Annual Report 2013

for the

Surat Underground Water Impact Report

December 2013

Version history

Version	Date	Description
1.0	23/12/13	Approved by Randall Cox for submission to DEHP

This publication has been compiled by the Office of Groundwater Impact Assessment, of the Department of Natural Resources and Mines.

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Abbreviations

CDA	Central Development Area
CMA	Cumulative Management Area
CSG	Coal seam gas
DNRM	Department of Natural Resources and Mines
DEHP	Department of Environment and Heritage Protection
EIS	Environmental Impact Statement
IAA	Immediately Affected Area
LAA	Long-term Affected Area
NDA	Northern Development Area
OGIA	Office of Groundwater Impact Assessment
QWC	Queensland Water Commission
SDA	Southern Development Area
SIMS	Spring Impact Management Strategy
UWIR	(Surat) Underground Water Impact Report 2012
WCM	Walloon Coal Measures
WMS	Water Monitoring Strategy

Executive Summary

The production of coal seam gas (CSG) involves the pumping of water from coal formations to reduce water pressure and release the gas. This can affect overlying and underlying aquifers because of interconnectivity between the formations. Petroleum tenure holders are required to make good impairment of bore water supplies, to assess future impacts and monitor water resources. In areas of concentrated development the impacts on water pressures from multiple operations can overlap and a cumulative approach is needed. In those situations the Office of Groundwater Impact Assessment (OGIA) carries out a cumulative assessment, specifies integrated monitoring and other management requirements and assigns responsibility for implementation of separate parts of those management requirements to individual petroleum tenure holders. These assessments are set out in an Underground Water Impact Report.

The Surat Underground Water Impact Report (UWIR) was approved in December 2012. The 2013 Annual Report describes changes that have occurred since the UWIR was prepared and OGIA activities that are currently being carried out in preparation for the revision of the UWIR in December 2015.

A regional groundwater flow model was constructed to predict the impacts of current and planned CSG development on water pressures in aquifers. Output from the model was the basis for preparation of the UWIR. The model remains widely accepted as the most appropriate tool for assessing regional impacts and is used by industry to meet a range of regulatory requirements. A new model will be constructed to support the revision of the UWIR in December 2015. Until then the existing UWIR groundwater model will continue to be used for assessing regional impacts.

Production on individual petroleum leases will commence and cease at different times over the life of the industry. The collective set of commencement and cessation times is the cumulative industry development profile. The cumulative industry development profile is used as input to the UWIR groundwater model to predict impacts on water pressures. Industry planning for development will change over time for many reasons.

The industry development profile has now been updated. Overall, there has been little change to the footprint of planned development. Santos/GLNG is likely to propose expansion in the north of the area which would be reflected in the 2014 annual report on the UWIR. However, there have been changes with regard to timing. CSG development is not being commenced as early as was planned at the time the UWIR was prepared.

The changes to the industry development profile do not change the extent of long-term predicted impacts. In the short-term (by 2015), impacts will be smaller for the most part than previously predicted. However there is a small area where the short-term impacts will be slightly larger than previously predicted and as a result there are four (4) additional private water bores that may experience impairment of supply in the short-term. OGIA has advised the responsible tenure holder that it would be appropriate to commence bore assessments and enter into make good agreements with the owners of those bores.

The UWIR specifies a regional monitoring network and assigns to individual tenure holders responsibility to implement separate parts of the network. Installation is a little behind schedule due to implementation issues. It is too early in the development of the industry to detect any clear water pressure impacts in aquifers adjacent to the coal formations resulting from CSG development.

The UWIR identifies where there is a predicted long-term pressure impact in any aquifer underlying a spring. It specifies monitoring requirements for 33 representative spring vents. The monitoring seeks to provide information about the background variability in the hydraulic function of the springs. Tenure holders have commenced monitoring and are coordinating with OGIA to test new monitoring methodologies.

The UWIR also identifies five spring complexes where water pressure impacts are predicted in the source aquifer for the springs in the long term. Although the predicted pressure impacts are relatively small (up to 1.5m), tenure holders have been required to investigate options to prevent or mitigate impacts. Those assessments show that at two sites effective mitigation options are available for activation when and if necessary. At the other three sites investigations of the local hydrogeology is required before options can be further assessed. Those investigations are continuing. It is intended to review the required actions during the revision of the UWIR in December 2015 in the light of the outcomes of site investigations by tenure holders and updated regional water pressure impact modelling by OGIA.

A major current focus for OGIA is to undertake research to build new knowledge about the groundwater flow system. Outcomes from research projects will be incorporated into the construction of a new groundwater flow model which will be used in the revision of the UWIR in December 2015. The research projects are being carried out by OGIA in collaboration with CSIRO, Geoscience Australia, Universities and petroleum tenure holders. Project summaries are as follows.

Condamine Connectivity Project: The UWIR predicts that the impact on the Condamine Alluvium from depressurisation of the underlying Walloon Coal Measures will be relatively small. However, the water resources of the alluvium are an essential resource for the irrigation industry and are heavily developed. Therefore improving understanding about interconnectivity between the formations is important.

Some 130 bores have been surveyed to collect water level and hydrochemical data. All existing primary geological data is being reviewed. Some 3,000 existing hydrochemical datasets are being reviewed to identify the character and origin of the water. Aquifer pump testing is in progress using new monitoring bore complexes that record responses in multiple formations to pumping from one of the formations. Core recovered from drilling is being subject to laboratory analysis.

Outputs from these activities will contribute to a regional reconceptualisation of the groundwater flow system.

Walloon Coal Measures Connectivity Project: The Walloon Coal Measures will be extensively depressurized during CSG production. The hydraulic properties and distribution of the overlying and underlying material are the primary factors affecting the extent to which overlying and underlying aquifers will be affected.

For this project a similar approach is being used to that used for the Condamine Connectivity Project. Due to the extent of the area, the project is focused at both regional and local scales. Local scale investigations are being carried out in collaboration with tenure holders.

Geologic Modelling Project: A new geological model is being prepared as a basis for the later construction of the new groundwater flow model. An initial model is being progressively updated. Stratigraphic reinterpretation is in progress using geophysical wireline log data. To date 3,100 wireline logs have been processed.

Groundwater Modelling Methodology Project: A groundwater flow model for the Surat Cumulative Management Area needs to represent complex multilayered geology and the movement of groundwater in gaseous coal formations. Improved techniques for modelling are being identified and tested.

Geological Structures Project: Geological structures, such as faults, have the potential to affect the flow of groundwater. It is intended to represent faults and their hydraulic nature in future groundwater flow modelling. The project will update the mapping of structures and assess their hydraulic characteristics.

Spring Function and Monitoring Methodology Project: Improved understanding of the risk to springs requires improved understanding of spring function. Conceptual options for the hydrogeological setting of representative springs have been developed and field data is being collected to identify the correct conceptualisation. The results will be applied to other springs when updating the risk assessment.

Monitoring spring flow is difficult. The project will identify the most efficient and effective methodology for future monitoring. Options available have been evaluated and a field trial is currently being designed.

Other Projects: Water pressure surfaces for all aquifers are being developed having regard to the effects of variable density and temperature in deep formations. OGIA is also collaborating with the University of Queensland on a project that it is carrying out to improve estimation of recharge to aquifers.

Chapter 1: Introduction

1.1 Regulatory framework

Under the Queensland regulatory framework, petroleum and gas tenure holders have rights and responsibilities in relation to the extraction of groundwater in the process of producing petroleum and gas. These responsibilities are to 'make good' impairment of private groundwater supplies caused by the water extraction activities and to carry out monitoring and other management activities.

In areas of concentrated development, the impacts of groundwater extraction activities by multiple petroleum and gas operations on groundwater resources can overlap and an integrated management approach is needed. Such an area of overlapping impact can be declared to be a 'cumulative management area' (CMA). When a CMA is established, the Office of Groundwater Impact Assessment (OGIA) becomes responsible for carrying out a cumulative impact assessment and preparing an Underground Water Impact Report (UWIR). A UWIR contains:

- predictions of short and long-term impacts on water pressures in aquifers;
- a regional water monitoring strategy;
- a regional spring impact management strategy;
- assignments of management responsibilities to individual tenure holders; and
- a research program to build knowledge to improve predictions of impacts.

The significance of the component parts of a UWIR are as follows.

Prediction of impacts: Multiple aquifers can be affected because of interconnectivity between aquifers. Impacts are identified using a regional groundwater flow model. For each affected aquifer an Immediately Affected Area (IAA) is identified. The IAA for an aquifer is the area where water pressure reductions of more than statutory triggers (5 metres for consolidated aquifers such as sandstone and 2 metres for unconsolidated aquifers such as alluvium) are predicted within three years. For bores sourcing water from the aquifer in its IAA, responsible tenure holders must, on approval of the UWIR, carry out a bore assessment and enter into a make good agreement with the bore owner. This proactive arrangement ensures make good actions are timely. A Long-term Affected Area (LAA) – where modelling indicates statutory triggers may be exceeded at any time in the future - is also identified to show the predicted whole of life regional impacts.

Regional Water Monitoring Strategy (WMS): Specifies a regional network of monitoring bores for water pressure and water quality data collection, to improve the accuracy of future regional groundwater flow modelling.

Regional Spring Impact Management Strategy (SIMS): The flow of water to springs can potentially be affected by groundwater extraction. The SIMS specifies spring monitoring and other spring management arrangements needed to understand and manage risks to springs.

Assignment of management responsibilities to individual tenure holders: Rules in the UWIR assigns responsibilities for implementation of component parts of the WMS and SIMS to individual tenure holders. Rules also provide for the identification of a single petroleum tenure holder as being responsible for make good responsibilities in relation to any particular water bore.

Research: A UWIR is revised every three years to take into account new knowledge from research and monitoring data. The UWIR describes the research program.

1.2 The Surat Underground Water Impact Report

The Surat CMA was established in April 2010. A draft UWIR was published for comment in May 2012 by the then Queensland Water Commission (QWC). It was approved by Department of Environment and Heritage Protection (DEHP) in December 2012. The relevant responsibilities of the QWC have now transferred to the Office of Groundwater Impact Assessment (OGIA).

The Surat UWIR is currently being implemented. It will be revised to incorporate new knowledge in December 2015.

1.3 Purpose of the Annual Report

The purpose of this annual report is to provide updates about changes to circumstances that would impact on the predictions in the 2012 Surat UWIR, and to provide updates on the implementation of management strategies specified in the UWIR.

Chapter 2: Update on industry development profile

2.1 Planned development

In order to prepare the Surat UWIR, a whole of life cumulative industry development profile was prepared and used as the input scenario for the regional groundwater flow model. Output from the model provided short-term and long-term predicted cumulative impacts on water pressures in aquifers for that input scenario.

Information about the cumulative development profile used in the UWIR was given in Figures A-1 and A-2 of the UWIR. Those figures showed the then planned time of commencement and cessation of production on tenures across the CMA. This cumulative development profile was prepared by obtaining planned development information from individual tenure holders.

Many factors can change development planning over time. Changes can relate to the timing of development of individual petroleum lease areas, relinquishment of leases altogether and/or the planned development of new areas.

Since changes to the cumulative development profile can alter the predicted impacts, changes are reviewed annually.

2.2 Description of changes to planned development

The current cumulative development profile is given in Figures 1 and 2 and is based on current development plans provided by tenure holders. Changes since the UWIR was prepared are summarised below.

Origin/APLNG: Origin/APLNG is developing both the Walloon Coal Measures (WCM) and the Bandanna Formation. There is no change to the footprint of planned development from either formation. In relation to scheduling, there is no change in relation to production from the Bandanna Formation. However, for the WCM, commencement of production for some areas has been rescheduled to a later time. In northern areas previous planning for commencement in 2014 has now been changed to 2020. In areas to the west, planned commencement has changed from 2016 to 2020. In areas to the south, planned commencement has changed from 2020 to 2025.

Origin/APLNG has also rescheduled the commencement of its Ironbark Project near Tara to a later date. Under the current development plan, production will commence in late 2016 in the western parts of the project area, with development progressing eastwards over a 5 year period while no production is proposed in the southern part of the tenure.

QGC: There is very little change to the overall footprint of planned development for QGC tenures. QGC has reduced its proposed development footprint in the marginal areas of its Northern Development Area (NDA). Planned early commencement in the NDA has been rescheduled to 2014 with the area progressively coming into production until 2023. In some parts of the Central Development Area (CDA) commencement is occurring a little earlier than planned. However, in the southern part of the CDA commencement has been delayed by up to 6 years. The northern part of the CDA has been expanded through acquisition of tenure from Arrow Energy, with QGC scheduling commencement in 2014 which is earlier than the

previous scheduling by Arrow Energy. In the Southern Development Area (SDA) there has been some rescheduling to later commencement dates.

Santos/GLNG: Currently there is no change to the footprint of planned development or scheduled commencement. However, Santos/GLNG is considering expanding the planned development of both the Bandanna Formation and the WCM under a proposed Gas Field Development Project. A Terms of Reference for an Environmental Impact Statement (EIS) for the proposed project was released by the Queensland Coordinator-General in March 2013. Proposed changes to development would be specified through the EIS process.

Arrow Energy: Arrow Energy has revised its proposed development footprint through a Supplementary EIS published in June 2013. Arrow Energy has relinquished tenure over some lands primarily in the southern development area but also along the easterly extent of Arrow's holdings to the north of Dalby which have reduced Arrow's project development area from approximately 8,600 km^2 to approximately 6,100 km^2. There have also been changes to scheduled commencement of development. Most areas previously scheduled for early commencement are now scheduled for commencement in 2014 or later. However there are some areas south west of Lake Broadwater where production is now scheduled to commence earlier than previously planned.

2.3 Summary of changes to planned development

There have been changes to planned commencement and cessation dates. Overall, planned commencement of production has been rescheduled to commence at later times than previously planned. There has been some relinquishment of tenures. Potential expansion on Santos/GLG tenures has been foreshadowed which may result in changes to the cumulative development profile in the 2014 Annual Report for the UWIR.

Although the number of constructed wells has increased from 2,477 to 4,134 most of these are appraisal wells or wells that will not be brought into production until 2014. Accordingly water production has not increased significantly at this stage.

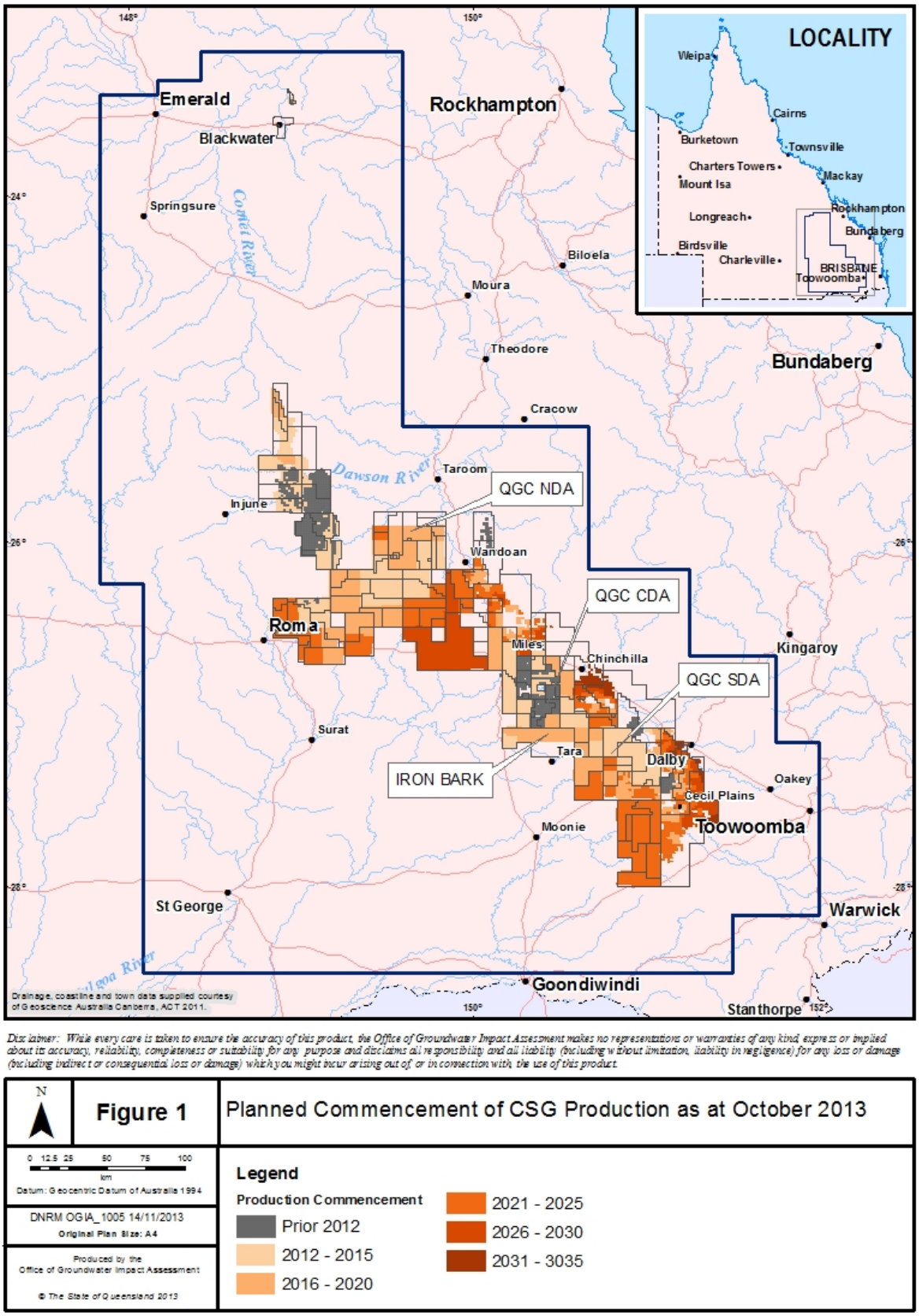

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Figure 1: Planned Commencement of CSG Production as at October 2013

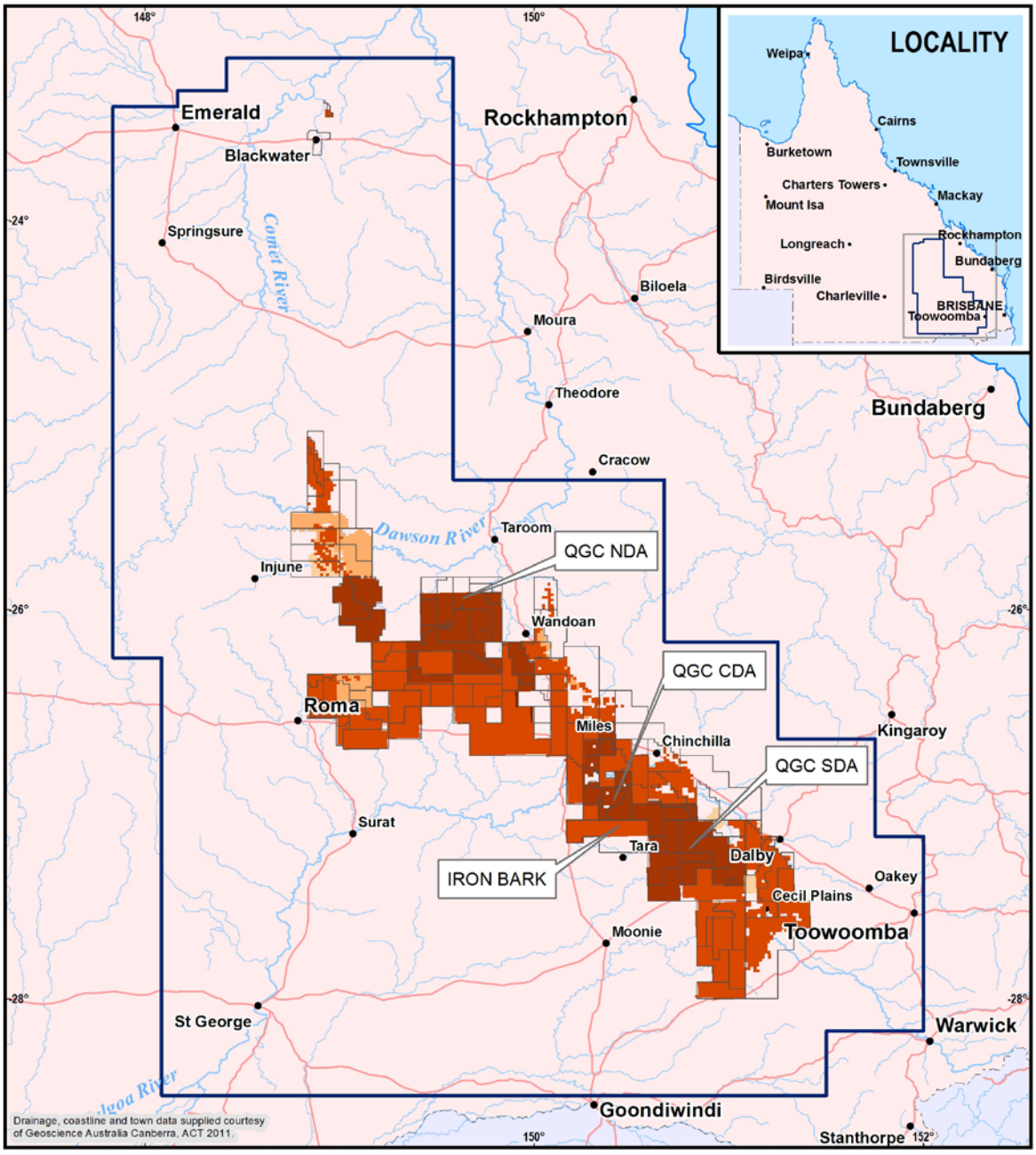

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Figure 2 Planned Cessation of CSG Production as at October 2013

0 12.5 25 50 75 100
km

Datum: Geocentric Datum of Australia 1994

DNRM OGIA_1006 14/11/2013
Original Plan Size: A4

Produced by the
Office of Groundwater Impact Assessment

Legend

Production Cessation

- Prior 2025
- 2025 - 2035
- 2036 - 2045
- 2046 - 2055
- 2056 - 2065
- 2066 - 2069

Figure 2: Planned Cessation of CSG Production as at October 2013

Chapter 3: Update on predicted impacts on water pressures

3.1 The UWIR groundwater model

A regional groundwater flow model was constructed to support the preparation of the Surat UWIR. It was used for predicting the impact of the cumulative industry development profile on water pressures in aquifers. Since then minor amendments have been made to the model arising from local issues and to improve the operational efficiency of the model. The alterations do not affect predictions of short-term impacts and only slightly affect predictions of long-term impacts. In the long-term the alterations result in a slightly smaller number of affected bores than predicted in the UWIR. The alterations also result in slight changes to predicted long-term impacts in aquifers beneath springs in the northern margin of the development area. In consideration of these changes and their consequences, the spring impact management arrangements specified in the UWIR remain precautionary and appropriate. The model, as amended, is referred to in this report as the UWIR groundwater model.

The UWIR groundwater model is widely recognised as the most up to date and comprehensive model for cumulative groundwater impact predictions for the Surat CMA. It is used by the tenure holders to meet various regulatory requirements.

A new regional groundwater flow model will be constructed to support the revision of the UWIR in December 2015. OGIA is currently undertaking a number of research projects to build new knowledge about the groundwater flow system that will be incorporated into the new model. Until that time the UWIR groundwater model continues to be the most suitable tool for assessing regional impacts.

3.2 Assessing changes to predicted impacts

Changes to the whole of life cumulative industry development profile that have occurred since the preparation of UWIR are described in Chapter 2. The UWIR groundwater model has been used to predict the impact of the current cumulative development profile on water pressures in aquifers.

This Chapter describes the differences between the predictions in the UWIR and the predictions made using the current cumulative industry development profile.

3.3 Changes to short-term impacts

The UWIR identified the Immediately Affected Areas (IAAs). The IAA for an aquifer is the area where water pressures are predicted to decline in the aquifer by more than 5 metres by 2015 as a result of water extraction for CSG development. An IAA of any significance was only identified for the WCM. On approval of the UWIR, responsible tenure holders commenced bore assessments for bores tapping the WCM within its IAA and entering into agreements to make good the expected impairment of water supply.

A total of 85 bores were listed in the UWIR as sourcing water from the WCM in the IAA. Since then bore assessments by tenure holders and other investigations carried out by the CSG Compliance Unit of the Department of Natural Resource and Mines (DNRM) have resulted in changes to records about the source aquifer for some bores. These changes are discussed further in Chapter 4.

The most significant change to the cumulative industry development profile is the rescheduling of commencement to later times. As a result the short-term impacts will not be as extensive as predicted. Twenty eight (28) of the bores that were predicted to experience a decline of 5 metres by 2015 are now predicted to not experience that decline until a later time. Therefore, the current actions by responsible tenure holders in carrying out bore assessments in relation to those bores will result in the actions being more proactive and therefore more precautionary.

While the overall effect of the changes to the cumulative industry development profile is for short-term impacts to be smaller, a small area beyond the eastern edge of the IAA is expected to incur impacts earlier than previously predicted. There are four (4) bores in that area that source water from the WCM. OGIA has advised the responsible tenure holder that it would be appropriate to commence bore assessments and enter into make good agreements with the owners of those bores. If necessary, the Department of Environment and Heritage Protection (DEHP) has the power to direct that a bore assessment be carried out.

3.4 Changes to long-term impacts

The UWIR identified the Long-term Affected Areas (LAAs). The LAA for an aquifer is the area where water pressures are predicted to decline by more than 5 metres at any time in future.

The changes to the cumulative industry development profile result in insignificant changes to the long-term impact on water pressures in aquifers. For all aquifers, the area expected to experience a decline in water pressure of more than 5 metres at any time in future is effectively the same as the LAAs in the UWIR.

Chapter 4: Bore data corrections

4.1 Bores in Immediately Affected Areas

If the supply from a water bore is impaired as a result of CSG water extraction, the responsible tenure holder has an obligation under the *Water Act 2000* (the Act) to carry out a bore assessment and enter into an agreement with the bore owner about measures to make good the impairment.

The Act includes arrangements to trigger proactive action which seeks to ensure make good measures are in place before impairment occurs. It requires that on approval of a UWIR, the responsible tenure holders carry out assessments of bores that tap an aquifer within the Immediately Affected Area (IAA) for the aquifer and enter into a make good agreement with the bore owners about measures to make good impairment of bore supply. This is based on the premise that a water pressure decline of 5 metres in a bore would pose a risk of impairment to the water supply available from the bore.

Together with the maps showing the IAAs, the UWIR included a list of the water bores understood to tap an aquifer within its IAA. The list was provided to assist tenure holders in carrying out their responsibilities and also for community information purposes. The bores were identified using records in the DNRM groundwater database about the locations of bores and the aquifers tapped by the bores. The UWIR thereby identified 85 bores as accessing the WCM within the IAA for the formation.

The data in the DNRM groundwater database has been assembled from many sources over many years. In some cases the data held can be inaccurate or incomplete. Therefore, it was expected that information collected in the process of carrying out bore assessments, as well as from other sources, would result in corrections to the database.

4.2 Bore Assessments

Bore assessments for each of the 85 identified bores commenced following approval of the UWIR. In most cases a make good agreement is being negotiated with the bore owners following completion of a bore assessment. However, in 23 cases the bore assessment has concluded that the source aquifer for the bore is a shallower aquifer than the aquifer identified in the DNRM groundwater database. For most of these cases the recording of a coal band in the drillers log led to the DNRM groundwater database incorrectly identifying the WCM as the source aquifer rather than the Springbok Sandstone, which can contain some small coal bands. As a result, a water pressure reduction of more than 5 metres is not expected for those 23 bores in the short-term. The CSG Compliance Unit and OGIA have endorsed the results of these assessments.

The CSG Compliance Unit has also investigated situations where there is information to suggest that a bore has been incorrectly omitted from the list of bores predicted to experience a pressure reduction of more than 5 metres in the short-term. Three (3) such bores have been identified. These bores were either not registered in the DNRM groundwater database or had the source aquifer incorrectly recorded.

As a result of above changes it is currently expected that 65 bores source water from the WCM within its IAA.

4.3 Significance of the changes to bore records

If a bore has been found to be sourcing water from an aquifer that is shallower than the WCM, the bore will not be affected until a later time, and may not be affected at all. If an additional bore is found to be tapping the WCM then a bore assessment and make good agreement is required. DEHP is advising landholders and responsible tenure holders of these requirements.

The correction of bore records arising from bore assessments does not impact on the integrity of the UWIR groundwater model. The model was constructed using a wide range of data such as stratigraphic interpretations from research agencies. However, all new information will be considered when the next regional groundwater model is constructed.

Chapter 5: Implementation of UWIR Water Monitoring Strategy

5.1 The UWIR Water Monitoring Network

The UWIR specified a regional monitoring network at 142 monitoring sites consisting of 498 monitoring points for pressure monitoring and 120 monitoring points for water quality monitoring. Of these, some were in existence at the time the UWIR was prepared, others were to be installed by the end of 2013, with the remainder to be installed by the end of 2016.

The regional monitoring network is designed for the collection of long-term data to meet multiple objectives related to regional assessment. There is additional monitoring carried out by tenure holders and DNRM to meet other objectives. OGIA will utilise that data, as appropriate, in carrying out assessments.

The UWIR assigns to individual tenure holders responsibility for implementing specified parts of the regional monitoring network. The UWIR recognises that the location of the identified sites may need to be altered during implementation due to practical operational issues. It provides for tenure holders to propose to OGIA variations to implementation requirements that overcome operational constraints while not undermining the attainment of the objectives of the monitoring network.

5.2 Variations to the Water Monitoring Network

5.2.1 Location of monitoring points

Tenure holders have proposed variations to the location of monitoring sites because of operation issues. Most of the variations proposed relate to changes of less than one kilometre. Some of the proposed variations involve relocations of up to 10 kilometres to make best use of existing infrastructure. OGIA has ensured that these variations collectively retain value in terms of the monitoring objectives.

Most of the variations proposed have been endorsed by OGIA either as proposed or after negotiation in relation to the proposed variation. However, changes continue to be proposed as installation issues are experienced and at any time there are likely to be proposals that are under consideration for endorsement. If an issue arises that cannot be resolved through negotiation then the matter would be referred to DEHP.

5.2.2 Timing of installation

The UWIR specifies the monitoring points that are to be installed by the end of 2013. This timing was set with a view to data from those works being available as input to hydrogeological research projects, such as the aquifer interconnectivity projects described in Chapter 7, to support the revision of the UWIR in December 2015. Some proposed changes to timing requirements have been endorsed by OGIA where the changes are part of a set of changes that also involve relocation and collectively do not diminish the attainment of objectives.

Responsible tenure holders are experiencing delays in completing the installation of some of the monitoring works required for installation by the end of 2013. The delays relate to site practicality, the time required to arrange land access agreements with landholders, and technical challenges associated with the installation of monitoring works in gaseous environments.

OGIA has advised the responsible tenure holders and DEHP that delays to March 2014 would not cause significant difficulties, but that delays beyond that date would start to have implications for the research projects that will support the updating of the Surat UWIR in 2015. As at the end of September 2013 more than half of required new works for 2013 had been drilled or installed. On the basis of current scheduling by petroleum tenure holders, some 80% of the works required to be operational by the end of 2013 will be installed by the end of March 2014. Tenure holders have been advised that every effort is to be made to complete installation of required works by March 2014.

5.3 Monitoring data

5.3.1 Monitoring instrumentation

Prior to commencing the implementation of the water monitoring network specified in the UWIR, there were monitoring works in existence operated by DNRM or petroleum tenure holders. These existing monitoring works are mostly located at shallow depths where there is a higher concentration of private water bores.

The monitoring network specified in the UWIR requires the installation of a large number of monitoring works to complement the existing network for CSG impact assessment. In and around areas of gas development monitoring points are required to be installed in gaseous environments in the coal formations as well as is in underlying formations. This poses new challenges in terms of monitoring techniques.

To deal with these challenges tenure holders have used a variety of equipment and techniques including vibrating wire piezometers and a range of pressure gauges and pressure transducers. Data is now becoming available from these new installations. The data shows that there are likely to be instrumentation and installation issues influencing the data in some cases. In consultation with tenure holders, OGIA will review the range of monitoring installation and instrumentation systems that have been used, to identify the most appropriate systems and to identify any adjustments necessary.

5.3.2 Water pressure trends

The monitoring network is designed to provide data to meet a range of objectives relevant to improving knowledge about the system so that modelling of future impacts can continue to be improved. One of the objectives is to identify trends in water pressure caused by water extraction by CSG operations. Although monitoring data has been accumulated over time for shallow aquifers, in the area of current development data from the coal formations and aquifers above and below the coal formations has, for the most part, only become available over the last year. Also, as mentioned in the previous section, the data from some of the recent installations is likely to be influenced by installation and instrumentation issues. Subject to those constraints the following preliminary comments are made with regard to water pressure trends in relation to CSG operations:

- The WCM is the CSG bearing formation in the Surat Basin. Water pressure behaviour in the WCM is variable with no discernible trend at this time. The formation is heterogeneous, with monitoring works being installed in a range of materials in gaseous environments using a variety of techniques. In general the recorded decline in pressure at some locations is less than anticipated. This could be related to issues with installation and instrumentation systems as previously discussed, or be related to complexities associated with permeability variations within the WCM. OGIA will continue to assess water pressure behaviour.

- The Springbok Sandstone is the aquifer overlying the WCM. Water pressures in the formation in and around the areas of CSG development remain stable.

- The Hutton Sandstone is the aquifer underlying the WCM. In the area of CSG development south west of Chinchilla, the data records of less than a year suggest an annual decline of approximately 2 metres in the Hutton Sandstone. In this area the top of the Hutton Sandstone is some 650 metres deep and is separated from the WCM by some 60 metres of the Eurombah Formation, generally a low permeability material. There are also a number of water bores near the area that pump significant volumes from the Hutton Sandstone for stock intensive and industrial purposes. OGIA will continue to monitor water pressure behaviour and assess the factors affecting the behaviour having regard to CSG and non-CSG water extraction and aquitard characteristics.

- The Precipice Sandstone is the basal formation of the Surat Basin. It comes into contact with the Bandanna Formation, the gas bearing formation of the Bowen Basin, in the northern part of the CMA. The data available from the area at this time is scattered and limited. It shows some decline but no discernible trend from the short period of records. OGIA will continue to assess water pressure behaviour in this area.

- For other aquifers there is no discernible trend in water pressures in relation to CSG development.

5.3.3 Suitability of the monitoring network

No changes are required to the monitoring network or the monitoring strategy as a result of alteration to the cumulative industry development profile or other related factors.

Chapter 6: Implementation of the UWIR Spring Impact Management Strategy

6.1 The UWIR Spring Impact Management Strategy

The Spring Impact Management Strategy (SIMS) in the UWIR identified springs that may be at risk due to underlying aquifers being affected by CSG water extraction. The criteria for identifying potentially affected springs was conservative and used the limits of the modelled long-term pressure impacts. There have been small changes to the regional groundwater model and small changes to the cumulative industry development profile. This has resulted in slight alteration to the limits of long-term predicted impacts, but these do not significantly change the situation with regard to predicted spring impacts.

The SIMS also included a risk assessment for springs and specified a monitoring program for springs that have higher risk of being affected. Responsibility for implementing the monitoring program was assigned to individual tenure holders.

Among the springs to be monitored there is a group of five (5) complexes, which on the basis of UWIR model predictions, are expected to experience some pressure reduction in the spring's source aquifer. For those springs the UWIR requires tenure holders to assess options for prevention or mitigation of those impacts.

6.2 Spring monitoring

The UWIR identifies 10 spring complexes (33 spring vents) and five (5) watercourse springs for quarterly monitoring. The monitoring approach and parameters to be measured at each site are specified in the UWIR.

In addition to requirements under the UWIR, CSG companies have obligations under Commonwealth jurisdictions in relation to spring monitoring. Tenure holders will collectively engage a single contractor to undertake and meet their spring monitoring obligations. The intent of this approach is to ensure consistent and uniform implementation of the monitoring methods and to allow for uniform reporting of results to OGIA and the Commonwealth Government.

The purpose of the monitoring is to build an understanding of the variability of the flow condition at the springs and the existing impacts from current land use activities. It is necessary to understand these complex flow characteristics so that any later trends of change can be detected.

The first full round of monitoring under the combined program was completed in October 2013, following completion of land access agreements with landholders. Prior to this date monitoring was carried out at sites located on tenure. The data record is too short to show any trends.

Understanding the variability in flow characteristics requires an understanding of the hydrogeological setting of the springs which is a focus for spring research as described in Chapter 7. The spring monitoring activities are being closely integrated with spring research. Spring monitoring requirements are likely to be modified over time as a result of this

research. OGIA is working closely with tenure holders as the monitoring program is implemented to test new approaches for the collection of spring monitoring data.

6.3 Prevention or mitigation of spring impacts

The UWIR identifies five (5) spring complexes where water pressure impacts in the spring's source aquifer from current or planned CSG water extraction are expected to exceed 0.2 metres at the location of the spring at any time in the future. The maximum long-term pressure reduction in the source aquifer at any of the sites is 1.5 metres. Although such pressure reduction may not cause significant change in actual flow to the spring and spring ecology, the UWIR required that tenure holders evaluate the options for avoiding or mitigating the predicted pressure impact in the source aquifer at the springs. Those evaluations have been carried out and the outcomes are as follows.

At two sites (Barton and Scott's Creek), the potential future aquifer water pressure impacts can be fully offset by relocating existing stock water bores that currently impact on the water pressure in the source aquifer at the locations of the springs. The relevant bore owners have agreed in principle to cooperate in the implementation of the measures when, and if, appropriate.

At the other three sites (Lucky Last, Spring Rock Creek and 311/Yebna 2), investigations carried out in the process of completing the evaluation of mitigation options have shown that the local hydrogeologic setting is complex and requires further investigation before options for mitigation of potential pressure impacts are fully evaluated. At this stage, from information available about hydrogeological settings that has become available since the UWIR was prepared, it is likely that impacts at these sites will be smaller and occur later than predicted in the UWIR.

It is intended that when the UWIR is revised in December 2015 it will be on the basis of modelling that incorporates new knowledge about the groundwater flow system. The spring impact management strategy in the revised UWIR will include an updating of the spring risk assessment, the source aquifer assessment and timing of impact at springs as is relevant under the then current groundwater modelling. The need for the development of detailed proposals for mitigation of impacts will be a matter for review at that time.

Chapter 7: Update on OGIA's research projects

7.1 Overview

Extensive knowledge has been built over many years about the regional groundwater flow system and this was used as the basis for the development of the UWIR in 2012. However the groundwater system in the Surat Basin is complex and knowledge about the groundwater system is continuing to improve over time. The new understanding will be incorporated in the preparation of subsequent revisions of the UWIR.

In preparing the UWIR the areas where knowledge would be most beneficially improved were identified. The UWIR described those research needs and OGIA has subsequently implemented a research program to meet those needs. This Chapter provides a summary of the research projects that are being implemented, progress made and future directions.

7.2 Project delivery and coordination

Several hydrogeological research projects are being carried out concurrently. In mid to late 2014 the outputs from the projects will be brought together as a re-conceptualisation of the regional groundwater flow system.

In parallel with the hydrogeological projects, new approaches to groundwater modelling are being evaluated. Construction of a new regional groundwater flow model will commence when the new conceptualisation of the regional groundwater flow system is finalised.

OGIA is undertaking research in collaboration with various partners. OGIA maintains a core technical team and compliments those skills with the purchase of expert services and collaborative relationships with research agencies, universities and CSG companies. The intention is to bring the best skills to bear on the research needs within a time frame that supports revision of the UWIR in December 2015.

Separately from those collaborative arrangements, OGIA seeks advice and peer review from external experts in relation to the design of projects and project outputs.

7.3 Project progress

7.3.1 Condamine Connectivity Project

This project seeks to improve understanding of the hydrogeological relationships and potential for interconnectivity between the Condamine Alluvium (CA), the underlying Walloon Coal Measures (WCM) and other associated formations. Outputs from the project will improve the representation of the formations in future groundwater modelling that will support the revision of or the Surat UWIR in December 2015.

The project involves three parallel streams of investigations:

1. *Field investigations* that include both regional and local scale activities to acquire additional water pressure and hydrochemical data;

2. *Re-conceptualising* of the system by updating current datasets, synthesising the newly collected field investigation data and re-interpreting the primary and secondary data; and
3. *Sub-regional modelling and hypothesis testing* to test the significance of possible hydrogeological relationships between formations.

Progress and planned activities as at the end of 2013 is as follows.

Water level mapping of selected bores in the CA and WCM had been completed to identify as clearly as possible the current differences in water levels between the two formations across the CA footprint. The mapping together with hydrochemical analysis will provide information on the likely limits of hydraulic connectivity between the formations. A total of 130 bores were surveyed to support the water level mapping. Key additional water level data will be obtained from new monitoring bores scheduled for completion in early 2014.

Hydrochemical characterisation and multivariate analysis of some 3,000 existing hydrochemical data sets from bores in the CA footprint has been completed to interpret how water in the formations has evolved and the extent to which there has been past mixing of water between the formations.

Aquifer pump testing and associated drilling of observation and investigation bores is a major field component. This involves measuring the pressure response at multiple levels in the stratigraphic sequence to the pumping of water from one of the formations. Testing is planned for four sites that are representative of different hydrogeological settings. One test has been completed, the second test is due to commence before the end of 2013, and land access negotiations are in progress for the other two sites with a view to commencing drilling and testing in early 2014. In the process of constructing the observation bores, core is taken for laboratory testing.

All existing geological data is being reviewed to better understand the distribution of the low permeability material at the base of the CA and the top of the WCM. Work is in progress preparing detailed geological cross sections. The geological interpretation will be used to construct a local geological model to support hydrogeological re-conceptualisation of the sub-region.

Re-conceptualisation of the sub-region is ongoing and involves the bringing together of the outputs of the component sub-projects. The final re-conceptualisation will be used in the construction of a new regional groundwater flow model in 2015.

Collaboration with the major tenure holder in the area, Arrow Energy, is ongoing with regard to the carrying out of aquifer pump testing.

7.3.2 Walloon Coal Measures Connectivity Project

The objective of this project is to improve the understanding of aquifer connectivity between the WCM, the overlying Springbok Sandstone and the underlying Hutton Sandstone. As for the Condamine Connectivity Project, outputs will directly contribute to the regional re-conceptualisation of the groundwater system that will in turn underpin the preparation of the new regional groundwater flow model in 2015.

The project includes evaluation of:

- vertical hydraulic permeability of the aquitard material between the WCM and overlying and underlying aquifers;
- distribution and thickness of aquitard material across the study area, particularly in areas where the system is expected to be stressed;
- distribution and nature of geological structures such as faults and fractures; and
- external factors that could affect the flow of water, such as poorly constructed bores and wells.

As the area of the WCM within the area of significant long-term depressurisation is large (>30,000 km^2), investigations are targeted at both the regional and local scale. Regional scale investigations include: preparation of regional cross sections; mapping of aquitard thickness; geological modelling; hydrochemical characterisation of formations; and potentiometric surface mapping. At a local scale, three investigation areas have been selected for detailed assessment and field investigations. These areas were selected based on data needs, availability of existing information and current investigations by tenure holders. Progress and planned activities as at the end of 2013 is as follows.

The literature is being progressively reviewed to identify relevant case studies that provide insight and learning that could be relevant to the project.

Cross sections have been developed for the region and the three local scale investigation areas. Private water bore data in the three investigation areas has been reviewed and bores for water level and hydrochemical sampling have been selected and collection of field data has commenced. Data from groundwater monitoring bores installed by tenure holders as part of the regional groundwater monitoring network will also be included in the analysis.

Core samples have been obtained from tenure holders for centrifuge permeameter testing and quartz helium analysis to provide data on the hydraulic characteristics of lithologic materials. Six samples have been forwarded to the University of New South Wales for centrifuge permeameter testing. The usefulness of applying the quartz helium method is being assessed in consultation with CSIRO.

Hydrochemical characterisation of aquifers overlying and underlying the WCM together with a multivariate analysis of hydrochemistry data is in progress across the region. New data will be added to the analysis as it becomes available. This will be used to identify past mixing and improve baseline information for future investigations.

Collaboration is ongoing with research organisations (CSIRO, Geoscience Australia and universities) and tenure holders (QGC, Origin and Santos) regarding their approach to interconnectivity studies and the availability of their data for integration into OGIA's project.

7.3.3 Geological Modelling Project

The objective of this project is to develop a new geological model for the Surat and Bowen Basins in the Surat CMA that incorporates recent data. The model will underpin the re-

conceptualisation of the groundwater system and subsequent development of a new regional groundwater flow model.

The geological model used for groundwater flow modelling at the time of development of the UWIR was based primarily on secondary data (i.e. interpreted data) with limited use of primary data. Also, that geological model did not explicitly represent geological structures such as faults. The revised geological model under the current project will incorporate new information generated since the preparation of UWIR and will also include outcomes from the interpretation of primary well and bore data.

OGIA has established a collaborative team with the School of Earth Sciences at the University of Queensland to construct the regional geological model. A preliminary version of the model has been constructed using an existing geological model which has been updated with new stratigraphic interpretations and fault data from Geoscience Australia. Development work is in progress.

The regional geological model area is divided into sub-regions for prioritisation of development. Prioritisation by sub-region will facilitate robust correlation across the region and coordination with related connectivity projects and spring hydrogeology projects being carried out by OGIA.

Interpretation and correlation of geophysical wireline log data from wells and bores is a key aspect of model development. Wireline data from a total of approximately 3,100 wells have been processed. Sequence stratigraphy and facies schemes have been developed and are being used to constrain the geometry and lithology of the geological model.

7.3.4 Groundwater Modelling Methodology Project

The objective of this project is to develop improved methodologies for the modelling of regional groundwater impacts caused by CSG water extraction in coal seams and surrounding aquifers. Outputs from the project will guide the development of the next regional groundwater flow model which will be constructed to support the revision of the UWIR in December 2015.

In developing the current groundwater flow model, a number of aspects of the methodology used were identified for investigation before the development for the next model. These include: improved representation of dual phase flow; the optimal scale for modelling complex geological formations; and better representation of local scale processes and multiple realisations. The project involves identifying and testing methodology options that can provide improvements in these areas.

OGIA has established a project team that includes collaboration with research agencies (Flinders University, CSIRO) and tenure holders (QGC and Arrow Energy). The collaboration seeks to ensure that the methodologies applied in both the hydrogeology and petroleum reservoir management sectors are fully considered.

Work is progressing on researching modelling platforms, testing the differences between the platforms, and developing modifications to meet project needs. The platforms under assessment are ECLIPSE which is used in the petroleum industry to model fluid behaviour in reservoirs, and MODFLOW-USG an updated version of the platform used to construct the current OGIA groundwater model.

The expectation is that the methodology developed will become best practice for the modelling of groundwater behaviour in aquifers affected by water extraction from gas reservoirs.

7.3.5 Geological Structures Project

The objective of this project is to better understand the influence of geological structures on regional groundwater flow dynamics. Outputs from the project will be used in the development of the groundwater flow model that supports revision of the UWIR in December 2015.

The project will draw upon existing information and employ a variety of techniques aimed at identifying and assessing new geological structures as well as assessing current structural mapping and its potential influence on groundwater flow.

The initial phase of the project will involve updating the mapping of geological structures and a preliminary assessment of inferred hydraulic characteristics of those structures. Outputs will contribute to the development of the new groundwater model and may also be used to design detailed field investigations to be carried out in the longer term.

OGIA has consulted with Geoscience Australia in planning the project and is seeking a collaborative relationship for delivery of the project. The project is expected to commence in early 2014.

7.3.6 Spring Function and Monitoring Methodology Project

Understanding spring function

It is not only changes to water pressure in a source aquifer that determines if a spring will be affected by changes in groundwater pressure. The nature of how a spring has formed and how it is connected to the source aquifer will affect the susceptibility of a spring to a change in water pressure in the source aquifer. The objective of this project is to improve the local scale hydrogeological understanding of spring function to improve understanding of the risk to springs.

The literature on conceptual spring models has been reviewed to identify key spring processes. A framework for the hydrogeological conceptualisation of springs in the CMA has been developed as well as techniques to analyse individual springs in relation to the framework. A desktop hydrogeological assessment has been completed for five representative sites using the framework, resulting in identification of the multiple possible hydrogeological conceptualisations for spring function at each site. A field program for the sites has been prepared to collect the data needed to identify the most appropriate sites of the possible conceptualisations.

The field program will commence in early 2014. It includes: bore water level and elevation surveys; spring and water bore sampling for chemical analysis; local geological mapping and geophysical investigations. At some sites, investigation bores are proposed. Following the completion of the field program and conceptualisation of the five representative springs, the relevance for risk assessment of springs will be reviewed. Outcomes will form the basis for review of the Spring Impact Management Strategy (SIMS) when the UWIR is revised in late 2015.

Reviewing the approach to spring monitoring

The UWIR includes a spring monitoring program. The objective of the spring monitoring program is to establish an understanding of the natural variability in spring flow associated with seasonal and other factors, so that any changes in spring flow resulting from changes in water pressure in the source aquifer can be identified. The spring monitoring data will be used in conjunction with water pressure monitoring data collected under the UWIR water monitoring strategy.

The UWIR specifies the monitoring methodology to be used. However, new methodologies are emerging that may have application for monitoring springs in the CMA. Within this context, the objective of the project is to identify and test emerging monitoring methodologies.

A literature review has been carried out. The outcomes provided the basis for a workshop for national experts to identify the most applicable methodologies for field testing in the CMA. Based on the outcomes from the workshop, OGIA is developing a field testing program. The field testing will commence in 2014 and operate over several years.

7.3.7 Other projects

Water level mapping and aquifer parameter characterisation

The objective of this project is to develop groundwater pressure surfaces across all aquifers in the CMA and characterise aquifer properties based on existing data. The project has linkages to the connectivity projects. The water pressure mapping will assist in the calibration of the new regional groundwater flow model. The data will also assist in the initial setting of hydraulic parameters of the geological formations in the new regional groundwater flow model.

A literature review has identified all data sources and emerging techniques for water level mapping in multilayered, deep, variable density and variable temperature groundwater systems. An approach to mapping has been developed and all necessary data is currently being compiled.

Groundwater recharge

The rate of recharge is an important component of the groundwater flow system. Rather than commencing a project to improve estimation of recharge rates, OGIA is collaborating with the Centre for Coal Seam Gas (CCSG) at University of Queensland in relation to a project that it is currently progressing.

The project will focus on recharge rates for geological formations other than the Hutton and Hooray Sandstones, which have been previously investigated. The project will assess the significance for recharge rates of surface water bodies and geographic settings such as hill-slopes, plateaus and mountain front. Work has commenced and preliminary outputs are expected to be available in mid to late 2014.

For enquiries:

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