling frequency and spatial coverage of monitoring sites, ideally over a period sufficiently long to characterise the impacts of climatic variability.

Groundwater

- Provide data from surveyed boreholes to demonstrate the varying depths of the hydrogeological units and associated standing water levels or potentiometric heads, including directions of groundwater flow, contour maps and hydrographs.
- Present information from site-specific studies (e.g., geophysical, coring/wireline logging) to characterise the local stress regime and fault structure (e.g., damage zone size, open/closed along fault plane, presence of clay/shale smear, fault jogs or splays).
- Provide site-specific values for hydraulic parameters (e.g., vertical and horizontal hydraulic conductivity and specific yield or specific storage characteristics, including the data from which these parameters were derived) for each relevant hydrogeological unit. In situ observations of these parameters should be sufficient to characterise the heterogeneity of these properties for modelling.
- Provide hydrochemical characterisation (e.g., acidity/alkalinity, electrical conductivity, metals and major ions) and a suitable suite of environmental tracers (e.g., heat; stable isotopes of water; tritium, helium, strontium isotopes) (e.g., Kurukulasuriya et al. 2022; OWS 2020) commensurate with the risks of the proposed development to water resources and water-dependent assets.
- Provide sufficient data on physical aquifer parameters and hydrogeochemistry to establish pre-development conditions, including fluctuations in groundwater levels at time intervals relevant to aquifer processes. This should include time-series data for water levels and water quality that represent seasonal and climatic cycles.
- Provide long-term groundwater monitoring data, including a comprehensive assessment of all relevant chemical parameters to inform changes in groundwater quality and detect potential contamination events.

Surface water

- Provide data for the hydrological regime of all watercourses, standing waters and springs across the site, including:
 - spatial, temporal and seasonal trends in streamflow and/or standing water levels
 - spatial, temporal and seasonal trends in water quality data (such as turbidity, acidity, salinity, relevant organic chemicals, metals, metalloids and radionuclides).

Ecology

- Provide clear statements of the goals of the baseline data, specifying how the information will address knowledge gaps (e.g., current ecological condition of water-dependent assets in the project area, potential impact pathways) and justifying the choice of parameters and measures.
- Describe and justify the sampling program (e.g., sampling frequency, locations of impact and control sites) and collection methods for gathering appropriate baseline data on all ecological water-dependent assets that have been identified in the risk-based assessment. The data and methods used may also help address

information gaps in the IPDs and be used to monitor responses to predicted impacts of the development and the effectiveness of mitigation measures.

- Ensure ecological sampling methods reflect best practice, are quantitative if needed, and comply with relevant state or national monitoring guidelines (e.g., Queensland Government (2015) for sampling stygofauna). Identify plants and animals (including stygofauna and aquatic invertebrates) to the lowest feasible taxonomic resolution to optimise the value of the baseline data. Where possible, make baseline data publicly available.
- Identify potential aquatic and terrestrial GDEs, using the method outlined by Eamus et al. (2006) and information from the GDE Toolbox (Richardson et al. 2011), the GDE Atlas (CoA 2023) and the GDE Explanatory Note (Doody et al. 2019).
- Present information on the distribution of potential aquatic and terrestrial GDEs within and near the project area, and explain how their groundwater dependence has been ground-truthed and on which hydrogeological units they are likely to depend (see Doody et al. 2019).

Monitoring and management

- Describe the rationale for selected monitoring parameters and their sampling duration, frequency and methods, including the use of satellite or aerial imagery to identify and monitor large-scale impacts. Target monitoring programs to address key areas of uncertainty, especially for valued assets and water resources that are at greater risk of impacts from the proposed development.
- Ensure water quality monitoring complies with relevant National Water Quality Management Strategy guidelines (ANZG 2018) and relevant legislated state protocols (e.g., Queensland Government 2018).
- Identify and justify monitoring sites representative of the diversity of potentially affected water-dependent assets and the nature and scale of potential impacts. Match suitably replicated control and reference sites (BACI design, Downes et al. 2002) to enable detection and monitoring of potential impacts.
- Describe the processes employed to determine impact thresholds for water-dependent assets (e.g., threshold at which a significant impact on an asset may occur).
- Describe proposed mitigation and management actions, and their adequacy, for each significant impact identified, including any proposed mitigation or offset measures for long-term impacts post mining.
- Identify modifications or alternatives to avoid, minimise or mitigate potential cumulative impacts, and provide evidence of the likely success of these measures (e.g., case studies).
- Propose adaptive management measures and management responses, giving details of trigger action response plans (TARPs) for valued assets and water resources that are at greater risk of impacts from the proposed development.

Groundwater

- Describe a robust groundwater monitoring program using dedicated groundwater monitoring bores – including nested arrays where there may be connectivity between hydrogeological units – and targeting specific aquifers, providing information on the groundwater regime and on recharge and discharge processes and identifying changes in quantities and quality of groundwater over time.
- Where reinjection schemes are proposed to manage wastewater (e.g., managed aquifer recharge), the monitoring program should include components specifically targeted at identifying any potential impacts from this management action.

Surface water

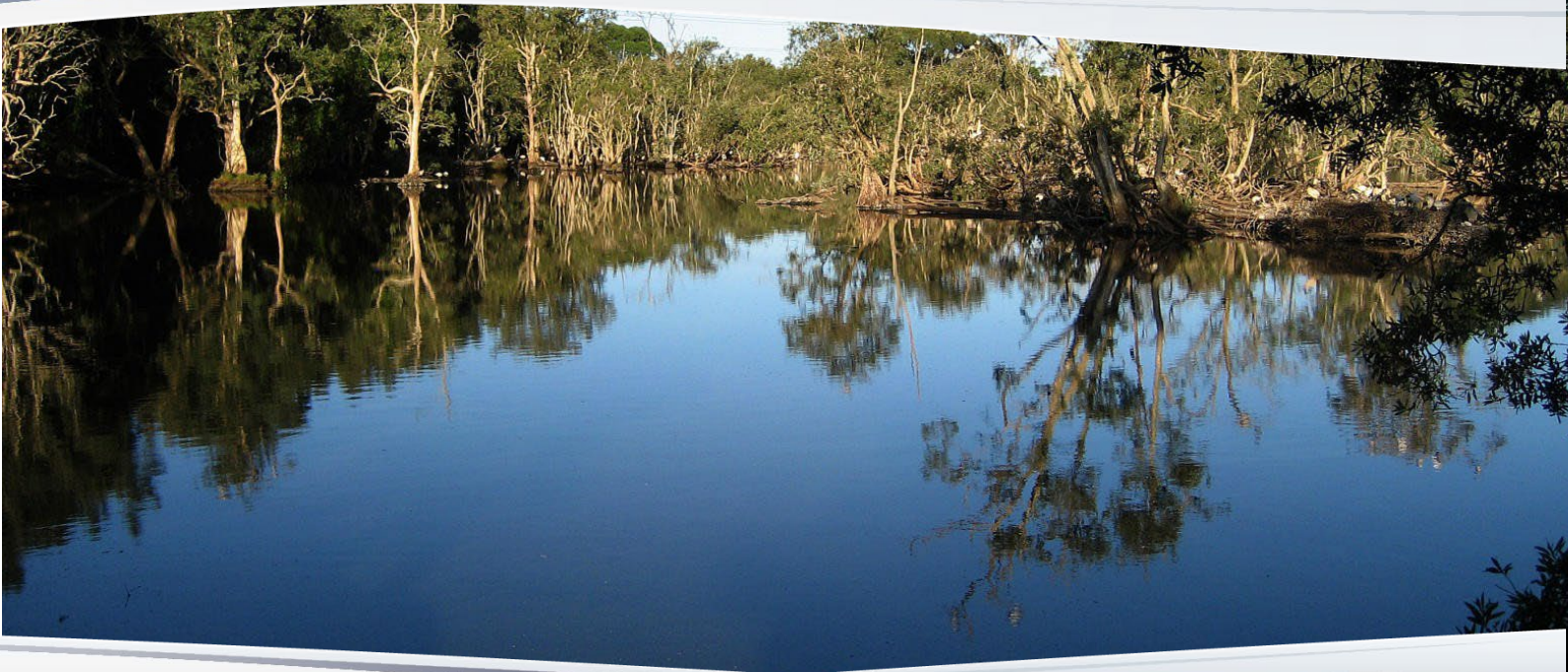
- Identify and justify dedicated sites to monitor hydrology, water quality, and channel and floodplain geomorphology before, during and for a suitable period after the proposed development.
- Describe a surface water monitoring program that will collect sufficient data to detect and identify the cause of any changes from established baseline conditions, and assess the effectiveness of mitigation and management measures. The program should:
 - include baseline monitoring data for physico-chemical parameters, as well as contaminants (e.g., metals)
 - compare physico-chemical data to national/regional guidelines or to site-specific guidelines derived from reference condition monitoring if available
 - identify baseline contaminant concentrations and compare these to national guidelines, allowing for local background correction (e.g., bioavailability) if required.

Ecology

- Provide clear statements of the goals of the monitoring program, specifying how the information will address knowledge gaps about, for example, changes in abundance, composition and condition of ecological water-dependent assets in and near the project area. Ensure that the monitoring program is powerful enough to detect relevant changes that indicate significant impacts or where management and mitigation measures are not working as predicted.
- Describe and justify the monitoring program (e.g., sampling frequency, locations of impact and control sites) and collection methods for gathering appropriate monitoring data on all ecological water-dependent assets that have been identified in the risk-based assessment. Where possible, match the methods to those used in the baseline surveys so that the data are directly comparable and can be used to monitor responses to predicted impacts of the development and the effectiveness of mitigation measures.
- Ensure that all proposed ecological monitoring uses standard sampling methods that reflect best practice and are quantitative if needed. Identify plants and animals (including stygofauna and aquatic invertebrates) to the lowest feasible taxonomic resolution to optimise the value of the monitoring data, and strive to make these data publicly available.
- Describe how the monitoring data will be analysed and reported, specifying how the information will feed back into regular assessment of whether (and where) impacts are occurring and whether mitigation measures are being effective. Ensure that this information is explicitly linked to TARPs that guide adaptive management of impacts of the proposed development on ecological water-dependent assets in and near the project area during and for a suitable period after the proposed development.
- Specify and justify all proposed management and mitigation measures to protect ecological water-dependent assets that were identified in the risk-based assessment. Present relevant evidence to demonstrate the likely effectiveness of these measures. Specify how the data to be collected in the monitoring program will illustrate the effectiveness of these management and mitigation measures, and present relevant TARPs describing this adaptive management.

Cumulative impacts

- Assess the condition and likely responses of all water-dependent assets and water resources likely to be cumulatively impacted by the proposed development combined with all developments (past, present and/or reasonably foreseeable) and other water-intensive activities.
- Assess the cumulative impacts on potentially affected water-dependent assets and water resources, considering:
 - the full extent of potential impacts from the proposed project (including whether there are alternative options for infrastructure and mine configurations which could reduce impacts)
 - all stages of the development, including exploration, operations and post-closure/rehabilitation
 - the likely spatial magnitude and timeframe over which cumulative impacts will occur (ensuring that the analysis has sufficiently broad geographic and temporal boundaries to include all potentially significant impacts)
 - opportunities to work with other water users to avoid or mitigate potential cumulative impacts to meet specified environmental objectives.



Australian Government

This initiative is funded by the Australian Government

www.iesc.environment.gov.au