CSIRO GISERA – Aquifer Managed Recharge using CSG Produced Water'

Box 1 **Case Study summary**

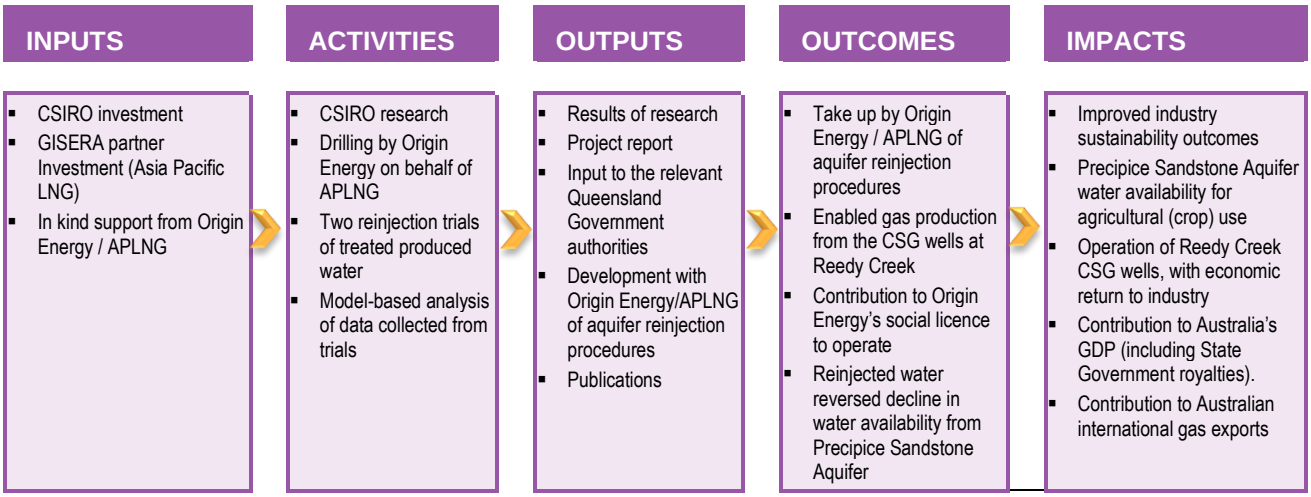
Key findings

- Key finding 1: Through its research for this project, CSIRO has developed a valuable approach to help neutralise the impacts of coal seam gas extraction on water resources and allow expanded beneficial use of coal seam gas (CSG) water for the wider community
- Key finding 2: Without reinjection, Origin Energy would have had to implement a more expensive water management scheme in order to draw CSG from the Reedy Creek wells
- Key finding 3: Without the CSIRO GISERA Aquifer managed recharge project it is possible that delays in gas production would have occurred.
- Key finding 4: The project has provided credible research and publicly available scientific knowledge to underpin decision-making in relation to the operation of CSG wells at Reedy Creek and other comparable locations and for the gas industry more widely.

Source: ACIL Allen Consulting

This case study uses the evaluation framework outlined in the CSIRO Impact Evaluation Guide. The results of applying that framework to a case study of aquifer managed recharge through the use of coal seam gas produced water are summarised in Figure 1. While aquifer managed recharge from CSG produced water has been achieved elsewhere (e.g. Powder River, Wyoming, USA), this was the first environmental analysis of aquifer reinjection which considered long-term sustainability of the water resource.

Figure 1 **CSIRO Case Study Geochemical response to reinjection–Impact Framework Diagram**



Source: ACIL Allen

1.1 Background

1.1.1 Purpose and audience for case study

This case study describes the benefits arising from the CSIRO GISERA project that provided the evidence base for safe and sustainable reinjection of treated Coal Seam Gas (CSG) water into an aquifer in the Surat Basin. The project has preceded the planned reinjection of approximately 80 megalitres per year of treated CSG produced water by Origin Energy. This water resource will then be available for future agricultural use such as crop irrigation.

The purpose of this document is to assess the positive impacts arising from this project. This case study can be read as a standalone report or aggregated with other case studies to substantiate the impact and value of GISERA projects as a whole, relative to the funds invested.

The information in this case study is provided for accountability, communication and continual improvement purposes. Audiences for this report may include Members of Parliament, Government departments, the GISERA partners, CSIRO and the general public.

1.1.2 Project origins and inputs

Coal seam gas production can require the management of large quantities of brackish water, called 'produced water', that is extracted with the gas. Queensland regulation require this water to be treated before it is released into the environment. It can then be discharged into rivers and dams, provided to nearby farmers or reinjected into aquifers as part of an aquifer managed recharge scheme. This last option is appropriate when other options are unable to continuously manage the volumes of 'produced water' from CSG wells allowing this water resource to be used at a later time without evaporation consequences.

Reinjection of this water contributes to the long-term sustainability of the industry through generating benefits for agriculture. However, despite extensive water treatment, there is, depending on local conditions, a possibility that the reinjected water may react with minerals in the aquifer, allowing for mobilisation of metals and / or metalloids. For this reason, a detailed understanding of the geochemistry associated with aquifer reinjection is necessary to predict and manage water quality and risks for the receiving aquifers.

The Surat Basin is now the major source of CSG in Queensland. In 2015-16 production from the Surat Basin was over 22 billion cubic meters, more than four times that of the Bowen Basin. Also in 2015-16, Queensland's 5127 CSG wells reported producing 60,499 megalitres of associated water.[1] The present project is the first of its kind to examine the potential for using aquifer managed recharge methods in generating sustainable outcomes for produced CSG water in the Surat Basin.

Planning for this project started in 2009-10. From the start, Origin Energy, a partner in Asia Pacific LNG (APLNG), had a strong collaborative relationship with the CSIRO GISERA team throughout this project. State and Federal environmental approvals required aquifer injection trials to be undertaken. By proving technical and economic feasibility, operational injection was able to be considered as part of the suite of CSG water management options.

CSIRO was able to draw on its previous research on using highly treated wastewater for recharging deep aquifers in Western Australia. The project took place over a four-year period in which CSIRO undertook research, with Origin Energy performing all necessary field work, including drilling. An Origin staff member describes this work as "collaborative and inclusive". This project was financed by the GISERA partners and CSIRO (see **Table .1**).

Table .1 SUPPORT FOR THE PROJECT

Contributor / type of support	2011-12 ($)	2012-13 ($)	2013-14 ($)	2014-14 ($)	Total ($)
Cash					
Asia Pacific LNG	120,264	305,689	279,041		704,994
In-kind					
CSIRO	11,600	18,466	76,422	69,760	176,248
Total					**881,242**

1.2 Project activities

CSIRO undertook the work for the site known as Reedy Creek. This included:

[1] Queensland Department of Natural resources and Mines 2017, Queensland's petroleum and coal seam gas 2015-16

- Geochemical and mineralogical characterisation of the Precipice Sandstone Aquifer
- Experimental determination of the reactivity of the aquifer material
- Examination of factors that influence adsorption (and thus the mobility) of arsenic in the Precipice Sandstone Aquifer
- Development of a computer model able to predict the adsorption of arsenic within the range of encountered geochemical conditions, and
- Model-based analysis of the injection trials
- Predictive modelling of the long-term risks and testing of possible mitigation strategies

The information gained from these studies has been used to provide practical advice on how best to manage the very low levels of arsenic resulting from the reinjection of produced water at this site.

1.3 Project outputs

The outputs from this project have been:

- Data on the geological and geochemical characteristics at the Precipice Sandstone aquifer at the Reedy Creek site
- Discovery of low levels of arsenic as a result of injecting alkaline water and higher levels of arsenic as a result of injecting oxygenated water
- Development of a model which can predict the fate of arsenic under temporally and spatially varying geochemical conditions, and
- Identification of an optimal strategy for ensuring that the levels of arsenic in Precipice Sandstone aquifer water are within appropriate limits.
- Scientific knowledge and know-how associated with the reinjection of treated CSG produced water into the Precipice Sandstone Aquifer.

Specifically, the research project found that by removing oxygen in the treated produced water and lowering the pH (i.e. slightly acidifying it), it was possible to effectively eliminate the risk of arsenic mobilisation resulting from reinjection into the Precipice Sandstone Aquifer.

Publications

Some of the publications associated with this project are listed below.

- Wallis I, Moore C, Post V, Wolf L, Martens E and Prommer H 2014, *Using predictive uncertainty analysis to optimise tracer test design and data acquisition*, Journal of Hydrology 515, 191-204.
- Prommer H, Rathi B, Donn M, Siade A, Wendling L, Martens E and Patterson B 2016, *Geochemical response to Reinjection*, Final Report, CSIRO Australia.
- Rathi B, Siade A, Donn MJ, Helm L, Morris R, Davis JA, and Prommer H 2017, *Multiscale characterization and quantification of arsenic mobilization and attenuation during injection of treated coal seam gas coproduced water into deep aquifers*, Water Resources Research 53, 10.1002/2017WR021240.
- Siade, A., Rathi, B., Prommer, H., Welter, and Doherty, J. 2018, *A Model-Independent, Constrained Multi-Objective Optimization Tool – Applications in Quantifying Predictive Uncertainty using Groundwater Flow and Reactive Transport Models* (submitted to Environmental Modelling and Software)

1.4 Status of Outcomes and Impacts

1.4.1 Nature of Outcomes and Impacts

This project has undertaken independent, credible research, providing publicly available, high quality scientific information to underpin decision making in relation to the Reedy Creek CSG wells. In doing so, it has maximised benefits (particularly environmental benefits) and helped Origin Energy to minimise costs associated with aquifer managed recharge using CSG produced water. It has improved the sustainability of the Precipice Sandstone Aquifer. The deep reinjection of treated CSG produced water at Reedy Creek has banked large volumes of water for later agricultural use (e.g. through crop irrigation), and allowed expanded beneficial use of CSG water resources for the wider community.

More generally, the research undertaken has provided farmers, gas companies, governments and local communities with useful scientific knowledge and economic and environmental information regarding the disposal of produced water from the CSG industry. It has also informed state and federal government policy on gas exploration, regulation and production and informed industry best practice for all future aquifer managed recharge procedures.

This CSG produced water reinjection project has:

- Enabled the effective and sustainable operation of the Reedy Creek CSG operation
- Created, at the time, Australia's largest reinjection scheme
- Resulted in industry uptake of research findings and scientific know-how
- Enabled the Queensland Government authorisation of the injection scheme
- Addressed a potential arsenic pollution problem associated with the reinjection of CSG produced water
- Allowed safe indirect re-use of produced water from CSG operations at Reedy Creek by farmers for crop irrigation and other users of the Precipice Sandston Aquifer
- Provided confidence in the preservation of the groundwater asset in the Surat Basin by recharging a depleted aquifer with CSG produced water
- Contributed to successful development of the Commonwealth's Government's Domestic Gas Strategy and its implementation through the Domestic Gas Strategy Implementation Plan.

Figure 2 **APLNG Gas Processing Facility, Reedy Creek**

Source: Lang O'Rourke

1.4.2 Counterfactual

The project enabled the approval/authorisation of the scheme to proceed on schedule. Should the approval have been delayed, there may have been some impact to early field commissioning, although there were some contingency measures in place. The project gave confidence that, with appropriate treatment, arsenic concentrations would not degrade the environmental values of the aquifer water resource. It has also helped to generate and maintain the industry's social licence to operate in southern central Queensland. An Origin staff member commented that, in this project, they would have struggled without the help of CSIRO.

1.4.3 Attribution

ACIL Allen has attributed 50 per cent of project impacts to CSIRO, and 50 per cent to Origin Energy.

1.4.4 Adoption

The adoption by Origin Energy of the outputs of this project at Reedy Creek have enabled the injection of coal seam gas produced water at that site and the research outcomes provide a template for other, comparable injection sites throughout the Surat Basin by Origin Energy or other companies (currently four companies operate in the region).

While the specific issue of a low-level presence of arsenic in the produced water at Reedy Creek may be unique to that site, CSIRO has established the benefits of research that informs reinjection and the treatment of production water from CSG wells elsewhere. CSIRO has also demonstrated the value of process-based numerical modelling in cases of injection of produced water into deep aquifers. The project demonstrated the significant benefit of close collaboration between researchers and their industry colleagues.

1.5 Assessment of impacts

1.5.1 Impacts to date

The impacts started from 2015 when the Origin Energy injection scheme was commissioned and are expected to continue for the at least the 25-year life of the Reedy Creek/Combabula CSG field. The Reedy Creek injection scheme is currently the only water option implemented to manage the produced water from more than 2000 authorised CSG wells (currently approximately 580 wells operational), feeding 425TJ/day of gas processing facility capacity. At $6.50/GJ, this represents approximately $1billion per annum in revenue. The entire gas field is estimated to have a life of another thirty years.

1.5.2 Potential future impacts

As noted above, the impacts are expected to continue for the life of the gas field. The benefits are primarily environmental. The beneficiaries are local farmers, APLNG and the Queensland Government. Local farmers have access to the water resource from a recharged Precipice Aquifer. APLNG has addressed potential problems with the CSG operations at Reedy Creek and obtains revenue from selling the CSG. The Queensland Government is receives royalties.

1.5.3 Cost Benefit Analysis

It has not been possible to provide a cost benefit analysis for this project. There have been economic benefits, given that reinjection is less expensive than other alternatives. However it has not been possible to quantify these benefits.

1.6 References

GasFields Commission Queensland 2017, *One the Ground: Lessons from development of the world's first coal seam gas industry*, June 2017, Accessed on 21 December 2017 at http://www.gasfieldscommissionqld.org.au/resources/documents/Report%20Learnings_%20FINAL.PDF

Prommer, H 2017, *Can billions of litres of coal seam gas water be safely reinjected into the ground?* The Conversation, accessed on 22 November 2017 at https://theconversation.com/can-billions-of-litres-of-coal-seam-gas-water-be-safely-reinjected-into-the-ground-67634

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Office of Groundwater Impact Assessment 2016, *Underground Water Impact Report for the Surat Cumulative Management Area* accessed on 21 December 2017 at https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0007/345616/uwir-surat-basin-2016.pdf

ACIL Tasman 2012, *Economic significance of coal seam gas in Queensland (Final report)* accessed on 21 December 2017 at http://www.acilallen.com.au/cms_files/ACIL_CSG_Queensland_2012.pdf

Queensland Department of Environment and Heritage Protection 2012, *Coal Seam Gas Water Management Policy*, accessed on 21 December 2017 at https://www.ehp.qld.gov.au/management/non-mining/documents/csg-water-management-policy.pdf