

## Advice to decision maker on coal seam gas project

### IESC 2014-051: Arrow Energy Bowen Gas Project (EPBC 2012/6377) – New Development

<b>Requesting agency</b>	The Australian Government Department of the Environment
<b>Date of request</b>	4 June 2014
<b>Date request accepted</b>	4 June 2014
<b>Advice stage</b>	Approval

#### Context

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) was requested by the Australian Government Department of the Environment to provide advice on the Arrow Energy Bowen Gas Project in Queensland.

The IESC previously provided advice on the Bowen Gas Project (BGP) Environmental Impact Statement (EIS) on 24 May 2013. Arrow responded to the IESC's advice in their *Response to Independent Expert Scientific Committee Advice on the Bowen Gas Project Environmental Impact Statement, June 2014* (Arrow's response). This advice draws upon information in Arrow's response, associated information provided in the Supplementary Report to the Environmental Impact Statement (SREIS) and expert deliberations of the IESC. The project documentation and information accessed by the IESC are listed in the source documentation at the end of this advice.

Arrow Energy's proposed BGP is a greenfield coal seam gas (CSG) development with a project life of up to 40 years. It is located in the Bowen Basin in Central Queensland, and covers an area of approximately 8000 km<sup>2</sup>. The BGP is located within the Isaac River and Mackenzie River sub-catchments of the Fitzroy River catchment and the Belyando-Suttor sub-catchment of the Burdekin River catchment.

The Bowen Basin is an area of significant mining development in Queensland. There are currently over 40 operational coal mines and one CSG project (Arrow Energy's Moranbah Gas Project) in the region. There are also several related infrastructure projects in the region, including the Arrow Bowen Pipeline project, which comprises a 580 km pipeline to carry gas from Arrow Energy's Bowen Basin projects (including the BGP and Arrow Energy's Moranbah Gas Project) to Gladstone for export.

CSG will be extracted through the development of approximately 4000 CSG production wells targeting coal sequences within the Late Permian Blackwater Group, clustered together in multi-well pads of 4–12 wells. Up to approximately 1000 wells (25 per cent) could be hydraulically stimulated. Wells would be placed over 33 "drainage areas" (each with a 6 km radius) from which pipelines would feed gas and water to two sites where central gas processing facilities and water treatment facilities

would be co-located. Total estimated water production is approximately 153 GL over 36 years. The proponent proposes to treat this water through desalination, and then discharge the treated water to the Isaac River, if other beneficial uses (as defined under Queensland legislation) cannot be secured, such as industrial or agricultural re-use.

Groundwater resources in the region include shallow (Quaternary Alluvium and Tertiary Basalt), intermediate (Triassic) and deep aquifers (Permian). The majority of groundwater use is from shallow aquifers, for a range of purposes including irrigation; intensive stock watering; domestic and town supply; industrial and mining. Four sites of indigenous cultural and spiritual significance that rely on the presence of groundwater (wells) have also been identified in the northern portion of the project area. Groundwater dependent ecosystems (GDEs) identified in the project region include: springs; spring wetlands; and groundwater discharge to rivers and wetlands. The EPBC listed black ironbox (*Eucalyptus raveretiana*) is endemic in the region and the EPBC listed brigalow (*Acacia harpophylla*) is relatively common in the project area.

#### Assessment against information guidelines

The IESC, in line with its Information Guidelines<sup>1</sup>, has considered whether the proposed project assessment has used the following:

##### *Relevant data and information: key conclusions*

Additional investigations carried out by the proponent in the SREIS have provided data and improved understanding of faulting, hydraulic stimulation, fracture propagation and subsidence in the region. This has addressed some of the IESC's concerns in the previous advice. However, as identified in the IESC's previous advice, there is inadequate primary data provided in the SREIS to substantiate understanding of groundwater, surface water and aquatic ecosystems within the project region.

Information that would further support a risk-based assessment of the potential impacts of the BGP include:

- spatially and temporally representative hydrostratigraphic and potentiometric field data to validate the groundwater model parameterisation and calibration
- characterisation of existing groundwater quality, surface water hydrology, aquatic ecology and groundwater dependent ecosystems (GDEs)
- the risk assessment and details of proposed chemicals to be used for hydraulic stimulation events.

##### *Application of appropriate methodologies: key conclusions*

The work undertaken by the proponent to theoretically characterise faults using data from international experience was extensive, however further data collection and monitoring in the Bowen Basin is needed to validate this work.

The numerical groundwater model has been peer reviewed. The peer review noted that the groundwater model conforms to best industry practice, however is classified as Class 1 (Barnett et al. 2012) due to limited regional hydrogeological data. Further detail on maximum predicted drawdown in model layers needs to be provided. The representation of springs in the groundwater model will be important in predicting potential impacts and developing appropriate management responses, and should be informed by field hydraulic information. The representation and extent of the Rewan Formation should be updated in the groundwater model.

*Reasonable values and parameters in calculation: key conclusions*

To improve the groundwater model's predictive capability, aquifer parameters need validation with long term pump test data. Transient model calibration needs to be undertaken with additional, updated and representative long term time series groundwater level and pressure data. An update to the sensitivity and uncertainty analyses should also be undertaken in future revisions of the model.

Further information on the relevance of the water quality data obtained from coal mines in the region is needed to inform whether it is suitable to define existing conditions for this project.

**Advice**

The IESC's advice, in response to the requesting agency's specific question is provided below.

Question 1: Taking into account Arrow's response to matters raised by the Committee in their advice of 24 May 2013 (refer to Arrow's Response to the *Independent Expert Scientific Committee advice on the Bowen Gas Project Environmental Impact Statement*) and the monitoring regime proposed by Arrow, what does the Committee consider are the features of a monitoring and management framework that would address any remaining uncertainties or risks to water resources associated with the project?

Response

1. Arrow has done significant work to address many of the IESC initial concerns, particularly around faults, subsidence, hydraulic stimulation and connectivity between consolidated and unconsolidated aquifers. However data gaps remain, particularly regarding recharge (as a component of the water balance), time-series groundwater level / pressure data (to enable transient calibration of the regional groundwater model), and data on surface water and aquatic ecosystems within the project region. This has limited the identification of the specific potential risks and uncertainties associated with the project.
2. Taking into account Arrow's response and the SREIS, the remaining risks and uncertainties to water resources associated with the project include:
  - a) Groundwater drawdown and potential changes to groundwater flow associated with faults and interaquifer connectivity between hydrostratigraphic units.
  - b) The storage and the management and disposal/re-use of co-produced CSG water.
  - c) Impacts to groundwater, surface water and aquatic ecosystems present within the project region, including the springs in Blackdown Tableland National Park.
  - d) Cumulative impacts on groundwater and surface water resources due to CSG and other mining projects in the region.
  - e) Potential impacts of hydraulic stimulation and associated chemical use on water quality in aquifers.
3. Monitoring and management measures to address these risks and uncertainties would include:
  - a) The establishment of a groundwater monitoring network, which would include the installation of dedicated monitoring bores; baseline and ongoing groundwater monitoring; a bore census; collection of additional hydrogeological data representative of all hydrostratigraphic units; and

characterisation of baseline groundwater conditions to inform groundwater level and quality thresholds.

- b) Validation and refinement of the conceptual model for groundwater and surface water dynamics associated with GDEs.
  - c) Regular revision of the groundwater model including updated uncertainty and sensitivity analyses and demonstration of how uncertainties in the model have been reduced; additional representative climate data; any changes to inflows and outflows of the model; and additional regional hydrogeological data.
  - d) Undertaking additional surveys to characterise surface water hydrology and water quality in locations proposed for water treatment facilities and co-produced water discharge.
  - e) Management of co-produced water and evaluation of the range of potential environmental impacts when determining potential re-use/disposal options for co-produced water.
  - f) Additional aquatic ecology surveys, particularly focussed in the areas of proposed discharge of treated co-produced water.
  - g) Monitoring and risk assessment of hydraulic stimulation events, including risks associated with the use of particular chemicals.
  - h) Validation of theoretical fault analysis with field data and testing from the Bowen Basin.
  - i) Consideration of cumulative impacts to groundwater and surface water resources.
4. These monitoring and management measures are described in detail in the “explanation” section below.

#### Explanation

5. The features of a monitoring and management framework needed to address the risks and uncertainties of the project are detailed below under the sub-headings: groundwater monitoring; groundwater model; surface water characterisation; co-produced water management; salt management; ecological values and water related assets; hydraulic stimulation and chemical use; faults; subsidence; and cumulative impacts.

#### *Groundwater Monitoring*

6. Based on the IESC’s previous advice, a groundwater monitoring program is needed to determine a baseline for ongoing impact assessment and management. The key components of a monitoring program for this project are:
- a) Installation of dedicated monitoring bores, including nested bores and vibrating wire piezometers, in relevant formations and at appropriate depths and locations. The sensitivity analysis of the groundwater model will help inform the location and depths of monitoring bores. Monitoring bores should be sampled at an appropriate frequency to establish seasonal trends and identify aberrations in groundwater pressure, level and quality. A minimum twenty four months of data would be needed to establish seasonal variation in groundwater characteristics. Further:
    - i. The density of monitoring bores needs to be higher in areas where known and newly identified faults are located. At these locations, groundwater monitoring in a range of

formations, including those immediately above the target coal seams and assumed aquitards, and at a range of depths and locations, is needed to monitor the potential influence of the faults on groundwater flow due to depressurisation. Nested bores are particularly important to measure groundwater levels from different depths and formations at specific sites, providing clear evidence of head differences between strata.

- ii. The density of bores and the frequency of monitoring should also be higher in areas of predicted drawdown, areas where the Rewan Formation is not present or thin, and areas with GDEs.
  - iii. Long term groundwater monitoring in all bores, analysing all appropriate aquifer physical and chemical characteristics, including groundwater pressure, water level and hydrogeochemical characteristics is needed.
- b) Collation of additional groundwater field data from long term pump tests is necessary, to develop hydrogeological understanding of parameters such as hydraulic conductivity and storage within the project region. This information will help substantiate the groundwater conceptualisation and inform the numerical groundwater model parameterisation.
  - c) Additional field tests and observations to characterise the Rewan Formation are needed. This will be important to confidently conceptualise and represent its extent and role as a regional aquitard in the groundwater model.
  - d) Census to identify bores and groundwater use in the region given the project tenures cover an area of 8000 km<sup>2</sup> should be undertaken prior to project commencement.
  - e) Early warning triggers for groundwater drawdown and water quality should also be developed prior to production, particularly for sensitive shallow aquifers, to minimise risks to other groundwater users.
7. As part of the management framework, details on refinements made to the reservoir model should be provided. The proponent states that refinement to the reservoir modelling shows lower water extraction rates are expected from production wells than was predicted in the EIS. This reduction is said to be due to a combination of improved well placement, fewer wells and lower extraction rates.

#### *Groundwater Model*

8. The numerical groundwater model is an important management tool to predict the location and magnitude of impacts arising from project operations. Following peer review, the current model has been classified as Class 1 (Barnett et al. 2012), due mainly to the limited hydrogeological data for parameterisation and inadequate time series groundwater level and pressure data for transient calibration. Given the model's current limitations and the scale of the project, the model should be reviewed on a regular basis to predict impacts before they occur and inform appropriate management responses. This should include updated uncertainty and sensitivity analyses and demonstration of how uncertainties in the model have been reduced. Timeframes for major review and update could coincide with updates (every 3 years) to the Underground Water Impact Reports required under the Qld *Water Act 2000*.
9. To address the limitations associated with data and parameterisation in the model, and to increase and demonstrate the model's predictive capability:
- a) Model parameterisation should be updated, in particular with additional long term pump test data to determine hydraulic conductivity and storage parameters for all model layers.

Recharge values should also be confirmed through independent field tests, ideally using multiple lines of evidence.

- b) Clarification of how the fault analyses will inform and refine the regional groundwater flow model should be provided.
- c) Transient model calibration needs to be undertaken with additional, updated and representative long term time series groundwater level data.
- d) The Rewan Formation should be represented in the model as a specific layer rather than coupled with the overburden of the Rangal Coal Measures (RCM), because it is a key aquitard. In addition, the current conceptualisation and extent of the Rewan Formation presented in the SREIS needs to be updated in the model. Given the variability of the Rewan Formation and its significance in mitigating potential impacts on shallow groundwater aquifers, the current conceptualisation needs to be regularly assessed through field observations and tests, and its parameterisation updated in the groundwater model.
- e) Individual water balance inputs in the model should be reported separately, particularly maximum leakage from streams.
- f) Modelling of springs within the project region needs to be informed by field hydraulic information, in order to predict potential impacts.
- g) The model should be updated to include and/or take into consideration other groundwater users in the region, including coal mines and agricultural use. This will help provide an estimate of cumulative impacts as a result of the ongoing use of groundwater resources in the region and inform the project's contribution to these cumulative impacts.
- h) Maximum drawdown estimates for each model layer should be provided during production, at the end of production and post-production. Table 8.1 provided in the SREIS (App E) does not provide adequate detail on the magnitude of potential drawdown impacts.

#### *Surface water characterisation*

- 10. As part of the management framework, additional surface water sampling and assessment is needed to increase understanding of spatial and temporal variability in water quality. The proponent proposes to complete many of the surface water quality baseline monitoring measures recommended by the IESC during the application stage for an Environmental Authority. This includes survey of receiving environments once infrastructure layout is confirmed. A minimum twenty four months of data to establish existing conditions would be favourable for these assessments, to enable ongoing adequate impact assessment and management.
- 11. Additional contextual information, including location and timing of sampling, should be provided for the water quality dataset that is presented in the SREIS. This will help address the IESC's initial concerns around characterising existing surface water quality. A robust statistical analysis is also needed to ensure the dataset is fit for use in establishing water quality objectives for the project.
- 12. The IESC reaffirms its previous advice in relation to surface water sampling as outlined under paragraph 14 and 15 of that advice, in particular: paragraph 14b; paragraph 4d; paragraph 14e; paragraph 14f; paragraph 14g; and paragraphs 15a to 15c.
- 13. Impacts of groundwater drawdown on baseflow in all relevant water courses need to be accounted for in the groundwater model. Where potential impacts are identified, field based

investigations and monitoring might be needed to assess impacts to water related assets within the region.

#### *Co-produced water management*

14. The proponent intends to use design and operation information from its Surat Gas Project water treatment facilities to inform the design and operation of water treatment facilities for this project. Given the conceptual nature of information provided, the IESC's previous advice (paragraph 16) in relation to the management of co-produced water is still relevant. In particular, paragraph 16c, paragraph 16d, and paragraph 16e.
15. In a region of relatively sparse groundwater resources, options for re-injection of treated CSG water into shallow aquifers or groundwater substitution should be carefully considered. This consideration will be important in maintaining the overall water balance and go some way to relieving the pressure on groundwater resources in the region. Environmentally sustainable outcomes for the beneficial use of co-produced water should be ensured. The proponent states that re-injection is not a viable option, however further information should be provided as to why the various aquifers in the region are not considered suitable for reinjection.
16. Where discharge to the environment is proposed, a discharge strategy should be developed that considers the flow requirements of water related assets and the influence of other discharges occurring in the region. McGregor et al. (2011) outlines a process for assessing and managing impacts of changes to flow regimes which may arise from discharges of CSG water. To inform the development of the discharge strategy, particular information requirements would include: location and sizing of water management infrastructure such as dams, discharge point locations, discharge water quality, discharge scenarios, timings and volumes.
17. The proposed CSG water management and discharge strategies should demonstrate that there are sufficient discharge opportunities to dispose of the necessary quantities of CSG water, should beneficial use not be practical. It should also address how water storage and discharge are proposed to be managed during periods of extended cease-to-flow duration. The lack of adequate storage may lead to the need to discharge co-produced water during no-flow periods, which is likely to impact on the natural flow regime of the Isaac River.
18. As part of the management framework, further information is needed on the design of discharge outlets. The mode of CSG water transport from the water treatment facilities to the Isaac River main channel also needs to be identified. Details on these aspects would assist in assessing impacts and determining appropriate management responses to mitigate risks to downstream water-related assets.
19. The proponent has identified that there may be a third water treatment facility located near Blackwater in the Mackenzie River catchment. It is unclear whether the proponent is considering discharges from this location, and if so, to what watercourse, given that the Isaac River main channel is not present in that vicinity. It is not possible to comment on the adequacy of mitigation in this region, given the limited details. In particular, conclusions drawn from the assessment carried out for the Isaac River may not be applicable to the Mackenzie River catchment, given the likely differences in flow regime and environmental values. If such discharges are proposed for this region, a site specific impact assessment would need to be carried out.
20. As part of the management framework, the significant discrepancies in the measured and modelled bankfull flow discharge volumes needs to be reconciled, to demonstrate there is sufficient assimilative capacity in the Isaac River main channel at the proposed discharge locations. For example, the proponent has identified the 1 in 2 year ARI event as the bankfull flow at the Goonyella and Deverill gauges with discharge rates of 1.9 and 18.0 GL/d, respectively.

However, the modelled bankfull flow discharge rates at the potential Water Treatment Facility 1 and Water Treatment Facility 2, which are represented by these gauges, are 23.3 and 203 GL/d respectively. Such discrepancies suggest that the assimilative capacity of the Isaac River may be overestimated and there is potential for discharge of CSG water to adversely affect the geomorphology and aquatic ecosystems of watercourses.

#### *Salt Management*

21. Further consideration of options is needed for the disposal of salt generated from the project. Currently 4.3 tonnes of salt are estimated to be produced per megalitre of treated co-produced water. Based on the current total water production estimate of 153 GL for the project, this equates to approximately 657 900 tonnes to be produced over 36 years. While the disposal of salt to landfill is currently deemed the most viable option, given the timeframes for this project, alternative options should be considered.

#### *Ecological values and water related assets*

22. The IESC's previous advice (paragraph 14) needs to be addressed, in particular, the need for aquatic ecology surveys to establish a baseline at the proposed sites of water discharge.
23. The monitoring regime for GDEs proposed in the SREIS should not be delayed until the Environmental Authority application stage. This is important as the revised proposed timeframes for these surveys may not enable an adequate assessment of existing conditions prior to groundwater extraction. Additionally, the survey should be carried out with a particular focus on vegetation including *E. raveretiana* and *A. harpophylla*.
24. The proponent should clarify the source aquifer for the North Escarp Spring. In addition, in order to evaluate risks to this spring, further verification of the thickness of the Rewan Formation and the influence of any faults in this part of the Blackdown Tableland National Park is needed. While the proponent states that the spring will be managed under the Surat Cumulative Management Area (CMA) Spring Impact Management Strategy (SIMS), the current Office of Groundwater Impact Assessment (OGIA) model does not take Arrow BGP CSG operations into consideration. As a result, potential impacts on this spring and others in the area may be underestimated. As part of the management framework, future iterations of the OGIA groundwater model and SIMS may need to consider impacts from the Arrow BGP.
25. The project is located within a region that may provide habitat for the EPBC listed vulnerable Fitzroy River Turtle. Appropriate surveys are needed, particularly near discharge locations, to identify and mitigate potential impacts.

#### *Hydraulic stimulation and chemical use*

26. In addition to the reporting requirements under the Petroleum and Gas (Production and Safety) Regulation 2004 and the Environmental Protection Act 1994 for hydraulic stimulation events, the complete Environmental Risk Solutions (ERS) report "Well Stimulation Risk Assessment, ATPs 831, 1025, 1031 and 1103", dated 15 June 2012 should be provided. A summary of this larger report was provided as a memo in the EIS, titled Hydraulic Stimulation Risk Assessment Summary, 16 October 2012. As such, specific detail on hydraulic stimulation and the chemical risk assessment was not available for review, but should include details on:
  - a) how hydraulic stimulation and fracture propagation will be monitored and controlled
  - b) whether both horizontal and vertical wells will be stimulated and whether the effectiveness of monitoring and control processes will vary between proposed well types



- c) estimates for water use and source
  - d) the risk assessment undertaken on individual chemicals and total frac fluid.
27. The use of surface tiltmeters (18 to 20 tiltmeters for any given event) and microseismic monitoring should be considered in monitoring fracture propagation and geometry. Other methods such as Radio Active (RA) tracers, sonic anisotropy logging, geochemical modelling and treatment pressure history-matching data would also contribute to an integrated method of interpreting fracture propagation and geometry (Raymond et al. 2010). The monitoring of fracture propagation is important in managing potential impacts of inter-aquifer connectivity, particularly to shallow aquifers.
28. The chemicals risk assessment should include an assessment of the necessity for ecotoxicology testing of individual chemicals and the total frac fluid mixture. In relation to the 27 hydraulic fracturing fluids proposed to be used by the proponent in the EIS, the following observations are made:
- a) The constituent Bentonite, Benzyl (hydrogenated tallow alkyl) Dimethylammonium Stearate Complex (CAS 121888-68-4) is not registered for import or use in Australia as an industrial chemical.
  - b) The inclusion of Sweet Orange Oil in drilling and hydraulic fracturing fluids should be informed by an appropriate risk assessment.
  - c) The wrong name has been provided for CAS 61789-40-0 (Cono dimethylaminopropyl betaine).
  - d) A CAS number has not been provided to justify the use of the following constituents:
    - i. Alcohol surfact mix
    - ii. Enzyme Enzyme
    - iii. Ethoxylated Fatty Acid
    - iv. Terpene hydrocarbon by-product
    - v. Hemicellulase Enzyme carbohydrates.

#### *Faults*

29. The additional research undertaken by Arrow to conceptualise and characterise faults in the region was extensive. However, it cannot be confidently concluded from this research, that faults will act as barriers to groundwater flow in this region due to the lack of specific data from the Bowen Basin.
30. As part of the management framework, Arrow states that they will actively avoid faults when planning their drilling program. However, given the significance and prevalence of faulting within the Bowen Basin, the risk of aquifer interconnectivity around fault zones remains and needs to be monitored and managed.

#### *Subsidence*

31. Monitoring is needed to validate the current estimates for subsidence at the surface, which is currently estimated to be relatively low (15mm to 75mm).

### Cumulative Impacts

32. Consistent with the IESCs previous advice, the groundwater model needs to be updated to take into consideration the existence of more than 40 coal mines and other groundwater users within the region. Even if groundwater drawdown from the project is not predicted to intersect with drawdown from mining operations, the total water balance should be identified. Planning and management of proposed surface water discharges need to take discharges from nearby mines into consideration.

### Other

33. Commitments for surface and groundwater monitoring should be presented as part of a water monitoring plan and should be consistent with the National Water Quality Management Strategy.
34. Data and relevant information from the proposed project should be made accessible to assist the knowledge base for future research and regional scale assessments.

---

<b>Date of advice</b>	18 July 2014
-----------------------	--------------

---

<b>Source documentation available to the IESC in the formulation of this advice</b>	<p>Arrow Energy 2014, Response to Independent Expert Scientific Committee advice on the Bowen Gas Project Environmental Impact Statement</p> <p>Arrow Energy Pty Ltd 2014, Supplementary Report to the Environmental Impact Statement</p> <p>Barnett et al. 2012, <i>Australian groundwater modelling guidelines</i>, Waterlines report, National Water Commission, Canberra</p> <p>DotE 2014, <i>Co-produced water – risks to aquatic ecosystems</i>, Background Review, Office of Water Science, Department of the Environment, Canberra.</p> <p>IESC 2013, Advice to decision maker on coal seam gas development, Bowen Gas Project, Arrow Energy Pty Ltd, 24 May 2013</p> <p>Raymond et al. 2010, <i>Evaluating hydraulic fracture effectiveness in a coal seam gas reservoir from surface tiltmeters and microseismic monitoring</i>, Society of Petroleum Engineers, Conference paper</p>
---	---

---

<b>References cited within the IESC's advice</b>	<p><sup>1</sup> Information Guidelines for Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals available at: <a href="http://iesc.environment.gov.au/pubs/iesc-information-guidelines.pdf">http://iesc.environment.gov.au/pubs/iesc-information-guidelines.pdf</a></p>
--	--

---