Independent Peer Review

by Dr. Glenn Harrington, Director & Principal Hydrogeologist
Reissued 26th April 2016

Arrow Energy Surat Gas Expansion Project
CSG Water Monitoring & Management Plan
Section 13(b) report (version RevB) prepared by CDM Smith

This document has been revised and reissued by IGS to provide greater clarity around one of the issues (disconnected streams – item 10) that was identified in an earlier version of the document (dated 1st April 2016). The issue in question is also no longer considered by IGS to be a "major limitation" of the work to date, as CDM Smith have acknowledged that their explanations of process understanding and modelling approaches for disconnected streams needs to be improved.

Summary of Review Findings

This report by CDM Smith presents a considerable body of high quality work to help Arrow Energy (Arrow) address Condition 13(b) of the Approval for the Surat Gas Expansion Project (SGEP), which is to be included as part of a Stage 1 Coal Seam Gas Water Monitoring & Management Plan (WMMP).

The report is variable in style and level of scientific rigor, however the key modelling chapters that underpin the technical assessment are logical, sound and defensible. Additional contextual information, including a hydrogeological conceptual model, is required, and further justification is needed for the methodologies that have been employed. The report presents very effective applications of the existing OGIA Surat CMA model, the Central Condamine Alluvium Model (CCAM), and two Integrated Quantity and Quality Models (IQQM). However, some further analysis of the model outputs is required to demonstrate confidence in the predicted impacts of CSG development on surface water, dependent ecosystems and licensed allocations.

There is one obvious limitation of the work to date that should be addressed for the WMMP, which is an assessment of potential impacts to watercourses other than the Condamine River and its northern anabranch. This assessment cannot be performed with the existing models, and thus a risk-based approach is recommended.

Major Comments and Suggestions

The following list of 12 items outlines the most significant issues that I have identified with the current report, and provides a narrative for further discussion in a workshop with Arrow and CDM Smith. Items 1-7 should be easy to address as they mostly relate to either building a more complete context for the assessment that is required to underpin Condition 13(b), or to providing further explanation and justification for the methods used to estimate potential impacts of CSG development. The remaining items (8-12) will require careful consideration and ideally some further technical analysis, as they could have implications for the overall results of the assessment.

1. *Section 2: Surat Gas Expansion Project*

   Most of this section isn't about the SGEP. Consider moving sections 2.1 and 2.2 into the Introduction (section 1), and sections 2.3 and 2.4 into later sections (i.e., chapters) where they are relevant to the assessment.

2. *Condamine Alluvium extents*

   Sections 2.3 and 3.2 need much clearer justification for the adopted extent(s) of the Condamine Alluvium used in this assessment. They at least need to consider the locations of surface water features and dependent ecosystems (DEs), and the extent of likely and predicted changes in flux between the Surat Basin and the Condamine Alluvium due to CSG development.

3. *Hydrogeological conceptual model*

   Section 3.3 needs significantly more hydrogeological context, including details of the regional hydrogeology and aquifer connectivity. Assume that most readers of this document wont know background literature around hydrostratigraphy and conceptualisation of leakage processes, especially connectivity between the Walloon Coal Measures and Condamine Alluvium. A conceptual model cross-section would be very helpful.

   Section 6 (Conceptual Model) is actually more about Model Requirements and should be retitled accordingly. Regardless, the hydrogeological conceptual model needs to come much earlier than section 6.

4. *Section 4: Surface water – groundwater interaction*

   This is the first of two sections in the report (the other being section 7.3) that are a major distraction to the reader in terms of their style, relevance and scientific content. Section 4 definitely needs more "evidence-based" science, especially in section 4.2, which should explain the methodology and findings of previous work by CSIRO and others. Section 4.2.1 is very long and boring; the key points could be summarised in a few punchy sentences with high-quality references. Likewise, section 4.2.2 is very long, verbose and lacks a clear statement of its relevance or importance to this assessment.

5. *Section 6.2: Processes of Importance*

   This section needs clear statements about why these processes are important, what data is available to model them, and where any uncertainties may arise in the modelling. It needs evidence in the form of numbers and references rather than commentary about what is "believed" to occur.

6. *Section 7.2: Regional Scale Groundwater Modelling*

   This is the first of two exceptionally good sections in the report (the other being section 7.4) and is a key scientific component of the overall assessment. There are several areas where further explanation is warranted, for example why there should be differences in the results of some models.

   My only significant comment on this section is that I would like to see a map of peak change in vertical flux in each model cell for all realisations. I realise that this depiction may not be realistic in terms of the collective distribution of fluxes because it comes from all realisations with different hydrogeological properties that together may not yield a calibrated model. However, I think it is critically important to demonstrate that realisation 'r1' (in this case) and the High, Median and Low realisations (later in section 7.4.4.2) are representative in terms of both the range and distribution of changes in peak fluxes. It would also be useful to present an accompanying figure to show what realisation the peak change in flux comes from for each model cell.

   If these new figures show that the High, Median and Low case realisations do not adequately capture the full range and potential distribution of peak changes in fluxes, then further modelling that uses other realisations may be required.

7. *Section 7.3: Surface Water-Groundwater Interactions*

   This section is a major distraction to the reasoning and style of the report, and brings into doubt confidence in the assessment methodology. Much of the text comes across as a repetitive and incoherent critique of Brunner et al.'s work with no meaningful relevance to the current assessment. If this critique is not directly useful, then it should be deleted. The more relevant but still somewhat peripheral discussions (e.g., FEFLOW modelling) could be moved to an Appendix.

8. *Predicting impacts to other tributaries*

   Section 7.4.3.8 explains that only the Condamine River and its northern anabranch are represented in CCAM with river (RIV) boundary conditions, and therefore "no other tributaries" are simulated. I see this as the only major limitation of the assessment as reported to date. The immediate question that comes to mind is, how many important tributaries – either from a DE or surface water allocation perspective – are therefore unintentionally being excluded from this assessment?

If the answer to the question above is significant, then a new approach and further modelling should be undertaken to predict impacts at these locations. One possible approach is to add new RIV boundary conditions in the CCAM along these tributaries. Alternatively, a simpler, semi-quantitative approach may be possible. Regardless, this issue needs to be properly addressed for the WMMP.

9. *Representativeness of three flux realisations from Surat CMA model*

The single most critical input dataset to the CCAM for this assessment is, unquestionably, the change in net vertical flux from the underlying Surat Basin aquifers, which is derived from the Surat CMA model where the two model footprints overlap. This change in vertical flux is what drives the predicted drawdowns in the water table within the Condamine Alluvium, which in-turn affects fluxes to gaining reaches of the Condamine River and its northern anabranch, and they in-turn translate into additional loss nodes in the IQQM of surface water availability.

With this in mind, there needs to be confidence that the High, Median and Low realisations (as described in section 7.4.4.2) are representative in terms of both the range and distribution of changes in peak vertical fluxes. Without presenting and analysing a figure such as that recommended in item 6 (above) it is not clear whether the three selected realisations will enable prediction of maximum potential impacts on every section of the river and anabranch. For example, it is possible that the realisation with the low-case (P95) change in net vertical flux volume may have some cells in the model domain with much higher peak fluxes than other realisations, and vice versa.

In theory, this issue could have been avoided by taking all 200 NSMC realisations of the change in net vertical flux from the Surat CMA model and running them through the CCAM. This would have produced 200 realisations of the water table drawdown map (instead of the three shown in Fig 7-52) and enabled a stochastic representation of the predicted impacts to surface water.

10. *Predicting impacts to disconnected streams*

The impacts of CSG development on both gaining and losing 'connected' streams, and therefore any associated DEs or licensed surface water allocations, are assessed via the simulation of water table lowering in the CCAM. For 'disconnected' streams the impacts are predicted to be zero because an increase in depth to water table does not cause a change in leakage flux out of the stream.

It would be helpful to understand the transition from 'connected losing' to 'disconnected losing' (also often called 'maximum losing') as a result of potential CSG impacts to the water table in the Condamine Alluvium. During this transition there will be a capillary fringe connecting the clogging layer to the water table when it is close, however this is not simulated in MODFLOW. Therefore, is it possible to determine:

a) *How does simulated leakage from losing sections of the Condamine River (and northern anabranch) change as a result of water table lowering over the simulation period*?
b) *How many reaches change from a 'connected losing' to 'disconnected losing' state?*
c) *What is the potential uncertainty in the estimated fluxes from disconnected streams given (a) uncertainties in clogging layer properties, and (b) the simplifications used in MODFLOW?*

11. *Broadening the IQQM assessment*

In light of the limitation outlined above (item 8), it may be prudent to consider whether and how the IQQM can be used to simulate impacts on allocations from other tributaries not simulated with RIV boundaries in CCAM.

12. *Synthesis of all flux modelling*

It would be very useful to add a conceptual water balance diagram that pulls together all key information from both the Surat CMA model and the CCAM (and perhaps the IQQM) in section 8. Ideally this diagram would be in three parts: no CSG (i.e., baseline), all CGS development, and just Arrow CSG development. Annotations could include the range of and peak change in flux rates, the change in peak flux volumes from the Surat CMA model into the Condamine Alluvium, the same information but for fluxes into the CCAM, the range of and peak water table drawdown, and the range of and peak impacts to the Condamine River.

Minor Comments and Suggestions

Numerous relatively minor editorial changes, comments, questions and suggestions to the improve the readability of the text and presentation of results have been provided electronically throughout the document via Track Changes.

Kavita Singh
Groundwater Management Lead
Arrow Energy Pty Ltd
GPO Box 5262
Brisbane QLD 4001

21 October 2016

Dear Kavita

RE: Peer review of modelling, simulations and analysis supporting Condition 13(b) of the Arrow Energy Surat Gas Expansion Project

On 19th December 2013 the Australian Government Minister for the Environment approved the Surat Gas Expansion Project (EPBC 2010/5344) subject to conditions. Conditions 13(a) to 13(r) require that the proponent submits a Stage 1 Coal Seam Gas (CSG) Water Monitoring and Management Plan (WMMP) for the approval of the Minister.

Condition 14 specifies that "*The Stage 1 CSG WMMP must be peer reviewed by a suitably qualified water resources expert/s approved by the Minister in writing.*"

As the *suitably qualified water resources expert* approved by the Minister for the Environment on 7 July 2015, I have completed a review of work and documentation relating to Condition 13b, as presented in the following report:

> CDM-Smith (2016). **Arrow Energy Surat Gas Expansion Project – CSG WMMP Section 13 (b).** Report dated 15th August 2016, document reference: CDMSmith_BWS150002_RPT_ArrowSuratCWMMP_Rev0_20160722

The report details numerical modelling, simulation and analysis in support of Condition 13(b) which requires: "*A fit for purpose numerical simulation to assess potential impacts on water resources arising from the action in the project area, subsequent surface water-groundwater interactions in the Condamine Alluvium and impacts to dependent ecosystems*."

The peer review included:

- A field trip with Arrow Energy and CDM Smith to the Condamine Alluvium;
- Consultation with Arrow Energy and CDM-Smith regarding model parameters, key assumptions, modelling realisations and analysis;
- Progressive review of preliminary outputs, which allowed early identification and rectification of material concerns that included (a) representativeness of selected model realisations, and (b) the way in which disconnected streams and watercourses other than the Condamine River were considered in the assessment; and
- Review of the findings presented in the report CDM-Smith (2016).

Based on my review, I find that the key assumptions, numerical modelling, simulation and analysis presented in the abovementioned report satisfactorily addresses the specific requirements of Condition 13(b).

Sincerely,

Dr. Glenn Harrington
Director & Principal Hydrogeologist

Kavita Singh
Groundwater Management Lead
Arrow Energy Pty Ltd
GPO Box 5262
Brisbane QLD 4001

7 December 2016

Dear Kavita

RE: Peer review of 'Groundwater modeling technical memorandum' for the Surat Gas Expansion Project Stage 1 CSG WMMP

On 19th December 2013 the Australian Government Minister for the Environment approved the Surat Gas Expansion Project (EPBC 2010/5344) subject to conditions. Conditions 13(a) to 13(r) require that the proponent submits a Stage 1 Coal Seam Gas (CSG) Water Monitoring and Management Plan (WMMP) for the approval of the Minister.

Condition 14 specifies "*The Stage 1 CSG WMMP must be peer reviewed by a suitably qualified water resources expert/s approved by the Minister in writing."*

As the *suitably qualified water resources expert* approved by the Minister for the Environment on 7 July 2015, I have completed an iterative peer review of the following memo:

> Coffey (2016). **SGP Stage 1 CSG WMMP: Groundwater modelling technical memorandum.** Memo dated 1/12/2016, document reference: ENAUABTF20484AA-M01-Rev4

This memorandum includes:

- To address Approval Condition 13(d), a distillation of the key findings of the Supplementary Report to the EIS (SREIS) (Coffey, 2013) and CDM Smith report 'Section 13(b) ' (CDM Smith, 2016) describing groundwater and surface water modelling as relevant to the Stage 1 CSG WMMP.
- A summary of the impact predictions in relation to groundwater and surface water, including the predicted impacts indicated by IQQM modelling in CDM Smith (2016).

- Relevant modelling figures and data that will underpin the development of management and monitoring objectives.
- Discussion regarding the changes in conceptualisation and model design of the 2016 OGIA model, and the implications such changes have to the assessment of impacts due to CSG production.
- An analysis of the results of the OGIA 2016 Groundwater Model through comparison with the results from the OGIA 2012 Groundwater Model, as required under Approval Condition 13(a).

Based on my review, I find that the synthesis of work presented in this memorandum provides a sound technical basis on which to develop the Stage 1 WMMP, particularly in relation to addressing Conditions 13(a), 13(b) and 13(d).

Sincerely,

Dr. Glenn Harrington
Director & Principal Hydrogeologist

Kavita Singh
Groundwater Management Lead
Arrow Energy Pty Ltd
GPO Box 5262
Brisbane QLD 4001

15 February 2017

Dear Kavita

RE: Peer review of 'Flood risk technical memorandum' for the Surat Gas Expansion Project Stage 1 CSG WMMP

On 19th December 2013 the Australian Government Minister for the Environment approved the Surat Gas Expansion Project (EPBC 2010/5344) subject to conditions. Conditions 13(a) to 13(r) require that the proponent submits a Stage 1 Coal Seam Gas (CSG) Water Monitoring and Management Plan (WMMP) for the approval of the Minister.

Condition 14 specifies "*The Stage 1 CSG WMMP must be peer reviewed by a suitably qualified water resources expert/s approved by the Minister in writing."*

As the *suitably qualified water resources expert* approved by the Minister for the Environment on 7 July 2015, I have now completed an iterative peer review of the following memorandum with specialist surface water hydrology technical input provided by Hydrology and Risk Consulting Pty Ltd. (HARC):

> Coffey (2017). **SGP Stage 1 CSG WMMP: Flood risk technical memorandum**. Memo dated 2/02/2017, document reference: ENAUABTF20484AA-M02-V2

This memo includes:

- An overview of the flood risk assessment requirements.
- Arrow's proposed gas processing and produced water infrastructure footprints and approximate locations.
- Arrow's overall approach to flood risk assessment and management.

- Flood risk characterisation and model predictions of land inundation based on a 1,000 year average recurrence interval (ARI) event.
- A flood risk assessment and statement of Arrow’s commitment to risk elimination.
- An outline of further risk assessment steps (such as the assessment of brine and chemical release) that may be taken where the preferred approach of risk elimination cannot be achieved.

Based on my review and the specialist technical input provided by HARC, I find that the synthesis of work presented in this memorandum provides a sound technical basis on which to develop the Stage 1 WMMP, particularly in relation to addressing Condition 13(o).

Sincerely,

Dr. Glenn Harrington
Director & Principal Hydrogeologist

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Kavita Singh
Groundwater Management Lead
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1 April 2017

Dear Kavita

RE: Peer review of three new memoranda for the Surat Gas Expansion Project Stage 1 CSG WMMP

On 19th December 2013 the Australian Government Minister for the Environment approved the Surat Gas Expansion Project (EPBC 2010/5344) subject to conditions. Conditions 13(a) to 13(r) require that the proponent submits a Stage 1 Coal Seam Gas (CSG) Water Monitoring and Management Plan (WMMP) for the approval of the Minister.

Condition 14 specifies "*The Stage 1 CSG WMMP must be peer reviewed by a suitably qualified water resources expert/s approved by the Minister in writing.*"

As the *suitably qualified water resources expert* approved by the Minister for the Environment on 7 July 2015, I have now completed an iterative peer review of the following three memoranda:

> Coffey (2017). **SGP Stage 1 CSG WMMP: GDE and aquatic ecosystem impact assessment technical memorandum.** Memo dated 21/03/2017, document reference: ENAUABTF20484AA-M03_Rev4

This memo was developed to address Approval Conditions **13c** and **13p.**

> Coffey (2017). **SGP Stage 1 CSG WMMP: Assessment of impacts and development of management measures memorandum.** Memo dated 21/03/2017

This memo was developed to address Approval Conditions **13l**, **13m** and **13n**; and to partially address Approval Condition **13j(iv).**

> Coffey (2017). **SGP Stage 1 CSG WMMP: Condition h, i, q and r memorandum.** Memo dated 21/03/2017, document reference: ENAUABTF20482AA-M06_Rev1

This memo was developed to address Approval Conditions **13h**, **13i**, **13q** and **13r**.

Based on my review, I find that the synthesis of work presented in each of these three memoranda provides a sound technical basis on which to develop the Stage 1 WMMP.

Sincerely,

Dr. Glenn Harrington
Director & Principal Hydrogeologist

Kavita Singh
Groundwater Management Lead
Arrow Energy Pty Ltd
GPO Box 5262
Brisbane QLD 4001

15 May 2017

Dear Kavita

RE: Peer review of 'Subsidence Technical Memorandum' for the Surat Gas Expansion Project Stage 1 CSG WMMP

On 19th December 2013 the Australian Government Minister for the Environment approved the Surat Gas Expansion Project (EPBC 2010/5344) subject to conditions. Conditions 13(a) to 13(r) require that the proponent submits a Stage 1 Coal Seam Gas (CSG) Water Monitoring and Management Plan (WMMP) for the approval of the Minister.

Condition 14 specifies "*The Stage 1 CSG WMMP must be peer reviewed by a suitably qualified water resources expert/s approved by the Minister in writing.*"

As the *suitably qualified water resources expert* approved by the Minister for the Environment on 7 July 2015, I have now completed an iterative peer review of the following memorandum with specialist geotechnical input provided by Emeritus Professor John Carter of Fugro Ag Pty Ltd.:

> Coffey (2017). **Surat Gas Project – Stage 1 CSG WMMP: Subsidence Technical Memorandum.** Memo dated 28 April 2017, document reference: ENAUABTF2048AA-M05_Final

This memo includes:

- Assessment of long term subsidence associated with proposed Arrow Surat Gas Project operations based on:
  - Review of measurement of subsidence and groundwater levels carried out in proximity to existing Arrow domestic gas CSG projects; and
  - Estimates of subsidence based on predicted groundwater drawdown from the EIS and SREIS.

- An assessment of risks posed by subsidence to assets within or in close proximity to Arrow SGP operations.
- Recommendations for additional ground movement monitoring such as strategically located geodetic monitoring and extensometers.
- Recommended trigger levels for the SGP.
- Recommendations for continuing monitoring for the SGP.

Based on my review and the specialist geotechnical input provided by Emeritus Professor Carter, I find that the synthesis of work presented in this memorandum provides a sound technical basis on which to develop the Stage 1 WMMP, particularly in relation to addressing Condition 13(g).

Sincerely,

Dr. Glenn Harrington
Director & Principal Hydrogeologist

Muller Retief
Groundwater Management Coordinator
Arrow Energy Pty Ltd
GPO Box 5262
Brisbane QLD 4001

11 December 2017

Dear Muller

RE: Peer review of final two technical memoranda for the Surat Gas Expansion Project Stage 1 CSG WMMP

On 19th December 2013 the Australian Government Minister for the Environment approved the Surat Gas Expansion Project (EPBC 2010/5344) subject to conditions. Conditions 13(a) to 13(r) require that the proponent submits a Stage 1 Coal Seam Gas (CSG) Water Monitoring and Management Plan (WMMP) for the approval of the Minister.

Condition 14 specifies "*The Stage 1 CSG WMMP must be peer reviewed by a suitably qualified water resources expert/s approved by the Minister in writing.*"

As the *suitably qualified water resources expert* approved by the Minister for the Environment on 7 July 2015, I have now completed an iterative peer review of the following two memoranda:

> Coffey (2017). **SGP Stage 1 CSG WMMP: Monitoring network memorandum.** Memo dated 8/12/2017, document reference: ENAUABTF20484AA-M07_final_v2

This memo was developed to address Approval Conditions **13(e)** and **13(f).**

> Coffey (2017). **SGP Stage 1 CSG WMMP: Limits, indicators and triggers memorandum.** Memo dated 8/12/2017, document reference: ENAUABTF20484AA-M08_final_v2

This memo was developed to address Approval Conditions **13(j)i-iv** and **13(k).**

Based on my review, I find that the work presented in these final two memoranda provides a sound technical basis on which to develop the Stage 1 WMMP.

Sincerely,

Dr. Glenn Harrington
Director & Principal Hydrogeologist

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Muller Retief
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13 December 2017

Dear Muller

RE: Peer review of 'Subsidence Technical Memorandum' for the Surat Gas Expansion Project Stage 1 CSG WMMP

On 19th December 2013 the Australian Government Minister for the Environment approved the Surat Gas Expansion Project (EPBC 2010/5344) subject to conditions. Conditions 13(a) to 13(r) require that the proponent submits a Stage 1 Coal Seam Gas (CSG) Water Monitoring and Management Plan (WMMP) for the approval of the Minister.

Condition 14 specifies "*The Stage 1 CSG WMMP must be peer reviewed by a suitably qualified water resources expert/s approved by the Minister in writing."*

As the *suitably qualified water resources expert* approved by the Minister for the Environment on 7 July 2015, I have now completed an iterative peer review of the following memorandum with specialist geotechnical input provided by Emeritus Professor John Carter of Fugro Ag Pty Ltd.:

> Coffey (2017). **Surat Gas Project – Stage 1 CSG WMMP: Subsidence Technical Memorandum**. Memo dated 13/12/2017, document reference: ENAUABTF2048AA-M05_Final

This memo includes:

- Assessment of long term subsidence associated with proposed Arrow Surat Gas Project operations based on:
    - Review of measurement of subsidence and groundwater levels carried out in proximity to existing Arrow domestic gas CSG projects; and
    - Estimates of subsidence based on predicted groundwater drawdown from the EIS and SREIS.

- An assessment of risks posed by subsidence to assets within or in close proximity to Arrow SGP operations.
- Recommendations for additional ground movement monitoring such as strategically located geodetic monitoring and extensometers.
- Specific screening and investigation levels, and an approach for establishing whether a trigger threshold has been exceeded based on site-specific assessment.
- Recommendations for continuing monitoring for the SGP.

Based on my review and the specialist geotechnical input provided by Emeritus Professor Carter, I find that the synthesis of work presented in this memorandum provides a sound technical basis on which to develop the Stage 1 WMMP, particularly in relation to addressing Condition 13(g).

Sincerely,

Dr. Glenn Harrington
Director & Principal Hydrogeologist

Issue number	Date flagged	Reference/Memo Section	Peer Reviewer Comment	Response
	SGP Stage 1 CSG WMMP Groundwater modelling technical memorandum			
1	10/11/2016	1	Why not 13c as well?	Revised text: The key outputs from these models, which are described in more detail in Section 2, have been assessed and presented in Sections 4 and 5. Together, these models address Approval Conditions 13a, 13b and 13d. Approval Conditions 13(c), 13(f), 13(j) and 13(p) are also reliant on or underpinned by groundwater modelling and are to be separately addressed in other memoranda, and the WMMP.
2	10/11/2016	1	Not sure this has been done?	Revised in V4 document
3	10/11/2016	2.1	I realise all this is copied from the SREIS, but I wonder if you could provide a little more info – was it cumulative drawdown across all model cells for each aquifer, or maximum drawdown in any cell within each aquifer?	Revised text: The 200 predictions were ranked in an increasing order from lowest to highest predicted drawdown. Predictions beyond the 5th and 95th percentiles were treated as outliers. Predictions based on the calibration realisation were used in determining the groundwater impacts.
4	10/11/2016	2.1	I have read this a number of times herein and in the SREIS, but its still not clear what it means?	See above response
5	10/11/2016	2.2	DEHP?	Corrected
6	10/11/2016	4	Sections 4.2 and 4.3 actually lend more support to Condition 13(b)	Intro to section 4.2 edited to comment: As described in Section 4.1, depressurisation of the Walloon Coal Measures due to CSG production has a potential influence on the water balance of the adjacent Condamine Alluvium aquifer, as modelled for the SREIS. Based on the requirement of Approval Condition 13(b) (addressed separately in CDM Smith, 2016), additional modelling has been undertaken to further assess this influence, and to quantify the impact that flux changes to the Condamine Alluvium may have on surface water flow to the Condamine River.
7	10/11/2016	4.1	Ok, but isn't the CCAM also a more meaningful model of the CA given the OGIA 2012 model didn't have groundwater extraction, recharge or SW-GW interaction?	Text revised: Flux change predictions from this model to the Condamine Alluvium were then used as inputs to the more detailed CCAM to model Condamine Alluvium drawdown, at a better resolution than provided by the Arrow SREIS Groundwater Model.
8	10/11/2016	4.1	Will the results from these scenarios be used to support Condition 13l and 13m? If so, suggest including in Table 6.1	13L and 13m to be addressed in WMS and different memo.
9	10/11/2016	4.1	Please state here how much they reduced	Text revised: The OGIA EVT input files were revised to provide consistency with Arrow's current FDP at the time, which has reduced extractions (702 GL) compared with the 2012 OGIA modelling (717 GL).
10	10/11/2016	4.1.1	Agreed, so why are these volumes and rates the first "Key Findings"?	Water production was a key focus at the EIS stage. Text revised: The Arrow SREIS Groundwater Model simulated a water production with a peak extraction rate of 140 ML/d anticipated between 2021 and 2024. It is noted that the primary purpose of the model was to predict drawdown impacts under depressurisation scenarios, rather than water flows. This is because simulated water production rates are affected by the effects of dual-phase flow (i.e. gas and water) which cannot be fully accounted for in the model.
11	10/11/2016	4.1.1	Field development planning tools (based on reservoir modelling) for Arrow's current FDP have indicated that actual total water production expected for the duration of the SGP will be approximately 510 GL, which is lower than the 702 GL as modelled	Edits accepted
12	10/11/2016	4.1.2	How much?	Revised: Peak impacts in the Springbok Sandstone is up to 10 m and typically occurs at 20 years after peak impact in the Walloon Coal Measures. Peak impacts in the Hutton Sandstone is approximately 8 m and typically occurs at 75 years after peak impact in the Walloon Coal Measures. Drawdown impacts to the deeper Precipice Sandstone are less than 0.7 m and of limited extent.
13	10/11/2016	4.1.2	But Table 4.1 suggests the average is 0.18 m? Under the "maximum" realisation?	Revised: However, this maximum drawdown was only evident in a small proportion (<10%) of the Condamine Alluvium, and drawdown was typically less than 0.18 m across the remainder of the alluvium.
14	10/11/2016	4.1.2	Does localised reversal to a downward ever occur? Agreed it is small, but I don't think it is appropriate to make this comparison when the time of peak change in flux to CA is many 10s years after the time of simulated peak extraction?	Revised: Therefore flux changes resulting from coal seam water production cause a small reduction in the existing upward flux, which remains predominantly upward from the Walloon Coal Measures to the Condamine Alluvium, with only minor exception.
15	10/11/2016	4.1.2	And proposed?	Accepted
16	10/11/2016	4.1.2	8?	Figure reference corrected

Issue number	Date flagged	Reference/Memo Section	Peer Reviewer Comment	Response
17	10/11/2016	4.1.2	Please quantify	Revised: Cumulative maximum impact drawdown (50th percentile case) in the Springbok Sandstone is up to 15 m, and for the Hutton Sandstone is up to 15 m. Cumulative maximum impact drawdown (50th percentile) in the Precipice Sandstone is up to 5 m but of limited areal extent.
18	10/11/2016	4.1.2	As per earlier comment, I don't think it is correct to make this comparison.	Comparison removed
19	10/11/2016	4.2.3	Good to see that you've included a brief description of how three realisations were selected. However, it should be stressed that this approach is very different to the three OGIA 2012/SREIS realisations that were based on percentiles of (cumulative or maximum?) predicted drawdown.	Noted. Footnote added to second paragraph in Section 4.1 to describe the OGIA 2012 model uncertainty realisations and output: Uncertainty analysis comprised simulation of 200 separate realisations of the OGIA 2012 Groundwater Model and interpreted using a statistical approach whereby the 5th and 95th percentiles of head at each grid cell were computed (GHD, 2012). Mean and median values were also computed, and contours of the 95th percentile, median, mean and 5th percentile were produced.
20	10/11/2016	Table 4.3	Source: CDM Smith (2016)	Source acknowledged
21	10/11/2016	4.2.3	Need to refer to Figures 18 and 19 here	Reference to figures added in revised memo. Note that figure numbering has changed also.
22	10/11/2016	4.2.3	Need to refer to Figures 16 and 17 here	Reference to figures added in revised memo. Note that figure numbering has changed also.
23	10/11/2016	4.2.3	Need to refer to Figures 14 and 15 here	Reference to figures added in revised memo. Note that figure numbering has changed also.
24	10/11/2016	5.1.1	Which is it?	Row and column spacing 1.5km Text amended.
25	10/11/2016	5.1.3	This paragraph is awful – I understand what it means, but most readers wont. Therefore suggest rewording in simple terms or removing.	Awfulness noted. Text revised: Upscaling involves statistical generation of model parameters sets from probability distributions of the parameters, to enable hydraulic properties of formations to be represented in a manner that reflects their bulk properties.
26	10/11/2016	5.2.2	Insert reference	Reference added to revised memo
27	10/11/2016	5.3	Should also include comparison with SREIS model	Section 5.4 added - Comparison of results with Arrow SREIS Groundwater Model, as below: Figure 22 shows the maximum cumulative impact 5m drawdown contours, based on the Arrow SREIS Groundwater Model calibration realisation. This represents a suitable output for comparison with the OGIA 2016 Groundwater Model. The following are general comments in relation to changes to the LAAs in the 2016 UWIR when compared to the Arrow SREIS Groundwater Model: The Walloon Coal Measures LAA has contracted in the southwest and the reduction in the area of planned CSG development is likely the main contributing factor, however changes in the 2016 Walloon Coal Measures depth-permeability relationship is also likely to contribute. The Springbok Sandstone LAA overlies the Walloon Coal Measures and is approximately similar in area with the Arrow SREIS model. However the morphology has changed, and the LAA area between Tara and Chinchilla has reduced, and the area west of Miles extends further to the south. The Hutton Sandstone LAA is larger than assessed in the Arrow model, probably due to the lower Durabilla Formation aquitard assigned a lower permeability in the 2016 model. The Precipice Sandstone LAA, which was of very limited area for the Arrow model and confined to a small area between Chinchilla and Tara, and west of Dalby, is no longer present in the 2016 model. Observations based on the comparison between the OGIA 2016 Groundwater Model and the Arrow SREIS Groundwater Model are similar to those made for the OGIA 2012 Groundwater Model. Accordingly the discussion of material differences in Section 5.3.3 above is considered to equally relevant to the Arrow SREIS Groundwater Model comparison.
28	10/11/2016	5.3.1	Reduction in flux?	Text revised: The net reduction in flux to the Condamine Aquifer, as reported in the 2016 UWIR, is predicted to be 1,160 ML/year, compared with 1,100 ML/year for the 2012 UWIR
29	10/11/2016	5.3.2	What about SREIS Model?	Refer comment above
30	10/11/2016	5.3.3	Have they not done any benchmarking tests?	Limited testing only
31	10/11/2016	5.3.3	Some additional details on this (cf. OGIA 2012 model) would be helpful	Third bullet revised: The 2016 model does not adopt a vertical hydraulic conductivity/depth relationship that accounts for the reduced hydraulic conductivity associated with near-surface conditions. This known feature of the Surat Basin coal measures arises due to the effects of weathering and stress. Fracture closure due to increased stress with depth results in reduce hydraulic conductivity. In addition, near surface weathering increases matrix permeability. The OGIA 2012 Groundwater Model accounted for this on a cell by cell basis using a depth-K relationship (GHD, 2012).

Issue number	Date flagged	Reference/Memo Section	Peer Reviewer Comment	Response
32	10/11/2016	6	Ok, so can you now summarise what are the specific figures/outputs from these models that will be used?As a suggestion, I have included specific Figure references below in Table 6.1Also, should state somewhere if/how the SREIS 'GDE assessment drawdown extents' will be used to address any of the Conditions	Figures references added to the revised Table 6.2
33	10/11/2016	Table 6.1	Approval Conditions	Comments addressed in second draft memo and following discussion with peer reviewer.
34	10/11/2016	Table 6.1	This has not been done; would be good to include comparison in this Memo	Comments addressed in second draft memo and following discussion with peer reviewer.
35	10/11/2016	Table 6.1	Were the IAA/LAA maps created for SREIS? If so, they should form part of the comparisonWhat about GDE drawdown extents?	Comments addressed in second draft memo and following discussion with peer reviewer.
36	10/11/2016	Table 6.1	Not clear to me why SREIS Model is required for 13b – is it just "water resources" other than the CA?	Comments addressed in second draft memo and following discussion with peer reviewer.
37	10/11/2016	Table 6.1	At what time?	Comments addressed in second draft memo and following discussion with peer reviewer.
38	10/11/2016	Table 6.1	When specifically? At peak drawdown for each aquifer?	Comments addressed in second draft memo and following discussion with peer reviewer.
39	18/11/2016	Table 6.1	Should form part of Section 5.3	Text revised to provide firmer indication that Arrow and 2012 models essentially the same: "The 2016 UWIR provides comments in relation to differences in predictions between the OGIA 2016 Groundwater Model and the OGIA 2012 Groundwater Model. General comment can only be made due to the different CSG production profiles between these two models, a factor that also applies to comparisons with the Arrow SREIS model. In this regard we note that the Arrow SREIS represents a version of the OGIA 2012 model." Table 6.1 also revised to refer to Figure 19 in Appendix 4 of the SREIS which is a cumulative case figure showing extent of 5m drawdown figures for GAB aquifers.
40	18/11/2016	Table 6.1	Specifically which figures in this memo? Probably will become obvious when addressing my previous comments re including SREIS in Section 5.3	Table 6.1 also revised to refer to Figure 19 in Appendix 4 of the SREIS which is a cumulative case figure showing extent of 5m drawdown figures for GAB aquifers
41	18/11/2016	Table 6.1	Could also use Figure 19?	This is corrected now. Note that figure numbering has changed also. Now refers to: Predicted drawdown in Condamine Alluvium (Figures 15, 18 and 19) Predicted Condamine Alluvium flux change – Arrow only case (Figures 10 and 11) Predicted flux change to the Condamine River – Arrow only case (Figures 16 and 17)
42	18/11/2016	Table 6.1	Not sure this is correct – perhaps Figures 10/11 or Figure 12?	This is corrected now. Note that figure numbering has changed also. Now refers to: Predicted drawdown in Condamine Alluvium (Figures 15, 18 and 19) Predicted Condamine Alluvium flux change – Arrow only case (Figures 10 and 11) Predicted flux change to the Condamine River – Arrow only case (Figures 16 and 17)

Issue number	Date flagged	Reference/Memo Section	Peer Reviewer Comment	Response
	SGP Stage 1 CSG WMMP: Flood risk technical memorandum			
43			Use of at-site flood frequency analysis to estimate 1 in 500 and 1 in 1,000 AEP peak flow rates is not supported by the length of record at the individual streamflow gauges. Typically, at-site streamflow data can only be used to estimate flood quantiles within the range of approximately twice the length of record. For example, 50 years of record is generally regarded as sufficient to estimate the 1 in 100 AEP quantile. At-site frequency estimates of the 1 in 500 and 1 in 1,000 AEP events are shown in numerous locations throughout Section 3 as well as in Table 4-8. We recommend these values be removed from the report as they have the potential to mislead the reader.	Revised text added to Section 3.3.3 to reflect uncertainty with this approach: Typically, streamflow data can be used to estimate flood quantiles within the range of approximately twice the length of the available record. Based on the maximum available 92 year record of streamflow data at the Chinchilla station, at-site flood frequency analysis of an ARI event greater than 1 in 200 years would typically be beyond the statistical reach of the dataset. WorleyParsons' flood model was calibrated with the same 92 year record and used to predict flood inundation extents for a 1 in 1,000 year ARI event. Therefore, WorleyParsons' (2013) flood modelling predictions, while highly conservative compared to typical planning guidelines, contain a degree of calibration uncertainty which cannot be avoided when meeting the requirements of Condition 13(o).
44			The report does not describe the treatment of baseflow during the model calibration phase. Reviewing the calibration plots shown in Appendix 2, it appears that baseflow has not been removed from the gauged data record.	Comments added to Section 3.3.3 to discuss baseflow and implications on calibration, and model uncertainty. Text revised: It is noted that the WorleyParsons (2013) flood model report does not describe the consideration of baseflow contributions to the gauged data record during model calibration. Because the WBNM flood hydrograph model does not account for baseflow, typically the baseflow component is removed from the observed hydrograph record in order to make a valid comparison with model predictions, and a reliable calibration. If baseflow was not removed during calibration the loss rates adopted to achieve calibration may have been underestimated. This, in turn, has resulted in very low design loss rates adopted during the flood modelling. While the overall effect of adopting very low loss rates cannot be quantified by Coffey, it is expected to have resulted in conservative (higher) peak flood levels.
45			The implications of the above point are that the loss rates used may have been underestimated in order to attempt to match modelled surface flow only, with gauged surface flow plus baseflow. Despite the observation that loss rates in the December 2010 and January 2011 events are lower than typical values due to the sustained antecedent rainfall, the loss rates shown in Table 4-5 are so low as to be inconsistent with expected regional loss rates. We suggest that one factor contributing to these very low loss rates is that baseflow was not removed from the gauged streamflow data record.	As above
46			Adopting low loss rates for individual calibration events is not in and of itself a significant issue, however in this case it appears as though those low loss rates from calibration have significantly affected the selection of design loss rates. Table 4-9 shows that an initial loss of 0 mm and a continuing loss of 0.5 mm/hour has been adopted for design for the Condamine River catchment (including ungauged tributaries). Similar losses have been adopted for many of the ungauged catchments. We regard the use of such low loss rates as being difficult to justify based on the expected hydrological behaviour of this region	As above
47			Table 4-8 demonstrates that the design flood modelling has produced 1 in 50 and 1 in 100 AEP peak flow estimates which show a reasonable match to the at-site and regional flood frequency quantiles. In addition to this, the effect of the very low loss rates will tend to be conservative in that it will overestimate design flood flows and therefore flood extents. Therefore, while we have identified potential issues with the path taken to obtain the design flood estimates, the values themselves are considered appropriate for the level of detail inherent in this investigation. Addressing the issues identified above would make the study more robust and defensible, but also may not significantly change the calculated peak flow rates.	Text revised in section 3.3.1: Recent recorded flood events in 2010, 2011 and 2013 were simulated in the WBNM and TUFLOW model. These events correlated with 50 year ARI and 100 year ARI events. Model outputs were compared to the actual measured DNRM level and flow data. WorleyParsons (2013) concluded that the modelled and measured flood events showed relatively good correlation and were considered to validate the models reliability. WorleyParsons identified that there was significant overestimation of the peak water level at Chinchilla. The reason for this level difference was not resolved, but may be associated with the level of refinement of the terrain data in the area. It is considered that the over-estimation of water level adds a conservative bias to the modelled predictions.

Issue number	Date flagged	Reference/Memo Section	Peer Reviewer Comment	Response
48			there is a significant overestimation of the peak water level at Chinchilla, which is of some concern. It is not clear from the report whether this overestimation is due to coarse terrain data or some other reason. It potentially impacts the flood estimates in the tenement immediately upstream, so should be investigated and discussed in the report.	Noted. Added discussion of this issue in Section 3.3.1, and as noted above
49			The report does not discuss whether modelling of different storm durations has been undertaken in order to produce a single enveloped flood extent for each model. In larger catchments such as the Condamine River, there is likely to be a significant difference between the critical storm duration for the main river channel as compared to the smaller tributary streams. Whilst this appears to have been dealt with to some extent via the layout of the various WBNM hydrological models, there are a number of smaller tributaries which appear to not to have had specific flows estimated. This may tend to underestimate the flood extent in some of these smaller tributaries.	We understand that only the 72hr design rainfall event duration was modelled. Added discussion of this issue and comments around uncertainty to Section 3.3.3.
50		3.3.1	Section 3.3.1 notes that the Worley Parsons flood modelling report produced flood extents along "significant drainage lines" within the Arrow tenements. There is little discussion in either the technical memorandum or the Worley Parsons report to describe the criteria used to determine whether a drainage line/waterway was significant or not. It is apparent from Figure 2 and Figure 3 that there are a number of small waterways in some of the tenements (eg the western side of CGPF8 and south of Crawlers Creek in CGPF9) which have not been mapped. This suggests additional detailed modelling may be required to identify flood risk from these small waterways once preferred locations for the processing and storage facilities have been determined. The technical memorandum should include some discussion of this issue, potentially in Section 3.4.1.	We note HARC's comment that specific flows may not have been estimated for smaller tributaries and that this may have some impact on the net flood levels reported. Edits made to Section 3.3.1 and 3.3.3.
51		3.3.2	Section 3.3.2 states that "Further site-based confirmation of the historical flood extents was recommended to resolve discrepancies against 100 year ARI modelled flood extents in the upper and middle reaches of the Condamine River watershed." This is referencing text in Section 6 of the Worley Parsons report, however the recommendation in the Worley Parsons report does not clearly describe the specific actions which could be taken to resolve differences between modelled and recorded flood extents. It is suggested that this point be removed from the technical memorandum	Recommendation removed from Section 3.3.2.

Issue number	Date flagged	Reference/Memo Section	Peer Reviewer Comment	Response
52		3.3.3	Section 3.3.3 states that "Australian building codes adopt a 100 year ARI for siting and design of structures" and "...Australian best practice recommends a 500 mm freeboard for planning purposes." Typically, selection of the appropriate design flood event (and associated freeboard) for various types of infrastructure (residential, roads, industrial, etc) is a matter for the relevant regulatory authorities. Whilst the 1 in 100 AEP is a commonly adopted design flood event for residential planning, we are not aware of it being referenced in 'Australian building codes'. Similarly, we are unaware of any national documentation or guidance recommending 500 mm freeboard for planning purposes. These statements should be reworded or referenced.	This section has been significantly revised to correctly reference the relevant planning scheme (Chinchilla Shire Planning Scheme) and applicable design flood level. It has also been revised to reference the discussion on freeboard which is taken from the NSW Government Floodplain Development Manual, as cited in the Commission of Inquiry into the Brisbane River 2011 Flood Event.
53		3.3.13.3.4	The main conclusion of the technical memorandum is that "there is sufficient land available outside the predicted flood events (1,000 year ARI) to locate all major project infrastructure". This conclusion is reasonable given the relative sizes of the tenements compared to the estimated sizes of the processing and storage facilities. However, we feel that some additional clarification should be added to note some of the uncertainties inherent in the modelling undertaken by Worley Parsons. For example, it was noted above that the flood mapping does not cover a number of the smaller waterways. It is possible that further, more detailed mapping could change the conclusion that there is sufficient land to locate the processing facilities, and this uncertainty should be discussed in the technical memorandum.	Updated text added to section 3.3.3, and 3.4.1
54		3.4.2	The discussion of engineering and administrative controls presented in Section 3.4.2 provides a relatively comprehensive indication of what additional modelling and analysis may be required once the preferred location of the processing and storage facilities is known. We recommend noting that a site-specific stormwater management plan will need to be developed for each of the processing facilities which may help address our comments about minor waterways in the preceding dot point.	Edits made to Section 3.4.2. Arrow will develop and implement site-specific stormwater management plans, as required by any Environmental Authority, around major infrastructure.
	SGP Stage 1 CSG WMMP: GDE and aquatic ecosystem impact assessment technical memorandum			
55	8/03/2017	P.1	Approval Condition 13(p): I first noted here that this condition is not limited to only non-spring based GDEs, yet it took several pages to get the impression that spring GDEs did not need to be considered. If this is the case, I suggest stating this and giving reasons upfront in the memo.	Text following outline of Condition 13p updated to include: Condition 13p requires assessment of cumulative impacts on potential GDEs. A key function of the Office of Groundwater Impact Assessment (OGIA) is the assessment and management of cumulative impacts in the declared Surat Cumulative Management Area (CMA), which are set out in the Underground Water Impact Report (UWIR). The assessment and management of spring GDEs are covered under the Surat CMA UWIR, therefore have not been considered further to address Condition 13p here. This document sets out the assessment of potential cumulative impact on non-spring GDEs only.
56	8/03/2017	P.3, Sec 2.1.2	I am not convinced with the justification provided for the 1 m drawdown value and believe this is critical to the assessment. While the point about natural variations in groundwater levels is valid, I consider this to be an issue for monitoring and interpretation rather than whether the GDE will be impacted. The second dot point in regards to "recently endorsed neighbouring CGS proponent approaches" also requires further details and discussion to be meaningful.	Refer revised text.
57	8/03/2017	P.3, Sec 2.2.1	second sentence is not clear – consider rewording	Text updated to make it clear that OGIA manage springs and that this assessment only relates to non-spring GDEs.
58	8/03/2017	P.5, Sec 3.1	this doesn't seem to fit here, as I think it is more about predicted impacts than identification of GDEs	Agreed. Have restructured. This section now provides a summary of the GDEs identified in the SREIS.
59	8/03/2017	P.6, Sec 3.3	When was this merging done, and by whom? Also, this section addresses the terrestrial GDEs, but what about other types of non-spring based GDEs?	Text clarified and a flow chart added to the start of section 3 to summarise the evolution of GDE work/knowledge bank.
60	8/03/2017	P.7, Sec 3.5	When was this DSITI mapping undertaken relative to the other products used in this analysis? References for the GDE Atlas and RE mapping would be helpful.	Updated to include references and product development timing.

Issue number	Date flagged	Reference/Memo Section	Peer Reviewer Comment	Response
61	8/03/2017	P.7, Sec 3.6	Reference is made to the CDM Smith "median case" but it would be worth reminding the reader of what this represents so that they can understand it is only one realization and the basis on which it was selected.	Commentary included as a footnote.
62	8/03/2017	P.8, Sec 3.7	Given the importance of the 3D Environmental and Earth Search (2016b in draft) report, when will this be available for review?	Draft report now available.
63	8/03/2017	P.8, Sec 3.7	para. 2: weren't the areas outside these focus areas that we identified through analysis of the CDM Smith modelling outputs also included in Stage 1 and/or Stage 2?	Reference to CDM Smith (2016) included.
64	8/03/2017	P.9, Sec 3.7	Please consider rewording the second dot point about Lake Broadwater where it reads "expected to represent systems that are perched". Either there is good data (e.g., depth to water table) to suggest it is disconnected, or there isn't sufficient data and therefore we don't know if it is connected or not. If the latter, then this lake should probably be included as a potential GDE.	This dot point has been split in to two to address Lake Broadwater and Long Swamp separately. Added detail on current understanding on conceptualisation
65	8/03/2017	P.9, Sec 3.7	third dot point: please explain how the data in Figure 3.7 was generated and discuss its reliability.	Text updated to: • Riparian vegetation that represent terrestrial GDEs are likely to be present along significant reaches of the following some watercourses and their tributaries. This assessment was made based on review of Arrow landowner bore baseline assessment data, UWIR monitoring data and detailed vegetation mapping completed as part of the SREIS. These include reaches of (refer also Figure 3.7) .... Commentary on data reliability added
66	8/03/2017	P.9, Sec 3.8	please explain why the NRA study found that "further detailed site assessment is not considered necessary".	Additional text included - largely relates to the proceeding text and have made this link. Adopted "….therefore not considered to be required to inform potential impacts to aquatic ecosystems …."
67	8/03/2017	P.10, Sec 3.8.2	On what basis did the SREIS find that Lake Broadwater is not conceptualized as groundwater dependent?	This was primarily based on the descriptions set out in the Directory of Nationally Important Wetlands (DoEE). This reference and a little more detail has been added.
68	8/03/2017	P12, Sec 4	as per comment 7 above re "median case".	No changes made - detail provided in response to Comment 7 in Section 3.6
69	8/03/2017	P12, Sec 4	"there is no drawdown predicted… in units shallower than the Springbok Sandstone or deeper that the Precipice Sandstone". Should this read "there is no drawdown exceeding 1 m predicted… in units shallower than the Springbok Sandstone or deeper that the Precipice Sandstone"?	Clarification made that there is no drawdown >1m in these formations
70	8/03/2017	P12, Sec 4.1	shouldn't Figure 4.4 for condition 13(p) be from the CDM Smith Condamine Alluvium Model, as per the modelling memo?	CDM Smith (2016) presented cumulative flux only, not cumulative drawdown. Cumulative drawdown outputs have been obtained from CDM Smith and adopted for this assessment. Memo updated accordingly.
71	8/03/2017	P.13, Sec 5.1.1	reference to Figure 5.1 is in relation to terrestrial GDEs yet the figure only has the riparian veg GDEs; why isn't the DSITI mapping shown?	Figure 5.1 updated to include DSITI mapping. No GDEs of moderate or high potential are located in areas of >0.75m drawdown therefore no change to the assessment conclusions.
72	8/03/2017	P.13, Sec 5.1.2	at first glance of Figure 5.2 it seems the risk areas should be much larger than shown to cover the full overlap of GDEs with subcrop areas. Is this due to the presence of the Westbourne Formation? Regardless, further explanation is required.	Text added to explain that conceptually, to the west of the Westbourne Fm subcrop extent there is limited potential for DD to propagate to the watertable aquifer, but due to some uncertainty in the exact location of this boundary, potential GDEs in the immediate vicinity of the boundary have been included in the assessment. Risk areas presented in Figure 5.2 have been refined. Schematic cross section also provided for reference.
73	8/03/2017	P.13, Sec 5.1.3	why aren't riparian veg GDEs shown on Figure 5.3?	The really only relate to the area of Condamine Alluvium, therefore the WCM would not be considered the watertable aquifer. Regardless, they have been added to Figure 5.3. No change to the conclusions of the assessment.
74	8/03/2017	P.14, Sec 5.1.3	the inference that the mapped GDEs near Wandoan are associated with shallow alluvial channels requires further evidence and analysis before they can be ruled out from any further consideration in this assessment.	Review of available logs indicates the Injune Creek Group outcrop in this area typically comprising Westbourne Formation underlain by Springbok Sandstone (RN58259, RN12763, RN22117, RN23509). There is the potential however for shallow subcrop of WCM (typically top of WCM >15m) in some areas. The WCM is not indicated to outcrop in these areas, however given the potential for the shallow subcrop and that if the watertable was within this unit there is still the potential for deeper rooted vegetation to access this, a new Risk Area (Risk Area 4) has been included for assessment.

Issue number	Date flagged	Reference/Memo Section	Peer Reviewer Comment	Response
75	8/03/2017	P.15	please include risk areas on Figure 5.4. Attachment 2 doesn't appear to contain hydrographs for all bores shown on Figure 5.4.	Figure 5.4 updated to include the risk areas presented in Figure 5.2 (as refined to address comment 18). Single hydrograph missing (Arrow bore Kedron 570 - now included). Two others mislabelled - now corrected.
76	8/03/2017	P.16, Table 5.3	The DTW categories assigned to risk areas 1, 2 and 3 are all debatable when viewing the data in Figure 5.4 – all of these could equally be in the 10-20 m category. Bores RN 160348 and RN 160941 mentioned in the footnote are not shown on Figure 5.4.	Table 5.3 no longer included - impact assessment process has been revised. Refer revised Section 5.2 and associated figures.
77	8/03/2017	P.16-19, Sec 5.2.2	This section requires significantly more quantitative analysis and justification. Firstly, the two classifications for rates of drawdown seem completely arbitrary and unjustified. Secondly, I struggle to understand why, for example, a moderate likelihood GDE would only have a moderate impact ranking if its conservation value was high. Could another quantitative metric be used, such as magnitude of predicted drawdown compared to historical drawdown? Where are the bores used for predicted hydrograph analysis (e.g., KK_1) located relative to the risk areas?	Revised approach to assessment as discussed. Refer Section 5.2.
78	8/03/2017	P.21, Sec 6.	para. 4 needs to be brought forward in the memo to address my comment 16 above	As per response to comment 16
79	8/03/2017	P.21, Sec 6.1	Covers terrestrial GDEs, but why aren't riparian veg GDEs as mapped by the 3D Environmental field survey included? Also in regards to the opening sentence, it would be useful to show this screening in a map if possible?	Terrestrial and riparian GDEs plotted on figures, have updated text to include reference to riparian GDEs. Have also included 2 x new figures of the Hutton and Precipice Sandstone to demonstrate what is stated in the text.
80	8/03/2017	P.22, Sec 6.1.1	Again this section points to the significance of the adopted 1 m drawdown value, which I believe has not been adequately justified. Regardless, it is misleading to state that "no terrestrial GDEs are associated with the small areas of >0.75 m drawdown in the Condamine Alluvium therefore impact to terrestrial GDEs in the Condamine Alluvium is not considered to occur".	The 1m drawdown value has been addressed in response to comment 2. Section 6.1.1 has been re-worded to: .... terrestrial GDEs do not coincide with are associated with the small areas of >0.75 m drawdown in the Condamine Alluvium therefore impact to terrestrial GDEs in the Condamine Alluvium is not considered further in addressing Condition 13p.
81	8/03/2017	P.22, Sec 6.1.3	reference to "cumulative risk area 1" in first dot point should actually be "cumulative risk area 2"	Amended
82	8/03/2017	P.22, Sec 6.1.4	as per comment 20 above	Response as per Comment 20
	SGP Stage 1 CSG WMMP: Assessment of Impacts and Development of Management Measures Memo			
			No comments to address for endorsement	
	SGP Stage 1 CSG WMMP: Condition h,l,q and r memorandum			
			No comments to address for endorsement	

Issue number	Date flagged	Reference/Memo Section	Peer Reviewer Comment	Response
	SGP Stage 1 CSG WMMP: Subsidence technical memorandum			
105	15/04/2017	P8 3.1	What is the error of the method?	The error of the resulting values is not identified explicitly by Arrow. An indication of the magnitude for individual points can be assessed from the time variation of results for individual locations. These show variability typically within 5 mm form point to point around a trend.
106	16/04/2017	P13 3.2	ground movement?	Corrected
107	17/04/2017	P19 3.2.2	Looks like some dd in Figure 11?	Text revised: For the purposes of this assessment the Eurombah Formation (a sandstone unit) which is the lowest unit in the Walloon Coal Measures was not considered as it showed little drawdown response to CSG operations.
108	18/04/2017	P19 3.2.2	Need to refer to equation on next page and provide a reference?	Corrected
109	19/04/2017	P19 3.2.2	ratio	Corrected
110	20/04/2017	P19 3.2.2	Reference required	Santos 2014
111	21/04/2017	P20 3.2.2	over four years	Corrected
112	22/04/2017	P20 3.2.2	is this because the GWL monitoring data doesn't go back that far? regardless, further explanation is required for this statement	The change in groundwater level over this period is not clear in the monitoring because the groundwater level monitoring records do not go back far enough. For this reason, it is not considered productive to use this period for back analysis.
113	23/04/2017	P26 5.2	Reference required	Sanderson 2012
114	24/04/2017	P27 5.2	Sure, but what did they find?	ARUP (2014) predicted settlement of up to 85 mm after 25 years though higher values were recognised as being possible.
115	25/04/2017	P27 5.2	So why provide all the material above regarding the approach that uses the equation+measured core data, or the ARUP study?	Use of direct measurements is considered to provide a more robust basis for assessment.
116	26/04/2017	P27 5.2	Check meaning	Corrected - strain
117	27/04/2017	P28 5.2	would be good to back this up by stating max. ddn for Springbok and Hutton, referring to Figs 19-21.	Corrected - reference to figures updated
118	28/04/2017	P28 5.2	Arrow	Corrected
119	29/04/2017	P28 5.2	Not clear what this means	Corrected - text updated to ' These are shown in Figures 25 and 26 for the Arrow SGP Only Case and the Cumulative Case overlaid upon the Arrow SGP drainage areas'
120	30/04/2017	P31 Figure 25	Figures 25-26 (and to a lesser degree Figures 23-24) appear to be very poor resolution when viewed on the screen - perhaps they're better in hard copy?	Figures revised to high resolution outputs
121	1/05/2017	P35 6.1	Table 5?	Reference updated
122	2/05/2017	P36 6.2	Not in reference list	Reference updated - Commonwealth of Australia 2014
123	3/05/2017	P38 7	Table 7	Reference updated
124	4/05/2017	P38 7	Proposed	Corrected
125	5/05/2017	P38 7	What's the basis for this number?	A movement rate discernible using InSAR methods.
126	6/05/2017	P38 7	Confusion here and in table 7 with use of the term thresholds as opposed to triggers - the former shouldn't be reached as the latter should result in investigation and mitigating action.	Corrected - text updated to 'triggers'
127	7/05/2017	P39 7.1	Alternative?	Corrected
128	8/05/2017	P41 7.2	Table 7	Reference updated
129	9/05/2017	P41 7.2	at	Corrected
	SGP Stage 1 CSG WMMP: Subsidence technical memorandum (revised)			
130	12/12/2017	Section 6	Minor text edits	Accepted
131	12/12/2017	Section 6.6	Spelling corrections	Accepted
132	12/12/2017	Sectoin 7	Comment on wording of "Trigger thresholds have been developed " - Not according to Table 7	The investigation value may have occurred where no relevant assets are present or in a way which is of no adverse impacts on the asset. This trigger threshold is set such that it is considered to be exceeded where an adverse impact to a sensitive receptor has been confirmed.
133	12/12/2017	Sectoin 7	"Risk assessments"	No change made.
134	12/12/2017		Not provided so presume it is the same as previous versions?	Figure 29 consistent with the version in the WMMP - as reviewed
135	12/12/2017	Sectoin 7	Minor other text edits	Accepted, noting we failed to address comment of "Please define CDA" in the final document.

<table>
<tr><th>Issue number</th><th>Date flagged</th><th>Reference/Memo Section</th><th>Peer Reviewer Comment</th><th>Response</th></tr>
<tr><td></td><td colspan="3">SGP Stage 1 CSG WMMP: Limits, indicators and triggers memorandum</td><td></td></tr>
<tr><td>136</td><td></td><td>General</td><td>Please include rationale for setting limits in consolidated aquifers to top of the overlying confining unit.</td><td>Footnote added: Assigning top of confining layer provides a buffer to preclude dewatering of the confined aquifer .</td></tr>
<tr><td>137</td><td></td><td>General</td><td>Please include rationale for 2m CA drawdown limit.</td><td>Section 4.3 revised: CA groundwater limits are defined as drawdown levels that are not to be exceeded, and are derived from the trigger thresholds set for unconsolidated aquifers by the Water Act (Qld) 2000.</td></tr>
<tr><td>138</td><td></td><td>Table 1.2</td><td>Table 1.2 suggests no triggers for consolidated aquifers, yet more than one subsequent passage of text suggests otherwise?</td><td>Table 1.2 sets out the requirements in the conditions, and these do not require triggers for the consolidated formations, as stated in the opening paragraph of Section 3 “The Approval Conditions do not require early warning indicators or trigger thresholds for the consolidated aquifers. However, Arrow’s EWMS will voluntarily utilise an early warning indication system for these aquifers .”</td></tr>
<tr><td>139</td><td></td><td>1.1, Table 1.3</td><td>I find the definitions and explanations for early warning conditions and triggers difficult to differentiate. I wonder whether adding another vector above the trigger threshold line in figure 1.1 might help?</td><td>Noted. We agree and think the definitions are the main issue. Accordingly, Table 1.3 definitions revised as follows, and now include separate definitions for groundwater and ecosystem trigger thresholds, and for early warning condition:
<table>
<tr><th>Term</th><th>Definition</th></tr>
<tr><td>Trigger threshold (groundwater)</td><td>Maximum drawdown level that when projected forward, would result in a future limit exceedance in a relevant aquifer or at a GDE.</td></tr>
<tr><td>Trigger threshold (Ecosystems)</td><td>Maximum water quality parameter level that when projected forward, would result in a future limit exceedance at an aquatic ecosystem.</td></tr>
<tr><td>Early warning condition</td><td>A condition established (through trigger exceedance or monitoring data) which indicates a significantly increased impact or risk of future impact.</td></tr>
</table></td></tr>
<tr><td>140</td><td></td><td>3.3</td><td>Section 3.3 - what is the evidence that drawdown limits will not be exceeded?</td><td>Section 3.3 updated to include: “Groundwater modelling completed for the SREIS (discussed in detail in the Groundwater Modelling Technical Memorandum) does not indicate that the drawdown limits will be exceeded, because modelled groundwater pressure reduction is low compared with potentiometric level above aquifers”.</td></tr>
<tr><td>141</td><td></td><td>6.1</td><td>Section 6.1 - please be more specific than saying "few potential or known GDEs" and provide an appropriate reference.</td><td>Section reference is 5.1. Text revised to
As presented in the Surat CMA UWIR (DNRM, 2016), spring GDEs are not considered to be impacted by the Action and accordingly have no assigned monitoring responsibilities under the UWIR. The GDE and Aquatic Ecosystem Technical Memorandum (ENAUABTF20484AA-M03) provides the basis for the assessment of impact to non-spring GDEs, and identified three “risk areas” that require further assessment to ascertain ecosystem dependence on groundwater. As a result there are limited monitoring requirements for GDEs under the Stage 1 CSG WMMP.</td></tr>
<tr><td></td><td colspan="3">SGP Stage 1 CSG WMMP: Monitoring network memorandum</td><td></td></tr>
<tr><td>142</td><td>10/07/2017</td><td>1</td><td>Where are potential connectivity impact areas, and the what is the basis for these?</td><td>Memo revsied and this item is no longer relevant</td></tr>
<tr><td>143</td><td>10/07/2017</td><td>2</td><td>Network locations - please explain why does fig 2.2 only include wells in Arrow tenements?</td><td>Text in Section 2.2 updated to include:
Through the water management strategy in the UWIR, Arrow are assigned monitoring obligations. As set out in the Surat CMA UWIR, where a monitoring location is on a tenure holders land, the responsibility for monitoring will fall to that tenure holder. Monitoring obligations for locations that are not associated with a petroleum tenure holders land fall to the tenure holder closest to monitoring location.</td></tr>
</table>

Issue number	Date flagged	Reference/Memo Section	Peer Reviewer Comment	Response
	SGP Stage 1 CSG WMMP: Limits, indicators and triggers memorandum			
144	10/07/2017	2.4	Please include rationale for setting limits in consolidated aquifers to top of the overlying confining unit.	Text revised substantially, along with the drawdown limit, which is now the top of the aquifer, not overlying aquitard. Section 2.4 now includes a Background and Rationale sub-section that sets out the key issues that may be encountered if consolidated aquifers are dewatered to provide the basis for setting the drawdown limit as the top of the aquifer.
145	10/07/2017	3.4	Please include rationale for 2m CA drawdown limit.	Section 3.4 updated to now include: *The groundwater limit for the CA is provided in Table 3.1 and summarised against the relevant monitoring locations in Attachment 1. The drawdown limit is derived from the bore trigger threshold set for unconsolidated aquifers by the Water Act (2000).*
146	10/07/2017	Table 1.2 (formerly Table 2.1)	Table 2.1 suggests no triggers for consolidated aquifers, yet more than one subsequent passage of text suggests otherwise?	Memo and tables revised for consistency. Triggers are not required for consolidated aquifers.
147	10/07/2017	1.3	I find the definitions and explanations for early warning conditions and triggers difficult to differentiate. I wonder whether adding another vector above the trigger threshold line in figure 1.1 might help?	Trigger threshold representation figure (Figure 1.1) revised as well as the text explanations for the early warning conditions.
148	10/07/2017	2.4 (formerly 3.3)	Section 3.3 - what is the evidence that drawdown limits will not be exceeded?	Additional comment included to provide basis: *Based on current water pressure data for monitoring points that will screen the Hutton and Precipice aquifers, there is greater than 400 m of available drawdown/depressurisation prior to a drawdown limit being met, compared to the predicted drawdown of less than 20 m.*
149	10/07/2017	4.1 (formerly 6.1)	Section 6.1 - please be more specific than saying "few potential or known GDEs" and provide an appropriate reference	Text revised to: *The EWMS focuses on GDEs that may be impacted by the Action. As presented in the Surat CMA UWIR (DNRM, 2016), spring GDEs are not considered to be impacted by the Action and accordingly have no assigned monitoring responsibilities under the UWIR. The GDE and Aquatic Ecosystem Technical Memorandum (ENAUABTF20484AA-M03) provides the basis for the assessment of impact to non-spring GDEs, and identified three "risk areas" that require further assessment to ascertain ecosystem dependence on groundwater. As a result there are limited monitoring requirements for GDEs under the Stage 1 CSG WMMP.*
	SGP Stage 1 CSG WMMP: V3 draft WMMP			
150	23/11/2017	1.2	Duplication of use of Surat Basin	Removed
151	23/11/2017	Table 1.2	Is this required given Drawdown Limit already defined above ?	Deleted
152	23/11/2017	Table 1.2	Groundwater level ?	Correct - updated
153	23/11/2017	Table 1.2	what about drawdown limit in consolidated aquifers ?	Trigger thresholds for consolidated aquifers are not required. Text change to be more general: Maximum conceptual drawdown profile that could occur without resulting in exceedance of a groundwater limit, or a significantly increased impact at a GDE within 100 years.
154	23/11/2017	2.5.2	Cf. next para which says diffuse recharge is a major component?	Para 1 revised
155	23/11/2017	2.5.2	Please provide data or at least appropriate references to support this statement?	Text revised to: Vertical leakage between GAB aquifers is restricted in many areas by the low permeability aquitards present throughout the GAB, including the Evergreen and Westbourne formations and their equivalents (OGIA, 2016 (UWIR))
156	23/11/2017	2.5.4	Should this be Table 2.3 ?	Yes, corrected
157	23/11/2017	2.6.3	I don't think this is an appropriate original reference for stygofauna	The Department of Science, Information, Technology and Innovation have completed sampling in the Condamine Alluvium, and confirmed the presence of a variety of stygofauna, and results of stygofauna sampling in the nearby border rivers region indicated the widespread presence of stygofauna in groundwater (C. Schulz, DSITI, pers. Comm. - cited in CDM Smith 2016; Schulz et al. - cited in CDM Smith 2016).
158	23/11/2017	3.2.1	Suggest adding statement of total and peak annual water production here, as per first para of section 3.2.2	Added: Predicted water extraction for the Arrow SGP indicated a total production of 510 GL over the projected 40 year operational life, with a peak extraction of around 34 GL/yr approximately 7 years after commencement (refer Attachment 1 of Appendix G).

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159	23/11/2017	3.2.1	What does “maximum” mean here? I suggest introducing various modelling scenarios and realisations here, also giving percentiles selected for the assessment of potential impacts	Text revised to clarify, including footnote. "Maximum predicted drawdown under Arrow's SREIS FDP (based on the calibrated realisation of the SREIS Groundwater Model) in the main consolidated aquifers in the Surat CMA (Springbok Sandstone, WCM, Hutton Sandstone) are presented in Figures 3.1 and 3.2." Footnote: "Refer Appendix E for more information on model predictive realisations and calibration."
160	23/11/2017	3.2.1	Please add text to explain relevance of outputs at years 2030, 2050, 2094 and 2154?	Footnote revised: Refer Appendix E for more information on model predictive realisations and calibration. Refer to Section 8.4.3 of the SREIS for explanation of drawdown times selected, which correspond with peak predicted drawdown at different locations across the project area.
161	23/11/2017	3.2.1	Again, need to define “peak”	Text revised: Peak drawdown in the Springbok Sandstone (based on the calibrated realisation of the SREIS Groundwater Model) is up to 10 m and typically occurs at around 20 years after peak drawdown in the WCM.

Issue number	Date flagged	Reference/Memo Section	Peer Reviewer Comment	Response
162	23/11/2017	3.2.1	Relevance to this section unclear?	Deleted - not relevant
163	23/11/2017	3.2.1	Define wrt realisation	Revised: A maximum Arrow-related drawdown in the Condamine Alluvium aquifer (based on the calibrated realisation of the SREIS Groundwater Model) of up to 0.5 m was predicted to occur in central parts of this aquifer.
164	23/11/2017	3.2.1	need to define what this is	This is the calibrated case, as stated (also noted on the figures). The text revised somewhat to clarify: "The maximum cumulative predicted drawdown (calibrated model case) in the main consolidated aquifers in the Surat CMA (Springbok Sandstone, Walloon Coal Measures and Hutton Sandstone) as a consequence of cumulative impacts of CSG projects are shown in Figures 3.3 and 3.4. Based on modelling for the 50th percentile cumulative case (GHD 2013) the maximum impact drawdown for the Springbok Sandstone and Hutton Sandstone is 15 m, and for the Precipice Sandstone is <5 m (and of limited areal extent)."
165	23/11/2017	3.2.1	Compared with Arrow only case of between 1.25 and 2.8 ML/d	Added.
166	23/11/2017	Table 3.2	Looks too obvious for the uninitiated reader. Perhaps provide an explanation why not computed?	Revised table and added footnote referring to App F (the CDM Smith report)
167	23/11/2017	3.3.1	Need to be introduced and defined earlier	Noted. Added in Section 3.1.1: Model predictions comprised a calibrated case, as well as parameterised 'Monte Carlo' type uncertainty analysis simulations, including high (P5), median (P50) and low (P95) cases. These involved generation of 200 model predictions (based on statistically generated parameter sets). Predictions based on the calibration run were used in determining the groundwater impacts.
168	23/11/2017	3.3.1	Again, please be clearer about what these are	Checked against the 13b report and correct as is.
169	23/11/2017	3.5	Are you able to be more quantitative here?	Wording is consistent with the memo. No changes considered necessary
170	23/11/2017	5.1	Has this been done ?	No
171	23/11/2017	5.2.1	Ok, but these have not yet been defined, so might be a bit premature to say they wont be exceeded here.	Test updated to "…. and indicated that, where they have been established as part of this Stage 1 CSG WMMP, groundwater drawdown limits will not be exceeded"
172	23/11/2017	5.2.2	Brief technical justification warranted here please	Sentence added: The mechanical properties of consolidated aquifers are not expected to be altered due to drawdown associated with the Action (refer Appendix I), therefore the groundwater limit is set to avoid desaturation that could result in changes to the pore fluid hydrochemistry.
173	23/11/2017	5.3	Should this be Figure 5.3 ?	Yes, corrected
174	23/11/2017	5.3.2	Refer Section 3.2.1 ?	Included
175	23/11/2017	5.4	This is not convincing, and I wonder whether DoEE/OWS will want to see some interim EWIs and triggers established?	Text updated to: Lake Broadwater and Long Swamp are the subject of ongoing investigations to assess the connectivity of these systems to underlying aquifers that may be affected by the Action (in accordance with approval condition 13(f)). , early warning indicators and trigger thresholds are yet to be established for these features.Where connectivity is demonstrated, early warning indicators and trigger thresholds will be established for these features They will be established as part of the Stage 2 CSG WMMP. This is considered to be an appropriate approach as no gas extraction is permitted prior to Ministerial approval of the Stage 2 CSG WMMP therefore no impact to these features can occur in the interim. if the further investigations carried out demonstrate the potential for impact as a result of the Action. As described in Appendix F, the predicted groundwater impacts to these features are low.
176	23/11/2017	5.4	Figure 5.4 ?	Yes, corrected
177	23/11/2017	5.4.1	Please be more specific, as per my comments on this matter for the Memo	Text updated as per memo
178	23/11/2017	5.4.2	Again, will this be acceptable to DoEE given the wording of Condition 13(j)(iii)?	As above - made reference to the restriction on any gas production before Stage 2 approval therefore there is no risk to GDEs by developing the trigger thresholds based on better, site-specific information in Stage 2.

Issue number	Date flagged	Reference/Memo Section	Peer Reviewer Comment	Response
179	23/11/2017	5.4.2	Ditto	As above. Consider this to be adequately addressed above, no further edits made.
180	23/11/2017	6.1.1	is it worth stating that predicted impacts outside the UWIR monitoring locations are negligible, or that sufficient coverage is provided because….?	Do not consider it necessary to go in the much detail on this. Sentence added to en of paragraph: The assigned UWIR monitoring locations provide spatial coverage across the key areas of predicted impact across the range of aquifer units.
181	23/11/2017	6.1.2	Cf. 82 in Table 6.1 ?	Added clarifying text. Now reads: The Stage 1 CSG WMMP monitoring network comprises a total of 105 monitoring well/vibrating wire piezometer (VWP) intervals (82 aquifer intervals, as some locations monitoring the same aquifer at different intervals) at 32 discrete monitoring locations.
182	23/11/2017	6.2.3	Isn't this doc the Stage 1 WMMP ?	Yes - updated to Stage 2 CSG WMMP
183	23/11/2017	NA	Minor word and formatting edits in track changes	Adopted all suggested edits

Issue number	Date flagged	Reference/Memo Section	Peer Reviewer Comment	Response
	SGP Stage 1 CSG WMMP: V4 draft WMMP			
184	12/12/2017	3.1.1	Can you please provide a brief sentence to justify why the calibrated case was used for determining impacts rather than say the P5 realisation?	Section 3.1.1 revised as follows: Model predictions comprised a calibrated case, as well as parameterised 'Monte Carlo' type uncertainty analysis simulations, including high (P5), median (P50) and low (P95) cases. These involved generation of 200 model predictions (based on statistically generated parameter sets). Predictions for the 'Arrow only' impact assessment were based on the calibrated model case, because this case (by its nature) reflects the best estimate of the 'real world' parameter distribution in the SGP area, whereas the model cases for the uncertainty simulations, being based on statistically generated parameter sets (and not constrained by calibration data) cannot always be assumed to represent parameter selections that are plausible representations of field conditions. Predictions for the 'cumulative' impact assessment, are based on both the calibrated case, and on the uncertainty simulations. This is because the model output requirements for the cumulative assessment included specific plots of drawdown for the indicative range from P5 to P95. In those cases, the P50 (median) case was adopted as representative of typical conditions, and where referred to can be considered an approximate analogue to the calibrated case.
185	12/12/2017	3.2.2	This needs to be justified given that all previous references have only been to the calibrated model case.	See above response
186	12/12/2017	3.3.1	How is this different to 1(a)?	Revised as follows: 1. The OGIA 2012 Groundwater Model which predicted the flux impact to the Condamine Alluvium (CA), at the interface of the Walloon Coal Measures (WCM) and the CA. 2. The DNRM Central CA Model (CCAM) which used the outputs of the 2012 OGIA model to predict: a. Drawdown at the watertable in the CA, and b. Flux impact to the Condamine River. 3. The DNRM IQQM model which used the flux out of the Condamine River (estimated by the DNRM CCAM model) to predict impacts to water resources.
187	12/12/2017	3.3.1	To the CA aquifer?	See above response
188	12/12/2017	6.1.2	Please explain/justify, as previous text (section 3.2) has described calibrated, 50th percentile and 90th percentile. Calibrated case or 50th percentile?	Revised to: Figures 6.1 to 6.5 present the proposed groundwater monitoring network for unconsolidated and consolidated aquifer formations, superimposed on predicted drawdown (maximum cumulative drawdown (P95 case) for the Condamine Alluvium and the 1 m drawdown contour (P95 case) for the Springbok Sandstone, WCM, Hutton Sandstone and Precipice Sandstone aquifers for the 2050 cumulative case). Figure 6.6 presents the proposed groundwater flux monitoring network for the Condamine Alluvium aquifer, superimposed upon model-predicted change in groundwater flux (Arrow r27 median case – refer Figure 7-39 in Appendix F). This network utilises locations where there are existing co-located Condamine Alluvium and WCM monitoring wells to enable establishment of the differential pressure across the Walloon-Condamine interface. The flux monitoring network locations has taken into account:
	SGP Stage 1 CSG WMMP: Condition 13b technical report			
189		2-1 to 3-2	Section 2: Surat Gas Expansion Project Most of this section isn't about the Surat Gas Expansion Project. Consider moving sections 2.1 (Petroleum Leases and Drainage Areas) and 2.2 (Approved Activities) into the Introduction (section 1), and sections 2.3 (Condamine Alluvium) and 2.4 (Topography) into later sections (i.e. chapters) where they are relevant to the assessment.	"Section 2 Surat Gas Expansion Project" in the draft report has been split into two sections for the final report being "Section 2 Conceptualisation" and "Section 3 The Action". This addresses the peer reviewer comment by separating descriptions of the physical setting (such as Condamine Alluvium and Topography) and the project development (such as Petroleum Leases and Drainage Areas and Approved Activities) to sections of more relevance.

Issue number	Date flagged	Reference/Memo Section	Peer Reviewer Comment	Response
190		2-3 to 2-4 and 6-2 to 6-6	Condamine Alluvium extents Sections 2.3 (Condamine Alluvium) and 3.2 (Surface Water Resources) need much clearer justification for the adopted extent(s) of the Condamine Alluvium used in this assessment. They at least need to consider the locations of surface water features and dependent ecosystems (DEs), and the extent of likely and predicted changes in flux between the Surat Basin and the Condamine Alluvium due to CSG development.	"Section 2 Conceptualisation" was added to the final report and includes "Section 2.3 Condamine Alluvium" which addresses this comment. This section addresses the definition of the area known as the Condamine Alluvium as several authors have used slightly different extents. Justification has been provided in this section for the adopted extents of the Condamine Alluvium which also considers surface water features and prediction of flux. This includes documented discussion with experts on the Condamine Alluvium and the boundaries adopted in this study. "Section 6.2 Occurrence of DEs in the Condamine Alluvium" also addresses this comment and provides consideration of DEs based on the Condamine Alluvium boundary adopted in the study.
191		2-1 to 2-11 and 7-1 to 7-80	Hydrogeological conceptual model Section 3.3 (Groundwater Resources) needs significantly more hydrogeological context, including details of the regional hydrogeology and aquifer connectivity. Assume that most readers of this document won't know background literature around hydrostratigraphy and conceptualisation of leakage processes, especially connectivity between the Walloon Coal Measures and Condamine Alluvium. A conceptual model cross-section would be very helpful. Section 6 (Conceptual Model) is actually more about Model Requirements and should be retitled accordingly. Regardless, the hydrogeological conceptual model needs to come much earlier than Section 6.	"Section 2 Conceptualisation" was added to the final report which addresses this comment. This section includes description of the physical setting; the extent of the Condamine Alluvium; hydrogeology and aquifer connectivity; and groundwater flow process which provides more hydrogeological context and details as per the peer reviewer's comment. Conceptual model cross-sections have been provided in Figures 2-3 to 2-6 to illustrate the conceptual model. "Section 6 Conceptual Model" in the draft report has been retitled to "Section 7 Fit For Purpose Numerical Simulation" in the final report which addresses the peer reviewer's comment.
192		5-1 to 5-12	Section 4: Surface water – groundwater interaction This is the first of two sections in the report (the other being section 7.3 Surface Water – Groundwater Interactions) that are a major distraction to the reader in terms of their style, relevance and scientific content. Section 4 (Surface Water – Groundwater Interaction) definitely needs more "evidence-based" science, especially in section 4.2 (Surface Water and Groundwater in the Condamine Alluvium), which should explain the methodology and findings of previous work by CSIRO and others. Section 4.2.1 (Streambed Elevation) is very long and boring; the key points could be summarised in a few punchy sentences with high quality references. Likewise, section 4.2.2 (Depth to Groundwater) is very long, verbose and lacks a clear statement of its relevance or importance to this assessment.	Section 5 Surface Water – Groundwater Interaction" in the final report addresses this comment by providing a preamble stating the purpose of this section. The style, relevance and scientific content of this section which includes "Section 5.3.1 Streambed Elevation" and "Section 5.3.2 Depth to Groundwater" has been refined to address the peer reviewer's comment. Evidence –based science and previous work undertaken by CSIRO has been described in this section to address the peer reviewer's comment.
193		2-10 to 2-11 and 5-1 to 5-12	Section 6.2: Processes of Importance This section needs clear statements about why these processes are important, what data is available to model them, and where any uncertainties may arise in the modelling. It needs evidence in the form of numbers and references rather than commentary about what is "believed" to occur.	"Section 6.2 Processes of Importance" in the draft report has been replaced by "Section 2.5 Groundwater Flow Processes" in the final report. "Section 2.5 Groundwater Flow Processes" provides clear statements about processes that control groundwater flow and development of numerical models which addresses the peer reviewer's comment. Evidence in the form of numbers and references has also been provided in this section to address this comment. "Section 5 Surface Water – Groundwater Interaction" also addresses this comment by providing a review of processes and terminology with reference to prior work by CSIRO and others supporting the understanding of these processes.

Issue number	Date flagged	Reference/Memo Section	Peer Reviewer Comment	Response
194		7-6 to 7-72	Section 7.2: Regional Scale Groundwater Modelling This is the first of two exceptionally good sections in the report (the other being section 7.4 Modelling Groundwater in the Condamine Alluvium) and is a key scientific component of the overall assessment. There are several areas where further explanation is warranted, for example why there should be differences in the results of some models. My only significant comment on this section is that I would like to see a map of peak change in vertical flux in each model cell for all realisations. I realise that this depiction may not be realistic in terms of the collective distribution of fluxes because it comes from all realisations with different hydrogeological properties that together may not yield a calibrated model. However, I think it is critically important to demonstrate that realisation 'r1' (in this case) and the High, Median and Low realisations (later in section 7.4.4.2 Simulations) are representative in terms of both the range and distribution of changes in peak fluxes. It would also be useful to present an accompanying figure to show what realisation the peak change in flux comes from for each model cell. If these new figures show that the High, Median and Low case realisations do not adequately capture the full range and potential distribution of peak changes in fluxes, then further modelling that uses other realisations may be required.	"Section 7.2 Regional Scale Groundwater Modelling" in the draft report is presented as "Section 7.4 Regional Scale Groundwater Modelling" in the final report which addresses the peer reviewer's comment by providing additional explanation where warranted. Figure 7-5, Figure 7-19 and "Section 7.4.5.1 Predicted vertical flux at the base of the Condamine Alluvium" addresses the peer reviewer's comment in relation to peak change in vertical flux in each model cell for all realisations. Figures 7-5 shows vertical flux and realisation representativeness is described through this section including Tables 7-6 to 7-11 and Figures 7-5 to 7-50 and Figure 7-48 which shows which realisations contribute to flux in different areas.
195			Section 7.3: Surface Water-Groundwater Interactions This section is a major distraction to the reasoning and style of the report, and brings into doubt confidence in the assessment methodology. Much of the text comes across as a repetitive and incoherent critique of Brunner et al.'s work with no meaningful relevance to the current assessment. If this critique is not directly useful, then it should be deleted. The more relevant but still somewhat peripheral discussions (e.g., FEFLOW modelling) could be moved to an Appendix.	S7.3 Surface water-Groundwater interactions was replaced during a significant restructure of the document including a revision of S5 to more clearly describe terminology and surface water – groundwater interaction processes and Appendix B which describes modelling approaches including Feflow modelling and which provides background to S7.5.2 where these impact predictions are described.

Issue number	Date flagged	Reference/Memo Section	Peer Reviewer Comment	Response
196			8. Predicting impacts to other tributaries Section 7.4.3.8 (Surface water – groundwater interaction) explains that only the Condamine River and its northern anabranch are represented in CCAM with river (RIV) boundary conditions, and therefore “no other tributaries” are simulated. I see this as the only major limitation of the assessment as reported to date. The immediate question that comes to mind is, how many important tributaries – either from a DE or surface water allocation perspective – are therefore unintentionally being excluded from this assessment? If the answer to the question above is significant, then a new approach and further modelling should be undertaken to predict impacts at these locations. One possible approach is to add new RIV boundary conditions in the CCAM along these tributaries. Alternatively, a simpler, semi-quantitative approach may be possible. Regardless, this issue needs to be properly addressed for the WMMP.	This was addressed in Appendix B where modelling using Feflow was undertaken to assess the phenomenon of disconnected losing stream and whether detailed evaluation as currently feasible. S8 further justified the models used describing The IQQM and Condamine Alluvium models used in this work were also used by the Queensland Government to model groundwater and surface water allocations. Therefore, use of this assesses potential impacts to these in the same level of detail as they are managed by the Queensland Government. Section 5 describes that the majority of the Condamine Alluvium is disconnected from the Condamine River and S4.2 describe sthe tributaries included in the IQQM model. The tributaries not directly present in the models were minor and the significance of impact can be inferred from the work undertaken. Appendix B described modelling undertaken to assess the transition from losing to disconnected. It should be noted that Bioregional assessment of the area subsequently completed by CSIRO show surface water features in potential impact areas are in the area modelled.
197		7-30 to 7-33, 7-52 to 7-54, 8-4 to 8-6.	9. Representativeness of three flux realisations from Surat CMA model The single most critical input dataset to the CCAM for this assessment is, unquestionably, the change in net vertical flux from the underlying Surat Basin aquifers, which is derived from the Surat CMA model where the two model footprints overlap. This change in vertical flux is what drives the predicted drawdowns in the water table within the Condamine Alluvium, which in-turn affects fluxes to gaining reaches of the Condamine River and its northern anabranch, and they in-turn translate into additional loss nodes in the IQQM of surface water availability. With this in mind, there needs to be confidence that the High, Median and Low realisations (as described in section 7.4.4.2 Simulations) are representative in terms of both the range and distribution of changes in peak vertical fluxes. Without presenting and analysing a figure such as that recommended in item 6 (above) it is not clear whether the three selected realisations will enable prediction of maximum potential impacts on every section of the river and anabranch. For example, it is possible that the realisation with the low-case (P95) change in net vertical flux volume may have some cells in the model domain with much higher peak fluxes than other realisations, and vice versa. In theory, this issue could have been avoided by taking all 200 NSMC realisations of the change in net vertical flux from the Surat CMA model and running them through the CCAM. This would have produced 200 realisations of the water table drawdown map (instead of the three shown in Fig 7-52 Predicted maximum drawdown at the water table) and enabled a stochastic representation of the predicted impacts to surface water.	The realisations as discussed in S 7.4.4.2 were further assessed for representativeness as described in S7.6.4.2, S7.6.4.4, S7.4.7.3 and S8.2.2 addressed this comment. The representativeness is also discussed in S7.6.4.4 in terms of the alluvial footprint and in S7.4.7.3 in terms of vertical flux at the base of the Condamine Alluvium. The realisations representing the high median and low case predictions are described S7.6.4.2 as 5%, 50% and 95% probability of exceedance indicating that these representations cover the spectrum of potential vertical flux. In S8 the maximum fluxes as well as average fluxes are described to assist in assessing the representativeness of the results.

Issue number	Date flagged	Reference/Memo Section	Peer Reviewer Comment	Response
198		5-1 to 5-6, 7-14 to 7-17, Appendix B	10. Predicting impacts to disconnected streams The impacts of CSG development on both gaining and losing 'connected' streams, and therefore any associated DEs or licensed surface water allocations, are assessed via the simulation of water table lowering in the CCAM. For 'disconnected' streams the impacts are predicted to be zero because an increase in depth to water table does not cause a change in leakage flux out of the stream. It would be helpful to understand the transition from 'connected losing' to 'disconnected losing' (also often called 'maximum losing') as a result of potential CSG impacts to the water table in the Condamine Alluvium. During this transition there will be a capillary fringe connecting the clogging layer to the water table when it is close, however this is not simulated in MODFLOW. Therefore, is it possible to determine: a) How does simulated leakage from losing sections of the Condamine River (and northern anabranch) change as a result of water table lowering over the simulation period? b) How many reaches change from a 'connected losing' to 'disconnected losing' state? c) What is the potential uncertainty in the estimated fluxes from disconnected streams given (a) uncertainties in clogging layer properties, and (b) the simplifications used in MODFLOW?	This comment is addressed in Sections 5 and 7 and Appendix B. The process of simulated leakage from losing sections as the water table lowers is discussed in Appendix B and in Section 5 and its impact to the uncertainty in predictions is discussed both in terms of qualitative effects and spatial extents in section 5 and in section 7. S5 describes that the Condamine river and its tributaries are already mostly in a disconnected state and also describes In S7 the uncertainty from the model approach is discussed along with the scale of drawdown predictions indicating the majority of the area is subject to minor drawdown and this with the already disconnected state of the river results in a low significance to the overall results.

Issue number	Date flagged	Reference/Memo Section	Peer Reviewer Comment	Response
199			11. Broadening the IQQM assessment In light of the limitation outlined above (item 8), it may be prudent to consider whether and how the IQQM can be used to simulate impacts on allocations from other tributaries not simulated with RIV boundaries in CCAM.	In light of the response to comment 8 it was decided that generally disconnected nature of the tributaries and the small amounts of drawdown predicted to the east under these tributaries the significance of this was small and did not warrant further investigation at this time.
200		7-1 to 8-1, 7-65, 7-66	12. Synthesis of all flux modelling It would be very useful to add a conceptual water balance diagram that pulls together all key information from both the Surat CMA model and the CCAM (and perhaps the IQQM) in section 8. Ideally this diagram would be in three parts: no CSG (i.e., baseline), all CGS development, and just Arrow CSG development. Annotations could include the range of and peak change in flux rates, the change in peak flux volumes from the Surat CMA model into the Condamine Alluvium, the same information but for fluxes into the CCAM, the range of and peak water table drawdown, and the range of and peak impacts to the Condamine River.	This was addressed in Section 7 and 8 through the discussion of realisations and percentile results and in Figures 7-44 to 7-46 to illustrate the water balance for the high median and low cases to describe the fluxes as they pass from the regional model to the Condamine Alluvium model and eventually to the Condamine River.