

IESC Priorities for Research Projects

Introduction

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (the Committee) provides scientific advice to decision makers on the impact that coal seam gas and large coal mining development may have on Australia's water resources. The establishment of the Committee was designed to assist in building sciencebased framework to protect the long term health and value of Australia's water resources by ensuring that the management of coal seam gas and large coal mining development is rigorous, transparent and based on the best available science.

The Committee is a statutory committee under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act). This legislation includes as functions of the Committee:

- a. to provide advice to the Commonwealth Environment Minister about priorities for research projects to improve scientific understanding of the impacts of coal seam gas and large coal mine developments on water resources; and
- b. to provide advice to the Commonwealth Environment Minister about research projects commissioned by the Minister, in relation to the impacts of coal seam gas and large coal mines on water resources.

Purpose

The purpose of this document is twofold:

- a. to identify research priorities (called themes within this document), in order to improve scientific evidence that underpins decisions about the water related impacts of coal seam gas projects and large coal mining developments, enabling decisions to be based on the most rigorous science available.
- b. to suggest research questions, to enable the commissioning of robust science and research, within the identified research themes, in order to address critical knowledge gaps and inform and strengthen decisions relating to the impact of coal seam gas and coal mining developments and associated salt production and / or salinity on water resources.

Scope

In order to identify critical knowledge gaps and determine future research priorities a focussed consultation process has been undertaken over the last twelve months. This included a series of targeted consultations led by Professor John Langford, an interim Independent Expert Scientific Committee member and an eminent water resource scientist. Professor Langford worked with the Office of Water Science to consult with key stakeholders and determine the intersection between suggested knowledge gaps, previously commissioned research, and potential future research priorities. These consultations involved state and Commonwealth government agencies, industry bodies, industry organisations and academia. Organisations including the Murray Darling Basin Authority, Geoscience Australia, CSIRO, Office of Commonwealth Environment Water Holder, the National Centre for Groundwater Research and Training, the Office of Groundwater Impact Assessment, and the University of Queensland Sustainable Minerals Institute contributed to these discussions.

In parallel, a review of current and emerging research in this field has been undertaken. Reports considered included the Queensland GasFields Commission's collation of water related science and research activities¹ and a collation commissioned by the Office of Water Science of recently commissioned research covering over 800 references. This identified in the order of 55 projects of direct relevance². Research undertaken by state government agencies, coal seam gas companies, coal mining companies, and research brokers such as the Australian Coal Association Research Program and the National Centre for Groundwater Research and Training was also considered. Relevant international research, predominantly from Canada and the USA, was also identified. The results of this analysis are summarised in Attachment A: Recently Commissioned Research Matrix.

During 2012 the Australian Government commissioned 31 knowledge projects, including eight critical science literature reviews. These reviews were designed to identify critical gaps in scientific understanding about the potential water-related impacts of coal seam gas and / or large coal mining development. The information on the knowledge gaps identified in the critical science reviews also informed the review process.

Building on the work of the interim Independent Expert Scientific Committee and initial research review and consultation with key stakeholders, a Research Workshop was held on 19 March 2013 involving more than 20 participants from academia, consulting organisations, government, industry and the community with a mix of expertise and experience in geology, hydrology, hydrogeology and ecology. The purpose of the workshop was to assist the Committee in identifying research priorities and strategic national knowledge projects relevant to water-related impacts of coal seam gas and large coal mining developments³.

While the above steps identified recent research efforts, there remained a real need to consider the results within a thematic framework that took greater account of potential risks to water resources and the statutory responsibilities and functions of the Committee. For example, in considering advice on development proposals and key research priorities, the

http://www.gasfieldscommissionqld.org.au/key-issues/collating-csg-water-related-research-projects.html

² SMEC (2012).

³ http://www.environment.gov.au/coal-seam-gas-mining/committee/activities.html#workshop

Committee has identified a number of factors that may directly or indirectly impact on water resources. These factors include:

- 1. alterations to groundwater and surface water characteristics and processes, including:
 - a. water quantity;
 - b. water quality;
 - c. groundwater pressure, water table levels, and / or groundwater and surface water interactions;
 - d. surface water and/or groundwater flow regimes;
 - e. river / floodplain connectivity;
 - f. watercourse diversions or impoundments; and
 - g. landscape modifications, such as large voids and spoil piles.
- 2. alterations to the ecological characteristics and processes of a wetland, watercourse, or groundwater dependent ecosystem, including:
 - a. biological diversity, species composition and / or ecosystem function; and
 - b. the availability of water for the environment.
- 3. alterations that result in persistent organic pollutants, heavy metals, salt or other potentially harmful chemicals accumulating in the environment.
- 4. alterations to ecological, physical or chemical aspects of coastal processes.
- 5. increases in the demand for, or reductions in the quality or availability of, water for human consumption.

The Committee also felt that consideration of the impacts on water resources from a coal seam gas or large coal mining development is linked with the cumulative impacts on water resources from other existing and likely developments. The EPBC Act definitions of coal seam gas development and large coal mining development include references to the significance of impacts of a particular development on water resources when considered with other developments, whether past, present or likely to occur in the reasonably foreseeable future⁴. This is an important requirement when considering impacts from coal seam gas and large coal mines.

The potential impact factors outlined above align closely with the research questions and themes identified later in this document.

⁴ *EPBC Act 1999*, Section 528,

Guiding Principles for Research

In considering research priorities, the Committee felt that research priorities and potential future research investments should be informed by a number of guiding principles, namely that the research should:

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

Context

To better understand the priority knowledge and research gaps, there is a need to consider the risks to Australia's water resources from coal seam gas and coal mine developments and the extent to which these risks are likely to occur, and their potential consequences, in relation to the physical life cycle in which these developments are undertaken. The Committee has identified a number of factors that may directly or indirectly impact on water resources, as discussed above. The Committee is also mindful of uncertainties and risks to water resources and associated aquatic ecosystems. These include:

- What are the risks to freshwater resources of regional scale extraction of coal seam gas and / or large scale coal mining?
- What are the risks to land and water resources of bringing co-produced water to the surface?
- What are the risks to aquatic ecosystems of changed flow patterns or water quality?
- What are the risks to environmental health (both ecosystems and humans) of the chemicals in hydraulic fracturing fluids, or in co-produced water?
- What are the cumulative risks associated with these developments?

In targeted consultations with key stakeholders, including various workshops, research questions and key knowledge gaps were identified. These questions need to be answered in order to determine whether:

 a coal seam gas or coal mining development is likely to have a significant impact on water resources;

- sufficient information has been provided to determine the potential impacts on water resources; and
- if the mitigation measures proposed are sufficient to address the potential impacts on water resources.

Both coal seam gas and coal mining generally involve extraction of groundwater. In the case of coal seam gas, gas and water are often extracted from deep geological formations, which are overlain by layers of relatively low permeability.

Changes to groundwater hydrology can also occur as a result of the interconnections between aquifers, and can cause water quantity or water quality changes. These changes can impact on surface and subsurface connectivity and water flows between surface water ecosystems and aquifers. Understanding ecosystem tolerances to these changes in river flow – particularly in terms of water quantity, quality, rates and fluxes – and the impacts these changes have on aquatic ecology are relevant considerations when looking at the impacts of coal seam gas or large coal mining developments. For example, changes in watertable depth or flow direction can impact on groundwater-dependent flora and fauna. Techniques to monitor these hydrological changes and any resultant ecosystem health are equally important.

The risks from these mining activities in relation to water resources can be summarised as:

- the risks to water resources (groundwater and surface water) from regional scale extraction of coal seam gas and / or large scale coal mining;
- the risks to ecosystems of changed flow patterns, or changes to water quantity or quality (including implications of bringing co-produced water to the surface).

The operational techniques and approaches to coal seam gas and coal mining exploration, production, and closure can pose risks to water resources, and are relevant to understanding the context and nature of where research might already exist and where the scientific knowledge gaps need to be addressed. Invariably, prediction of likely impacts (either on water availability or on ecosystems) requires models, and it is important that we know the limitations of these models, and the uncertainty involved in any of these predictions.

Considering the risks to groundwater resources from coal seam gas and large coal mining activities requires an understanding of:

- recharge processes, and rates of diffuse and bed-based recharge;
- the structure of subsurface geological formations and their properties, and the flow of water through these materials;
- how the geological structure and properties can change following mining activities, or following extraction of water and gases from within different geological units, and what this might mean for the hydrology pathways;
- the natural permeability of the geological layers, and the role of fractures and faults in providing pathways through the low permeability layers along with the possible role of bores in creating similar pathways through the low permeability layers;

- the role any connectivity through low permeability layers can have on changes to overlying aquifers, and pathways for contaminant migration; and
- the possible impacts of the mixing between co-produced coal seam gas water that is re-injected and ambient groundwater, including any geochemical reactions that might take place.

Considering the risks to ecosystem health as a result of changes to water resource quantity or quality requires an understanding of:

- the connectivity of groundwater and surface water, and predictions of whether changes in groundwater levels will affect water levels or water flows in surface water ecosystems (including rivers, springs, and swamps);
- discharge options for co-produced water through infiltration or evaporation ponds, or released to ephemeral or perennial streams, and the related locations and rates of leakage from streams and ponds to underlying aquifers, and the possible impacts of this on aquifer water levels and water quality;
- changes in water availability which can cause changes in water temperature and salinity, and then how ecosystems will respond to changes in these parameters; and
- potential impacts from chemicals introduced into surface or groundwater (such as those that may be used in hydraulic fracturing processes), and what the ecosystem tolerances are to these different chemicals.

When discussing the potential risks associated with coal seam gas and large coal mine developments it is understood that there are multiple aspects in which science could be increased. For the purposes of this Committee, it is relevant here to link the identified priorities for research, and any potential research activities, to the specific remit of the Independent Expert Scientific Committee and its requirement to consider water and salinity related risks from these particular mining activities. The wider risks that may occur from mining activities, for example non-water risks to related human health associated with air quality issues, risks to humans from fugitive gases, and / or impacts on vegetation and habitat due to construction and installation of mining related infrastructure, are areas outside of the role of the Committee and are not included within this Research Priorities paper.

Research Themes and Sub Themes

The Committee has identified research priorities, which are described as themes, falling within the following four broad areas:

1. Hydrology: Changes in Dynamics and Aquifer Interconnectivity.

Coal seam gas extraction increases the risk of interconnectivity between aquifers with potential consequences for fresh water aquifers both in terms of quantity and quality. Changing connectivity between aquifers can also have implications for surface water resources. Large coal mines, on the other hand, disrupt surface flow through river diversions

and flood protection works, and dewatering of the mine can disrupt groundwater flow patterns.

2. Ecosystems and Water: Environmental Tolerances, Responses and Mitigation.

Aquatic ecosystems and water dependent terrestrial systems (such as flood plain vegetation) can be highly dependent on the timing, quantity, and quality of water in streams. Changes in water flows can also affect water temperature and salinity, and the connectivity of stream habitats. Serious, often unintended, damage can be done to these ecosystems unless the relationships between the health of these systems and their flow and water quality requirements are clearly understood. As well as impacts associated with changes in water flows, this theme includes risks associated with the storage and disposal of saline groundwater, which can be brought to the surface as co-produced water.

3. Chemicals: Water-related Risks to Environmental Health.

Coal seam gas extraction, and coal mining more generally, may potentially use or release chemicals into the environment that could be toxic to aquatic and terrestrial organisms. These chemicals can also affect water quality, which could in turn adversely impact on human health or other uses such as agricultural water; and their toxicity must be evaluated if the risks are to properly understood and managed. There is also the potential to inadvertently mobilise naturally occurring underground chemicals and bring them to the surface in co-produced water or mine discharge water. As well as chemical and ecotoxicological investigations, this theme includes potential cross-contamination of drinking water and other water resources through the interconnection of previously isolated aquifers and surface waters.

4. Cumulative Impacts.

The potential impacts on water resources from individual coal seam gas or coal mining developments need to be assessed in conjunction with the impacts from other existing and likely developments in the region, whether past, present or likely to occur in the reasonably foreseeable future. Changes in water quantity and quality, and consequential changes in associated aquatic ecosystems, need to be assessed in more holistic terms – impacts may potentially be cancellative, additive or even synergistic. As well as investigating potential tools and techniques for cumulative impact assessment, this theme also includes the development of criteria for evaluating cumulative impact assessment reports, and issues with scale (local-regional) and timeframe (tens to thousands of years).

The research subthemes and some of the key questions that the associated research activities should seek to answer are outlined below:

1. Hydrology: Changes in Dynamics and Aquifer Interconnectivity

a. Surface water and groundwater connectivity

How can we best develop methods for estimating aquitard permeability and / or aquitard leakage at large scales? How do the aquifer and aquitard properties change during mining operation? What is the role of fractures and faults on aquifer and aquitard permeability? How should we develop methods for estimating connectivity between aquifers and rivers at large

scales? How can we accurately predict changes and fluxes in surface and groundwater connectivity? Have the predictions been accurate, or are there indications that previous estimations require changing? What are the advantages and disadvantages of various groundwater modelling approaches?

b. Bore Integrity

How can we best develop methods for assessing bore integrity (including locating legacy bores)? What are the most appropriate methods to improve well construction to minimise leakage / contamination? What is the likely contribution of leaky and legacy bores to cross-formational flow?

c. Hydraulic Fracturing

What is the spatial scale and extent of permeability changes induced by hydraulic fracturing? How does this vary with the pressure used for hydraulic fracturing and with the rock type?

d. Reinjection

What are the possible geochemical reactions that might arise from mixing of reinjected treated or un-treated co-produced water into deep aquifers? What is the potential for contamination of shallow aquifers due to pressure gradients induced by reinjection?

e. Subsidence

What is the level of confidence in predicting the degree of subsidence following coal mining operations (in sites such as the Galilee Basin) or depressurisation from coal seam gas extraction? What is the potential for subsidence to alter the permeability of geological units?

f. Mine Site and Gas Field Remediation

What are the timescales for water levels to return to pre-development levels? What are the likely long-term impacts on water quality? How can we predict changes in water quality over time?

2. Ecosystems and Water; Environmental Tolerances, Responses and Mitigation

a. Water quantity and quality, flow regimes

How will changes in flow regimes affect river channel characteristics and surface water temperature and chemistry? What are the water level, temperature and salinity tolerances of key aquatic flora and fauna? How well do current models predict changes in channel characteristics and surface water level, temperature and salinity changes arising from changes in groundwater levels?

b. Ecosystem monitoring

What are the most effective and efficient means for monitoring ecosystem changes? How do the life spans of different species affect the success of monitoring programs? How can we distinguish ecosystem changes due to coal seam gas and coal mining operations from impacts due to other environmental changes?

c. Ecosystem response and mitigation measures

How will key aquatic flora and fauna evolve if surface water or groundwater level, temperature and salinity change over time? How can we develop better methods for predicting how ecosystems will response to changes in environmental conditions, and for determining whether impacts can be mitigated and damaged habitats successfully restored?

3. Chemicals: Water-related Risks to Environmental Health

a. Chemical Migration and Toxicity

What are the principal pathways for migration of chemicals used in or released as a result of coal seam gas or coal mining operations? What is the toxicity of chemicals used in coal seam gas and coal mining operations to humans and to the environment? What are the likely concentrations in co-produced water of contaminants that may be naturally present in coal deposits? What is the toxicity of chemicals that occur naturally in coal deposits that might be brought to the surface by coal seam gas operations? Can the toxicity to different compounds be treated in isolation, or is susceptibility enhanced by exposure to multiple contaminants?

b. Managing Salt and Heavy Metals

What will be the impacts on shallow aquifer chemistry from storage of coproduced water in surface impoundments or disposal to streams?

4. Cumulative Impacts: Monitoring, Assessment and Evaluation

a. Evaluation of cumulative impact assessment

What is the best approach, or combination of approaches, for evaluating the cumulative effects of coal seam gas and coal mining operations on groundwater and surface water systems and aquatic ecosystems? What are the best methods to incorporate heterogeneity in models? What errors are introduced when simple models are used to represent complex processes? What is the best approach for evaluating cumulative impact assessments and uncertainty of model predictions?

Future Knowledge and Research Activities

Science continually grows over time and inevitably there will be knowledge gaps associated with our understanding of the geological, hydrological and ecological systems. In some cases, our understanding is limited by the availability of data. In other words, there are

existing techniques that can be employed to obtain the data required to fill these knowledge gaps; but these techniques have not yet been employed at the site in question. In other cases our understanding is limited by the lack of proven or practical scientific methods or techniques for collecting and analysing the required data.

Environmental Impact Assessments and Bioregional Assessments are actions that are centred on bringing out and filling some of these data gaps. In some cases, however, the inability to predict the impact of proposed developments with the required level of certainty stems from a lack of understanding of key processes, or an absence of measurement techniques that can provide the information required at the appropriate scale. In these cases, research activities that can develop new measurement techniques or improve our fundamental understanding of important processes are required.

Research should aim to develop and test methods that can be widely applied to improve our knowledge base, mostly in the arena of improving the scientific techniques and methods. Hence research consistent with the guiding principles outlined above (see 'Guiding Principles for Research' on page 4) means that research projects should not be designed solely to provide information at particular field sites, but should also develop methods and understandings that can be transferred to other field sites. Methods will need to be developed and tested at particular sites, but the transferability of methods and capacity for extrapolation is an important component which should be included and it is in this way that the Independent Expert Scientific Committee can assist in augmenting the national scientific capacity.

The research priorities and themes identified above present a number of research questions and knowledge gaps. It is recognised that these gaps will require further investments through specific projects.

Relevant Research and IESC Research Priorities Matrix

Relevant Research Outside OWS	OWS Existing Research	Research Questions Identified during stakeholder consultations, research workshops, Critical Science Reviews, and Knowledge Projects
1. Hydrology: Changes in Dynamics and Ac	uifer Interconnectivity	
Sub-Theme 1a: Surface water and groundwate	r connectivity	
 National Centre for Groundwater Research and Training's research programs: Hydrodynamics and Modelling of Complex Groundwater Systems Surface water - Groundwater Interactions Innovative Characterisation of Aquifers and Aquitards Queensland Department of Natural Resources and Mines - Office of Groundwater Impact Assessment Surat Underground Water Impact Report Interconnectivity between the Condamine Alluvium (CA) and Walloon Coal Measures (WCM) Influence of geological structures on groundwater flow in the Surat CMA Hydrogeology of the Walloon Coal Measures; Reconceptualisation of the groundwater systems in the Surat and Bowen Basins in Surat CMA Second generation regional flow modelling for the Surat CMA Great Artesian Basin Water Resource 	 Critical science review: aquifer connectivity Comparison of groundwater modelling approaches Hydraulic properties of aquifer geology Regional hydrogeological characterisation - for the regions not covered in the five initial priority bioregions under the Bioregional Assessments 	How can we best develop methods for estimating aquitard permeability and/or aquitard leakage at large scales? How do the aquifer and aquitard properties change during mining operation? What is the role of fractures and faults on aquifer and aquitard permeability? How should we develop methods for estimating connectivity between aquifers and rivers at large scales? What are the advantages and disadvantages of various groundwater modelling approaches?

Relevant Research Outside OWS	OWS Existing Research	Research Questions Identified during stakeholder consultations, research workshops, Critical Science Reviews, and Knowledge Projects
Assessment		
Joint with NSW Government		
Namoi Catchment Water Study		
Commonwealth Scientific and Industrial Research Organisation		
Several projects on the Gippsland Basin		
 Up-scaling coal seam gas reservoir models for regional groundwater model impact assessment 		
 Water Information Research and Development Alliance (Partnered with BoM) 		
Australian Coal Research Limited		
 Several projects on groundwater and coal mining in NSW 		
eWater		
• eWater Source software (water modelling tool)		
Sub-Theme 1b: Bore integrity		
Cooperative Research Centre for Mining	Critical science review: bore integrity	How can we best develop methods for assessing
 Coal Technology and Fugitive Emissions Management 	Monitoring and managing bore integrity	bore integrity (including locating legacy bores)? What are the most appropriate methods to improve
Commonwealth Scientific and Industrial Research Organisation		well construction to minimise leakage / contamination? What is the likely contribution of leaky and legacy bores to cross-formational flow?
Critical Review- Bore construction		
Sub-Theme 1c: Hydraulic fracturing		
U.S Geological Survey	Critical science review: hydraulic fracturing	What are the timescales for water levels to return to
 Assessing Potential Effects of Hydraulic Fracturing for Energy Development on Water 		pre-development levels? What are the likely long- term impacts on water quality? How can we predict

Relevant Research Outside OWS	OWS Existing Research	Research Questions Identified during stakeholder consultations, research workshops, Critical Science Reviews, and Knowledge Projects
Resources		changes in water quality over time?
Pacific Institute		
Hydraulic Fracturing and Water Resources		
U. S. Environmental Protection Agency		
 Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coal Bed Methane Reservoirs 		
 Study of Hydraulic Fracturing and its Potential Impact on Drinking Water Resources 		
Sub-Theme 1d: Reinjection		
Gas Industry Social & Environmental Research Alliance (GISERA) projects		What are the possible geochemical reactions that might arise from mixing of reinjected treated or un- treated co-produced water into deep aquifers? What is the potential for contamination of shallow aquifers due to pressure gradients induced by
 High performance groundwater modelling for risk assessment and management option analysis of large scale injection schemes 		
Geochemical response to re-injection		
Re-injection of CSG water		
Coal Seam Gas companies		
 Arrow Energy, Santos, Origin and QGC are all individually funding reinjection projects 		
Sub-Theme 1e: Subsidence		
Australian Coal Association Research program	Critical science review: subsidence	What is the level of confidence in predicting the
 Impacts of Mine Subsidence on the Strata and Hydrology of River Valleys 	 Subsidence impact of aquifer drawdown due to underground longwall coal mining activities 	degree of subsidence following coal mining operations (in sites such as the Sydney Basin and the Colling Basin or depresenties lies from the
NSW Department of Planning	Subsidence impact of aquifer drawdown due	seam gas extraction? What is the potential for
 Potential coal mining impacts in the Wyong LGA – strategic inquiry 	to coal seam gas extraction	subsidence to alter the permeability of geological units?

Relevant Research Outside OWS	OWS Existing Research	Research Questions Identified during stakeholder consultations, research workshops, Critical Science Reviews, and Knowledge Projects
Underground coal mining in the Southern Coalfield – strategic inquiry		
Sub-Theme 1f: Mine site and gas field remedia	tion	
 NSW Department of Infrastructure, Planning and Natural Resources Management of Salinity for Closure of Open Cut Coal Mines 		What are the timescales for water levels to return to pre-development levels? What are the likely long- term timescales for water levels to return to pre- development levels? What are the likely long-term impacts on water quality? How can we predict changes in water quality over time?
2. Ecosystems and Water: Environmental T	olerances, Responses, and Mitigation	
Sub-Theme 2a: Water quantity and quality, flow regimes		
 CSIRO Water for a Healthy Country Project - Understanding ecological responses to altered flow regimes research cluster: Ecological models Flow regimes and ecological assets Assessing ecosystem condition and trend Flow dependent ecological responses University of Queensland: SMI Centre for water in the minerals industry Assessing impact of sulphate in saline mine site discharge in seasonally flowing streams in the Bowen Basin Guidelines for Establishing Ecologically Sustainable Discharge Criteria in Seasonally Flowing Streams. Tool to Assess Mining Impacts on River 	Critical science review: mining risks to water	How will changes in flow regimes affect river channel characteristics and surface water temperature and chemistry? What are the water level, temperature and salinity tolerances of key aquatic flora and fauna? How well do current models predict changes in channel characteristics and surface water level, temperature and salinity changes arising from changes in groundwater levels?

Relevant Research Outside OWS	OWS Existing Research	Research Questions Identified during stakeholder consultations, research workshops, Critical Science Reviews, and Knowledge Projects
Condition		
Sub-Theme 2b: Ecosystem response and mitigation	ation measures	
CSIRO Water for a Healthy Country Projects	Peat swamps - engineering subsidence	How will key aquatic flora and fauna evolve if
Understanding ecological responses to altered flow regimes research cluster	Peat Swamps - Remediation	and salinity change over time? How can we
National Centre for Groundwater Research and Training's research program		develop better methods for predicting how ecosystems will response to changes in environmental conditions and determining whether impacts can be mitigated and can damaged habitats be successfully restored?
Groundwater–Vegetation–Atmosphere Interactions		
Australian Coal Research Limited		
Criteria for Functioning River Landscape Units in Mining and Post Mining Landscapes		
 Guidelines for Establishing Ecologically Sustainable Discharge Criteria in Seasonally Flowing Streams 		
Australian Coal Association Research Program		
Impacts of Coal Mining on Aquatic Ecosystems in Central Queensland		
Sub-Theme 2c: Ecosystem monitoring	-	
University of Queensland: SMI Centre for water in the minerals industry	 Peat swamps - ecology monitoring Great Artesian Basin Coal Basins Springs 	What are the most efficient means for monitoring ecosystem changes? How do the life spans of
An assessment of the monitoring programs in the Newnes Plateau shrub swamp communities in the western coalfields of NSW	Survey Phase 1	different species affect the success of monitoring programs? How can we distinguish ecosystem changes due to coal seam gas and coal mining
Australian Coal Research Limited		operations from impacts due to other environmental changes?
Tool to Assess Mining Impacts on River Condition		
Queensland Department of Natural Resources		

Relevant Research Outside OWS	OWS Existing Research	Research Questions Identified during stakeholder consultations, research workshops, Critical Science Reviews, and Knowledge Projects
 and Mines - Office of Groundwater Impact Assessment Improving knowledge about springs Murray-Darling Freshwater Research Centre Integrated Ecological Condition Assessment Framework Chemicals: Water-Related Risks to Enviro Sub-Theme 3a: Chemical Migration and Toxicity 	onmental Health	
 University of Queensland: SMI Centre for water in the minerals industry A Water Chemistry Atlas for CSG Fields: Discovering value beyond baseline monitoring A Human Health Risk Assessment for developing CSG water resources in QLD Queensland Government Fitzroy Basin Water Quality Projects 	National assessment of chemicals associated with coal seam gas extraction	What are the principal pathways for migration of chemicals into the environment? What is the toxicity of chemicals used in coal seam gas and coal mining operations to humans and to the environment? What are the likely concentrations in co-produced water of contaminants that may be naturally present in coal deposits? What is the toxicity of chemicals that occur naturally in coal deposits that might be brought to the surface by coal seam gas operations? Can the toxicity to different compounds be treated in isolation, or is susceptibility enhanced by exposure to multiple contaminants?
Sub-Theme 3b: Managing Salts and Heavy Met	als	
 Gas Industry Social & Environmental Research Alliance (GISERA) project Monitoring of geochemical and isotopic characteristics of CSG formation waters, adjacent aquifers and springs University of Queensland: SMI Centre for water in the minerals industry 	 Critical science review: co-produced water environmental impacts The geochemical, organic and isotopic composition of coal seam gas co-produced waters Critical science review: managing coal seam gas co-produced water 	What will be the impacts on shallow aquifer chemistry from storage of co-produced water in surface impoundments or disposal to streams?

Relevant Research Outside OWS	OWS Existing Research	Research Questions Identified during stakeholder consultations, research workshops, Critical Science Reviews, and Knowledge Projects
 Understanding salt dynamics to facilitate water reuse on coal mine sites. Coal Seam Gas, Coal and Agriculture: Water Implications Water for the Future- Healthy Headwaters program Coal Seam Gas Water Feasibility Study 4. Cumulative Impacts: Monitoring, Assessing Sub-Theme 4a: Evaluation of cumulative impact 	ment and Evaluation	
 National Water Commission Potential local and cumulative impacts of mining on groundwater resources QLD Department of Environment and Heritage Protection Fitzroy Basin Water Quality Projects Queensland Department of Natural Resources and Mines - Office of Groundwater Impact Assessment Surat Underground Water Impact Report University of Southern Queensland Preliminary Assessment of Cumulative 	 Critical science review: cumulative and strategic assessment modelling Bioregional Assessments are science based studies that will develop detailed, multi-layered records of the natural environment in a particular geographic region. They will analyse the ecology, hydrology, geology and hydrogeology of a region; and assess the potential direct, indirect and cumulative impacts of coal seam gas and coal mining developments on water resources both above and below ground. Bioregional Assessments will be initially undertaken assess the potential direct. 	What is the best approach, or combination of approaches, for evaluating the cumulative effects of coal seam gas and coal mining operations on groundwater and surface water systems and aquatic ecosystems? What are the best methods to incorporate heterogeneity in models? What errors are introduced when simple models are used to represent complex processes? What is the best approach for evaluating cumulative impact assessments and uncertainty of model predictions?
Drawdown impacts in the Surat Basin Associated with the Coal Seam Gas Industry	 undertaken across six regions, being: Lake Eyre Basin Northern Inland Catchments of NSW and southern Qld Clarence-Moreton Basin in Qld and NSW 	

Relevant Research Outside OWS	OWS Existing Research	Research Questions Identified during stakeholder consultations, research workshops, Critical Science Reviews, and Knowledge Projects
	 Southern Sydney Basin in NSW 	
	 Northern Sydney Basin and the Gloucester Basin in NSW 	
	Gippsland Basin in Victoria.	

Research Projects

Research Themes and Sub-Themes	Project	
1. Hydrology: Changes in Dynamics and Aquifer Interconnec	tivity	
Sub-Theme 1a: Surface water and groundwater connectivity	1a.1 Selection, application, and evaluation of groundwater models to assess the impacts of coal seam	
	1a.2 Quantifying the impact of faulting and fracturing on groundwater flows and aquifer connectivity at	
	1a.3 Development and testing of methods for assessing inter-aquifer connectivity and aquitard leakage	
Sub-Theme 1b: Bore integrity	1b.1 Legacy and failed bores and the implications for aquifer interconnectivity	
Sub-Theme 1f: Mine site and gas field remediation	1f.1 Time-frames for aquifers to return to their natural state post coal seam gas and coal mining produ	
2. Ecosystems and Water: Environmental Tolerances, Responses, and Mitigation		
Sub-Theme 2a: Water quantity and quality, flow regimes	2a.1 Assessment of surface and groundwater interconnectivity, exchanges, and fluxes	
	2a.2 Tolerances of key species and ecological communities to changes in surface and groundwater flo with coal seam gas and coal mining	
Sub-Theme 2b: Ecosystem effects and monitoring	2b.1 Is the current monitoring undertaken by proponents sufficient to detect the changes in ecosystem coal seam gas and coal mining water	
Sub-Theme 2c: Ecosystem response and mitigation measures	2c.1 Evaluation of methods for mitigating or remediating impacts of coal seam gas and coal mining act	
	2c.2 Impacts and thresholds of watertable drawdown on groundwater dependent vegetation	
3. Chemicals: Water-Related Risks to Environmental Health		
Sub-Theme 3a: Chemical migration, contamination, and toxicity	3a.1 Chemical tracers to identify contamination of water resources from coal seam gas and coal mining	
4. Cumulative Impacts: Monitoring, Assessment and Evaluation		
Sub-Theme 4a: Evaluation of cumulative impact assessment	4a.1 Framework for evaluating Cumulative Impact Assessments – evaluation criteria, tools, and technic	

gas and coal mining activities
ocal and regional scales
rates
ction
w regimes and water quality associated
condition and trends associated with
ivities on aquatic ecosystems
3
ques