

INDEPENDENT EXPERT SCIENTIFIC COMMITTEE ON COAL SEAM GAS AND LARGE COAL MINING DEVELOPMENT

Invitation to comment on the IESC draft research priorities

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) is seeking comment on draft priorities for research on the water-related impacts of coal seam gas extraction and coal mining.

Stakeholder views are sought on:

- the draft research priorities at Appendix B of this document
- any synergies with current or planned research
- mechanisms for facilitating interdisciplinary and multi-disciplinary research
- strategies to achieve alignment and integration with research conducted by others
- any priority topics that may be missing from the list.

This paper provides background on the IESC's role in providing advice on research priorities, and outlines issues for stakeholders to consider when providing feedback on the draft revised priorities.

Why is the IESC reviewing its research priorities?

One function of the IESC under the *Environment Protection and Biodiversity Conservation Act 1999* is to provide advice to the Environment Minister about priorities for research projects to improve scientific understanding of the impacts of coal seam gas developments and large coal mining developments on water resources, including any impacts of associated salt production and/or salinity.

The IESC research priorities may inform research institutions, research funding bodies, government science agencies and industry in developing research plans and priorities.

In 2013 the IESC identified priorities for research projects under four broad themes: Hydrology, Ecology, Chemicals and Cumulative Impacts (<http://www.iesc.environment.gov.au/publications/iesc-priorities-for-research-projects>). The priorities were based on an analysis of current and emerging research, and were informed by consultations undertaken in 2012 by Professor John Langford and the IESC Research Subcommittee chaired by Professor Craig Simmons, and a consultation workshop in March 2013 in Canberra. Participants at the workshop were drawn from academia, state and Commonwealth government agencies, industry and the community, with a mix of expertise and experience in geology, hydrology, hydrogeology and ecology, as well as geographic coverage.

The Department of the Environment and Energy commissioned a suite of research projects (Appendix A) guided by the 2013 IESC priorities. To date, reports from 17 projects have been published on the Department of the Environment and Energy website ([Water publications and resources | Department of the Environment](#)), and five reports have been published by Geoscience Australia ([Data & Publications - Geoscience Australia](#)). The national assessment of chemicals associated with CSG extraction in Australia is nearing completion. Three further research projects will be completed this year: 'Bore and well induced inter-aquifer groundwater connectivity: Consequence modelling and experimental design' and 'Provision of hydrology research to better include faults and aquitards in Australian regional groundwater models to improve assessment of impacts of CSG extraction' in the Hydrology theme and 'Research to inform the assessment of ecohydrological responses to coal seam gas extraction and coal mining' in the Ecology theme (Appendix A). The bioregional assessments are underway and products are being published.

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Given the progress made in the Department of the Environment and Energy research program, the IESC's experience over the last three years in providing advice on the impacts of coal mines and coal seam gas extraction projects on water resources, and other research, it is timely to review the IESC research priorities.

What issues should be considered in a revision of IESC research priorities?

The guiding principles

In 2013 the IESC identified guiding principles to inform research priorities and research investments, namely that research should:

- strengthen regulatory decisions about coal seam gas and large coal mining development, including informing the advice the IESC provides to regulators
- prioritise areas where there is greatest scope to improve the necessary science
- focus on areas where the risk of getting decisions wrong is high
- produce outputs that are of national significance or capable of national relevance and where solutions require coordinated action across governments, and other sectors, at a national level
- be outcome-oriented and make a difference within the next three years.

Integration across themes and disciplines

The theme and sub-theme format of the 2013 research priorities helped to ensure investment was spread across the span of topics. The thematic approach has been retained in the draft revised priorities, but the IESC recognises that research projects are interlinked and complementary. The IESC seeks stakeholder views on mechanisms for facilitating transdisciplinary and multi-disciplinary research. One example is the development of shared hypotheses and conceptual models.

Linkages with research conducted by others including Commonwealth and state agencies

The IESC seeks advice from stakeholders on their existing research activities so that the IESC research priorities complement and do not duplicate current or planned work. Stakeholders' experiences and advice are sought on strategies to achieve alignment and integration with research conducted by others.

Emerging priorities

The Australian Government has developed a set of science and research priorities and corresponding practical research challenges (Australian Government 2015). Three of the nine priorities are directly relevant to the review of the IESC research priorities. Under the priority of 'Soil and Water' is 'Research should therefore focus on critical assets such as the Great Barrier Reef, Northern Australia, key agricultural regions, aquifers and urban catchments, and build capacity for improved accuracy and precision in predicting change'. Under 'Resources', departments and agencies should give priority to research that will lead to 'a fundamental understanding of the physical state of the Australian crust, its resource endowment and recovery; knowledge of environmental issues associated with resource extraction; and lowering the risk to sedimentary basins and marine environments due to resource extraction'. Under 'Environmental change' the challenge is 'improved accuracy and precision in predicting and measuring the impact of environmental changes caused by climate and local factors'.

Extent to which the 2013 IESC priorities have been addressed

The research priorities identified by the IESC in 2013 encompassed the range of data and information needed to address its Information Guidelines (IESC 2015) satisfactorily, and were sufficiently broad that a suite of potential projects could have been formulated to address each topic. All the priorities have been

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progressed to varying degrees, but because of their broad relevance to assessment of water-related impacts of coal seam gas and coal mining developments, there is still a need for further research in each area. Each of the Department of the Environment and Energy research reports identifies further research needs. These may be divided into gaps in understanding of a system or process, including requirements for baseline data, and the development of management actions, methods or guidelines.

The need for baseline data and data storage and management

The need to collate and analyse empirical data on baseline conditions is a consistent theme in the Department of the Environment and Energy research reports, in the IESC's advice on development projects, and in the scientific and grey literature. This lack of understanding of baseline conditions is not strictly a research question, but it limits the scope of research and increases the associated uncertainties.

Understanding of stratigraphy, the hydraulic properties of formations, and the presence and properties of faults remains a fundamental knowledge gap. Shallow alluvial aquifers are routinely overlooked in hydrogeological conceptualisation in environmental impact assessment, despite their ecological importance. Inadequate hydrogeological conceptualisation hampers the efficacy of groundwater models to predict impacts on water resources. Inadequate or no wetland and vegetation mapping, and a lack of information on the sources of water used by ecosystems, mean that ecological impacts cannot be identified.

Jackson et al. (2013) identify baseline geochemical mapping (with time series sampling from a sufficient network of groundwater monitoring wells) as an area where field-focused research is urgently needed to fill current science gaps related to unconventional gas extraction. Davies et al. (2015) highlight a lack of data, including issues of limited site-specific and longer-term groundwater monitoring, and access to government and industry reports and data, among a range of research needs. The NSW Chief Scientist and Engineer's report (2014) recommended the creation of a State whole-of-environment data repository so that data from coal seam gas operations can be interrogated as needed. The Hawke report on hydraulic fracturing in the Northern Territory also identified concerns about insufficient baseline data and limited public availability of information, and recommended that monitoring data should be collated in standard formats in a publicly available central data repository, with accompanying analyses and interpretation (Hawke 2014).

The need for baseline data is being addressed through increasing availability of online data repositories such as the bioregional assessment information platform.

Field-testing and comparison of methods

There have been extensive literature reviews that establish the background to matters of scientific interest and community concern regarding coal seam gas and coal mining developments. Future research could move to a hypothesis-testing approach to improve understanding of systems and processes using field, laboratory, expert elicitation and modeling approaches with the aim of developing methods, tools and guidance for direct application in environmental assessment of the water-related impacts of coal seam gas and coal mining developments.

Scale and the transfer and / or upscaling of results

The water-related impacts of coal seam gas and coal mining developments potentially span a hierarchy of spatial and temporal scales. Given the range of climatic and biophysical settings in which coal seam gas extraction and coal mining occur in Australia, and the knowledge gaps identified in the 2013 research priorities, the IESC frequently must rely on studies from outside the area of a specific project to formulate its advice. Understanding gained from literature review and site-specific research is frequently applied to other sites which may have different biophysical properties or spatial scales. Richardson et al. (2011b) suggest that

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caution should be exercised when knowledge is transferred or upscaled, acknowledging the increasing heterogeneity of systems with increasing scale, the increased inherent uncertainty, and the importance of ground-truthing and validation of extrapolations.

Consideration of scale is made complex by cross-scale linkages. For example, small-scale processes may have non-linear effects on large-scale processes (Corwin et al. 2006). Conceptual models of system components and processes may facilitate transfer of findings and testing of hypotheses among sites (Wondzell et al. 2010). Numerical models derived from conceptual models may be used to expand knowledge from individual research sites to other locations and regions, but monitoring data are required for calibration and testing.

To ensure that research outputs are useful for users, guidance on transfer and /or upscaling of findings could be included in the terms of reference for future research projects.

Cumulative impacts

Assessment of cumulative impacts continues to be an important issue that should be considered by research under the priority themes. Franks et al. (2010) define cumulative impacts as the successive, incremental and combined impacts of one or more activities. The bioregional assessment framework is a way of considering cumulative impacts in specific geographic areas.

Although the IESC Information Guidelines contain a checklist for consideration of cumulative impacts, further guidance is needed on specific methods for cumulative impact assessment. Daniel et al. (2015) tested two methods for detecting thresholds in fish assemblages associated with increasing levels of mining in catchments. Future IESC research priorities could include analysis of existing datasets to trial methods for detecting cumulative impacts.

Knowledge adoption

Uptake of research findings requires planning and investment to ensure that research products meet potential users' needs, that potential users are aware of the products, and that they know how to apply them. Research findings may be published in a variety of formats to suit users' needs and to allow ready application in conjunction with existing guidance documents such as the Australian Groundwater Modelling Guidelines (Barnett et al. 2012) and the Australian Groundwater Dependent Ecosystems Toolbox (Richardson et al. 2011b, Richardson et al. 2011a).

Draft revised IESC priorities for research

The draft revised IESC priorities for research are at Appendix B.

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APPENDIX A

IESC 2013 Research priorities and OWS research

Research Themes	Research sub-themes	OWS research projects
HYDROLOGY		
Sub-Theme: Surface water and groundwater connectivity	Selection, application, and evaluation of groundwater models to assess the impacts of coal seam gas and coal mining activities	Knowledge report: Coal seam gas extraction: modelling groundwater impacts In scope of current hydrogeological project 'Faults, aquitards and modelling' to be completed by December 2016.
	Quantifying the impact of faulting and fracturing on groundwater flows and aquifer connectivity at local and regional scales	
	Development and testing of methods for assessing inter-aquifer connectivity and aquitard leakage rates	
Sub-Theme: Bore integrity	Legacy and failed bores and the implications for aquifer interconnectivity	Background review: bore integrity; partially in scope of new project 'Bore and well induced inter-aquifer connectivity' to be completed by December 2016.
Sub-Theme: Mine site and gas field remediation	Time-frames for aquifers to return to their natural state post coal seam gas and coal mining production	
Sub-Theme: Water quantity and quality, flow regimes	Assessment of surface and groundwater interconnectivity, exchanges, and fluxes	In scope of current ecological project: 'Research to inform assessment of ecohydrological responses to coal seam gas extraction and coal mining' to be completed by Dec 2016
	Tolerances of key species and ecological communities to changes in surface and groundwater flow regimes and water quality associated with coal seam gas and coal mining	
CHEMICALS		
Sub-Theme: Chemical migration, contamination, and toxicity	Chemical tracers to identify contamination of water resources from coal seam gas and coal mining	

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Research Themes	Research sub-themes	OWS research projects
ECOLOGY		
Sub-Theme: Ecosystem effects and monitoring	Is the current monitoring undertaken by proponents sufficient to detect the changes in ecosystem condition and trends associated with coal seam gas and coal mining water	
Sub-Theme: Ecosystem response and mitigation measures	Evaluation of methods for mitigating or remediating impacts of coal seam gas and coal mining activities on aquatic ecosystems	Knowledge report: Temperate Highland Peat Swamps on Sandstone: evaluation of mitigation and remediation techniques, WRL, UNSW
	Impacts and thresholds of watertable drawdown on groundwater dependent vegetation	In scope of current ecological project: 'Research to inform assessment of ecohydrological responses to coal seam gas extraction and coal mining' to be completed by Dec 2016.
CUMULATIVE IMPACTS		
Sub-Theme: Evaluation of cumulative impact assessment	Framework for evaluating Cumulative Impact Assessments – evaluation criteria, tools, and techniques	Methodology for bioregional assessments of the impacts of coal seam gas and coal mining development on water resources

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APPENDIX B

Draft revised research priorities

Research priority	Key research needs
HYDROLOGY	
1 Characterising hydraulic properties of aquifers and aquitards	Modelling of the impacts of coal seam gas extraction and coal mining on groundwater requires an understanding of the lithology, hydrogeological characteristics and geological structures of aquifers and aquitards. A better understanding is needed at local and regional scales of hydrogeological characteristics including values of storage properties and vertical hydraulic conductivity for key aquifers and aquitards.
1a Leveraging from petroleum engineering and geology data	The petroleum industry has detailed information and data on the properties of petroleum reservoirs. There is a research opportunity to improve understanding of deep aquifers by better linking hydrogeology and petroleum data. A process is needed to capture data on hydrogeological characteristics from both sources in national databases.
1b Linking groundwater models of different scales	Groundwater models used in assessment of impacts of coal seam gas extraction and coal mining are often at different spatial scales. A review of methods to link groundwater models of different scales would assist in analysing potential cumulative impacts of multiple developments. Linked to Hydrology priority 5c.
1c Dual phase and dual porosity flow and geomechanical effects in groundwater models	The research needs are to identify methods for representing these processes in a simplified way for regional modelling and estimating the magnitude of the consequent errors; assess the extent to which these factors influence regional modelling and prediction of the volumes of produced water; and develop relationships to identify the areas/environments and times for which these factors are important for regional groundwater modelling.
2 Impacts to upland peat swamps and water bodies associated with coal mining	Temperate Highland Peat Swamps on Sandstone and Coastal Upland Swamps in the Sydney Basin Bioregion (collectively termed upland peat swamps) are listed as endangered ecological communities under the <i>Environment Protection and Biodiversity Conservation Act 1999</i> . Longwall coal mining beneath upland peat swamps may fracture the sandstone substrate and alter the swamps' water balance. An improved geomechanical understanding is needed of cracking and subsidence risks due to dewatering in coal mining, including the role of shallow cracking in impacts to the water holding capacity of the swamps.
3 Hydraulic fracturing	The experience of hydraulic fracturing in Australian coal seams could be reviewed to assess the impact of fracture stimulation activities on well integrity, the failure rates associated with coal seam targeting during perforation, and to improve understanding of fracture growth in and beyond coal seams. This could potentially include developing leading practice guidelines for fracture growth modelling.

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Research priority	Key research needs
4 Voids	There is a lack of knowledge of the status and impact of voids associated with open cut coal mines. The research need is to determine the number of voids; their types; water qualities; surrounding groundwater qualities; comparison of water qualities/quantities with model predictions; interaction between voids; impacts on surrounding environments; depth profiles of redox in voids and the effect on groundwater quality and flow characteristics.
5 Assessment and modelling of groundwater and surface water connectivity	Groundwater extraction may lead to changes in the flow regimes in connected stream and wetlands. Prediction of the cumulative water-related impacts of coal seam gas extraction and coal mining relies on understanding the nature of the groundwater and surface water connectivity regime.
5a Improving understanding of groundwater recharge from surface water bodies	Groundwater recharge from floods is a major component of recharge to alluvial systems, but few groundwater models include flooding. A first step is a review of techniques to estimate flood recharge to alluvial systems near existing or proposed coal and coal seam gas operations, and consequent leakage to deeper aquifers.
5b Seepage relationships between surface water and groundwater	Seepage relationships between groundwater and surface water bodies are poorly quantified. Integrated modelling and measurements of seepage in priority areas will improve understanding of potential water-related impacts of coal seam gas extraction and coal mining.
5c Linking surface water and groundwater models	Surface water and groundwater models are usually at different spatial and temporal scales. This research priority would investigate ways to improve modelling of surface water impacts at finer scales. Linked to Hydrology priority 1b.

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Research priority	Key research needs
CHEMICALS	
1 The fate, transformation and degradation of hydraulic fracturing fluids	There is limited information about liquid and gas migration from production wells to sub surface aquifers (particularly at depth), and long-term liquid and gas migration from the fracture zone via pathways in sub surface rock formations. Developing and applying stable isotope methods to detect contamination in aquifers is one possible research strategy.
2 The effects of fracturing fluids on the release behaviour of geogenic contaminants	Hydraulic fracturing fluids have the potential to mobilise geogenic contaminants. Potential mobilisation is affected by elevated temperature, pressure, coal type and fracturing fluid composition. It would be valuable to improve understanding of the transformation and fate of geogenics, including volatile geogenics and new products formed during fracturing, under different physico-chemical conditions.
3 Flowback and produced water	A better understanding is needed of the composition and effects of flowback and produced water. The research priority is to develop analytical laboratory methods for detecting and quantifying the chemical additives in hydraulic fracturing fluids and their concentrations, characterise their physico-chemical, chemical and ecotoxicological properties, identify factors that influence their composition (e.g. formation type, fracturing fluids used, sub-surface processes, interaction with mobilised geogenics and residence time, effects of microbially enhanced CSG production) and determine their effects on aquatic ecosystems. The toxicity of mixtures and the interactive effects of chemical additives also need investigation.
4 Waste water management	There are a number of potential treatment options (e.g. reverse osmosis) for waste water from coal seam gas and coal mining operations. A review of these treatment methods could consider: their effectiveness especially for total dissolved solids and endocrine-disrupting chemicals; effects of conductivity and total dissolved solids on freshwater aquatic biota (e.g. stygofauna, turtles, frogs); the persistence and mobilisation in soil/sediments of naturally occurring radioactive material decay products; and effects-directed screening approaches to assess endocrine-disrupting and other effects of mixtures.

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Research priority	Key research needs
ECOLOGY	
1 Assessment of water-related habitat requirements for selected species and ecosystems	Prediction of responses of species and ecosystems to hydrological change remains a research need which is hampered by paucity of data at adequate spatial and temporal scales. Predicted responses derived from modelling approaches need to be validated using field data. This research would articulate a set of specific hypotheses and supporting conceptual models for field-testing predicted responses of priority ecological endpoints (taxa, communities or ecological processes) to hydrological variables.
2 Linking hydrogeological and ecological conceptual models	Conceptual modelling is a fundamental tool which facilitates shared multidisciplinary working, makes assumptions explicit and informs hypothesis generation. Hydrogeological and ecological conceptual models are usually at very different scales. Development of a protocol for linking ecological and hydrogeological conceptual models would enable identification and assessment of vulnerable biota and their ecological responses to hydrological changes associated with coal seam gas and coal mining development.