Project Order, Variations and Research Progress

Project Title: Understanding and quantifying clogging and its management during re-injection of CSG water permeates, brines and blends

This document contains three sections. Click on the relevant section for more information.

1 Original Project Order

Research project plan

Proforma 2011

1. Short Project Title (less than 15 words)

Re-injection of CSG water

Long Project Title	Understanding and quantifying clogging and its management during re-injection of CSG water permeates, brines and blends
GISERA Project Number	W2 1114
Proposed Start Date	Dec 2011
Proposed End Date	June 2014
Project Leader	Peter Dillon

2. GISERA Research Program

- ☐ Biodiversity Research
- ☐ Marine Research
- ☐ Land Research
- ☒ Water Research
- ☐ Social & Economic Research

3. Research Leader, Title and Organisation

Peter Dillon, Stream Leader, Water Recycling and Diversified Supplies CSIRO Land and Water

4. Summary (less than 300 words)

Re-injection of CSG water permeate, brine or blends into overlying aquifers, underlying aquifers, and to the coal seams themselves on completion of mining, is a valuable approach to neutralise impacts of mining on water resources, to protect springs and

riverine ecosystems, and to allow new and expanded beneficial use of water resources for the wider community. Re-injection requires treatment of injectant to be compatible with the aquifer so as (a) not to clog injection wells and (b) to prevent adverse changes in water quality in the storage zone. The latter issue is addressed by a related proposal. Clogging of injection wells has been the single biggest cause of failure in aquifer storage and recovery (Pavelic and Dillon 1997). This project is aimed at (i) an advanced characterisation of the physical and hydraulic properties of aquifer material of aquifers targeted for re-injection (relying on the geochemical project for its part for the same samples), (ii) the development of appropriate laboratory experimental procedures that conform where possible to existing standard methods and using them to evaluate the potential for clogging with a range of agreed water types, (iii) the field evaluation of clogging using appropriate monitoring to evaluate reliability of lab prediction and to suggest alternative strategies for maintaining high hydraulic conductivity in the near well zone (iv) recommend design of a monitoring program for adoption at all reinjection sites to provide diagnostics in hydraulic conductivity changes in the near-well formation and to enable tracking of operational causes of these to improve redevelopment strategies, and to develop and, if possible, validate a conceptual/analytical model to forecast clogging to design diagnostics and operational procedures for broad application at reinjection sites.

5. Budget Summary (From Excel Budget Pack worksheet "Project Plan Summary")

Expenditure	2011/12 Year 2	2012/13 Year 3	2013/14 Year 4	2014/15 Year 5	Total
Labour	292,303	333,836	218,850	-	844,989
Operating	82,000	65,000	48,000	-	195,000
Total Costs	374,303	398,836	266,850	-	1,039,989
CSIRO	374,303	398,836	266,850	-	1,039,989
Total Expenditure	374,303	398,836	266,850	-	1,039,989

Expenditure per Task	2011/12 Year 2	2012/13 Year 3	2013/14 Year 4	2014/15 Year 5	Total
Task 1	374,303			-	374,303
Task 2		398,836			398,836
Task 3			133,425		133,425
Task 4			133,425		133,425
Task 5					
Total Expenditure	374,303	398,836	266,850		1,039,989

Cash Funds to Project Partners	2011/12 Year 2	2012/13 Year 3	2013/14 Year 4	2014/15 Year 5	Total
CSIRO	299,442	319,069	213,480		831,991
Sub Total	299,442	319,069	213,480		831,991
Total Cash to Partners	**299,442**	**319,069**	**213,480**		**831,991**

Source of Cash Contributions	2011/12 Year 2	2012/13 Year 3	2013/14 Year 4	2014/15 Year 5	Total
Australia Pacific LNG	299,442	319,069	213,480		831,991
Total Cash Contributions	**299,442**	**319,069**	**213,480**		**831,991**

In-Kind Contribution from Partners	2011/12 Year 2	2012/13 Year 3	2013/14 Year 4	2014/15 Year 5	Total
CSIRO	74,861	79,767	53,370	-	207,998
Total In-Kind Contribution from Partners	**74,861**	**79,767**	**53,370**	**-**	**207,998**

	Total funding over all years	Percentage of Total Budget
Australia Pacific LNG Investment	831,991	80%
CSIRO Investment	207,998	20%
Total Other Investment		
TOTAL	**1,039,989**	**100%**

Task	Milestone Number	Milestone Description	Funded by	Participant Recipient	Start Date (mm-yy)	Delivery Date (mm-yy)	Fiscal Year	Fiscal Quarter	Payment $
Task 1	1.1	Scoping meeting held. Research plan prepared to integrate with Australia Pacific LNG monitoring program. Laboratory study experimental set up detailed.	GISERA	CSIRO	Dec 11	June-12	2011/12	Quarter 4	$ 374,303
Task 2	2.1	Report on lab study and new methods, liaise on design of monitoring program for trials	GISERA	CSIRO	Feb 12	Mar-2013	2012/13	Quarter 3	$ 398,836
Task 3	3.1	Report on development of model to predict clogging. Field trial undertaken by Australia Pacific LNG at single well with several water qualities	GISERA	CSIRO	Mar 12	Dec-13	2013/14	Quarter 2	$ 133,425
Task 4	4.1	Collate trial results, validate clogging predictions at trial site in final report, workshop including diagnostics training, and journal papers. Prepare proposal for broad-scale validation at multiple sites with water quality options.	GISERA	CSIRO	Sep 13	Jun-14	2013/14	Quarter 4	$ 133,425

6. Other Researchers (include organisations)

Researcher	Time Commitment (whole of project)	Principle area of expertise	Years of experience	Organization
Dr Peter Dillon	0.25 FTE	MAR	36	CSIRO
Konrad Miontlinski	0.25 FTE	Hydrogeology, geochemistry.	6	CSIRO
Karen Barry	0.50 FTE	Field and lab methods in hydrogeology	20	CSIRO
Senior Researcher	1.30 FTE	Hydraulic characterisation of aquifers	?	CSIRO
Gupta Gregg	0.20 FTE	Microbial ecology	20	CSIRO
Dr Joanne Vanderzalm	0.12 FTE	Geochemistry in MAR	12	CSIRO
Dr Leif Wolf	0.20 FTE	Model conceptualisation, integration with GISERA water research activities, project management	12	CSIRO
Unknown Admin Assistant	0.13 FTE	Administration	?	CSIRO

7. GISERA Objectives Addressed

Research that improves and extends knowledge of environmental impacts and opportunities of CSG-LNG projects, enabling the CSG-LNG industry to better meet the expectations of relevant communities and the broader public.

Informing government, regulators and policy-makers on key issues regarding policy and legislative framework for the CSG-LNG industry.

8. Program Outcomes Achieved

Outcomes of this project include an assessment of clogging potential at the pilot site accounting for water quality and redevelopment strategy; validation of this by field measurements during the injection trial; a conceptual model to predict clogging behaviour for waters and aquifers of interest to CSG industry; diagnostics for reinjection well clogging, a conceptual model for clogging in relation to source water and aquifer characteristics; and validation and refinement of that model based on operational experience observed at a number of reinjection wells.

9. Program Outputs Achieved

Details are provided in *section 13. Project Objectives and Outputs*

10. What is the knowledge gap that these research outputs will address?

Research outputs will help with selecting economic treatment methods that will sustain re-injection. In so doing they will:

- identify water quality requirements to manage clogging of re-injection wells
- develop methods to characterise aquifers for clogging potential
- develop models using lab and field data to build confidence in management of clogging.

11. How will these Research outputs and outcomes be used in State Government and other water managers to achieve Adaptive Management of Water Resources?

The research outputs and outcomes provide assurance of the technical and economic ability to re-inject with minimum greenhouse emissions. Without assurance of re-injection longevity this practice cannot be relied on to replenish depleted groundwater resources.

12. Project Development (1 page max.)

This project was developed in consultation with Australia Pacific LNG staff. Since this project was proposed the Department of Environment and Resource Management (DERM) has indicated that re-injection is their preferred water management strategy. However a key barrier to re-injection is clogging, which we understand from our experience to be a manageable process. However there is no reliable model for predicting clogging. Such a model needs to be based on a sound characterisation of the aquifer and source water and an understanding of physical, chemical and biological clogging and unclogging processes. The additional complication of working with fractured hard rock requires new characterisation methods to be developed. The focus will be on establishing laboratory methods and models, with field validation occurring opportunistically in accordance with Australia Pacific LNG's evolving work program. A sequel project will be needed to implement validation of the methodology and model over a large number of sites and water compositions.

13. Project Objectives and Outputs

Project objectives and outputs include:

- Preliminary predictions of clogging for different waters at pilot re-injection site
- Evaluation of prediction methodology
- Tested diagnostics for clogging at pilot re-injection site
- Australia Pacific LNG staff trained to use the newly developed model for sites similar to that tested.

Even a small percentage improvement in hydraulic conductivity of the immediate vicinity of the re-injection well will result in significant reductions in energy requirements and green-house gas emissions over a project's life. The project will contribute to an operational strategy for maintenance of near-well hydraulic conductivity that minimises costs of injection including the cost of water treatment, pumping, redevelopment operations and the depreciation costs of premature well 'aging'.

14. Project Plan

14.1. Project Schedule

ID	Task Title	Task Leader	Scheduled Start	Scheduled Finish	Predecessor
1	Scoping meeting and research plan	Peter Dillon	Dec 11	June-12	-
2	Lab study aquifer hydraulic characterisation	Saeed Torkzaban	Feb 12	Mar-2013	1
3	Model development and field trial	Saeed Torkzaban	Mar 12	Dec-13	1, 2 part
4	Results, training, papers and proposal	Saeed Torkzaban	Sep 13	Jun-14	2, 3 part

14.2. Task Name
See section 14.1. *Project Schedule*

14.3. Task Leader
See section 14.1. *Project Schedule.*

14.4. Overall Timeframe
See section 14.1. *Project Schedule.*

14.5. Background
See section 10 to 12.

14.6. Task Objectives

Task 1. Establish research plan and coordinate with current activities to maximise research opportunities generated by the current work program.

Task 2. Develop laboratory measurement methods to establish hydraulic conductivity changes in core materials due to using re-injection water of different qualities. This needs to account for secondary porosity and confining pressures.

Task 3. Develop a conceptual model of clogging and unclogging in injection wells accounting for physical, chemical and biological processes. This will take account of literature and experience in MAR, secondary recovery in oil drilling, brine disposal and water filtration treatments. Apply the model to laboratory studies (in Task 2).

Task 4. Apply the model to an appropriately monitored field injection trial to assess performance of the model in predicting clogging and unclogging of the injection well, ideally with water of different qualities. Provide training to Australia Pacific LNG staff in use of the model and data requirements.

14.7. Task Outputs

Task 1. Report on aquifers that were selected for testing, likely candidate for field testing of injection, and an outline of the proposed lab test methodology.

Task 2. Report on aquifer core hydraulic testing giving comparisons with traditional tests and field data (pumping tests, down-hole flow meter and geophysical logs) and discussion on how to deal with dual porosity in a systematic framework.

Task 3. Report that includes a literature review, basis for model, model description and its ability to predict at core scale. The report will also include description of injection trials undertaken, which provides field data on near-well permeability declines and increases.

Task 4. Report on application of model to field trial with at least two water qualities. Other outputs include two journal papers on methodology and model, training materials for Australia Pacific LNG and documented progress meetings with the project reference panel each year.

14.8. Specific Deliverables

See section 14.7. *Task Outputs*.

14.9. Progress Report

Task 1. Regular meetings with representatives of APLNG were held and the lab experimental program to establish research priorities (sites/ aquifers/ waters) was discussed and agreed upon. CSIRO liaised with APLNG on the design of monitoring program for trials and CSIRO will be briefed on progress with the injection trials.

Task 2. An experimental setup has been designed and developed to systematically study the various mechanisms of well clogging and to test a range of parameters such as water quality, sediment mineralogy, and flow rate. The lab experiments were delayed until all the facilities such as core holder, pump, pressure transmitters were delivered and set up. Meanwhile, several initial experiments were undertaken at the department of petroleum engineering of the University of Adelaide. Observations suggest that the potential for clogging due to clay mobilization is very significant. More experiments are planned and will commence in March.

15. Budget Justification

The budget for this project has been approved by GISERA's Research Advisory Committee and Management Committee.

16. Project Governance

A project reference panel will be established. Twice a year, project meetings with Australia Pacific LNG and CSIRO staff will be held. Once a year, the project reference panel will be consulted. Modifications of the work plan may be discussed at these meetings.

Progress against milestones and tasks will be assessed twice a year within project meetings and reported in the minutes of these meetings. Beyond that, standard procedures defined in the overall GISERA management framework will be applied.

Users of the research output will be involved via the project reference panel.

17. Communications Plan

General communication will be managed by GISERA.

The pathway to impact for this project includes:

- This project is carried out in collaboration with Australia Pacific LNG experts who currently conduct injection trials, and the project has already led to improvements in the design of monitoring program for Australia Pacific LNG's injection trial. Therefore the work is directly informing existing industry trials and is building industry science capacity.
- The results from the modelling, laboratory studies, and injection trials will help with selecting economically feasible treatment methods that will sustain reinjection. Developed models verified with lab and field data will provide methods to characterise aquifers for clogging potential.
- The research undertaken in this project will provide assurance of technical and economic ability to re-inject with minimum greenhouse emissions. Even a small percentage improvement in hydraulic conductivity of the immediate vicinity of the reinjection well will result in significant reductions in energy requirements and greenhouse gas emissions over a project's life. The project will contribute to an operational strategy for maintenance of near-well hydraulic conductivity that minimises costs of injection including the cost of water treatment, pumping, redevelopment operations and the depreciation costs of premature well aging.
- The research will provide the water quality requirements to build confidence in management of clogging. As a result, the pre-treatment of the injectant will be optimized to decrease the energy demands of pre-treatment. Information enabling this to occur will be provided by the direct involvement of industry stakeholders in the project and, there will be public access to published research results.
- Direct technical cooperation with the industry experts in the planning of the laboratory experiments, the collection of field data and the analysis of the modelling results ensures effective knowledge transfer. Australia Pacific LNG experts will be trained to use any newly developed model for sites similar to that tested.
- The openly published project reports will provide information on the spatial and temporal extent to which well clogging will have an impact on water injection. Existing relationships with the regulator will be used to ensure that they are kept informed of project results as the project progresses.
- For broader public benefit, stakeholder workshops with government agencies, interested communities and GISERA representatives will be organised.
- The results will be disseminated at national and international conferences as well as a number of peer reviewed journal papers.
- A PhD student supported by the National Centre for Groundwater Research and Training (NCGRT) has been included in the work program to allow for direct capacity

building. The lead researcher in the project, Dr. Saeed Torkzaban will supervise the student to study modelling of clogging processes.

18. Risks

The new senior hydrologist position has been advertised but not yet closed. Rate of progress will depend on the timing at which a suitable appointment can be made. Therefore a potential risk a delay in delivery for this project.

19. Intellectual Property and Confidentiality

Background IP (clause 10.1, 10.2)	**Party**	**Description of Background IP**	**Restrictions on use (if any)**	**Value**
	CSIRO	Extensive knowhow on clogging, its measurement and management in ASR systems, through laboratory and field-based methods.	No. This is all in the public domain, or will be as relevant journal papers are produced.	
	Australia Pacific LNG	Knowhow on construction of CSG wells and reinjection wells. Knowhow on geophysical logging, pumping tests, water quality sampling and monitoring specific to CSG sites. Knowhow on operating a water treatment plant for CSG associated water prior to well reinjection.		
Ownership of Non-Derivative IP (clause 11.3)	According to the GISERA head agreement			
Confidentiality of Project Results (clause 15.6)	Project results are not confidential. It is a requirement of CSIRO in undertaking this project that work undertaken by CSIRO is to be published in peer reviewed journals and in conferences. CSIRO is to acknowledge contributions of partners through co-authorship where appropriate, and acknowledge funders of the project as is standard practice.			

2 Variations to Project Order

Progress against milestones are approved by the GISERA Director, acting with authority provided by the GISERA National Research Management Committee, in accordance with the National GISERA Alliance Agreement.

The table below details variations to research Project Order.

Register of changes to Research Project Order

Date	Issue	Action	Authorisation
19/04/13	Research project start date delayed; milestone dates require rescheduling	Milestone dates for tasks 3 and 4 rescheduled to reflect later project start date; timing of milestones relative to start date not altered.	Peter Stone
05/03/15	Additional experiments will be run 1) Investigating the couple effect of chemical and velocity on clogging and 2) Demonstration and evaluation of a new environmentally friendly clay stabilizer. Following completion of these experiments, the team will model the results and complete the final report.	Milestone 4 will be pushed back to May 2015.	
25/06/15	To accommodate for revisions to be made to the final report, milestone 4 will be pushed back to 31 July 2015.	Milestone 4 will be pushed back to July 2015.	

3 Progress against project milestones

Changes to research Project Orders are approved by the GISERA Director, acting with authority provided by the GISERA National Research Management Committee, in accordance with the National GISERA Alliance Agreement.

Progress against project milestones/tasks is indicated by two methods: Traffic Light Reports and descriptive Project Schedule Reports.

1. Traffic light reports in the Project Schedule Table below show progress using a simple colour code:
   - Green:
     - Milestone fully met according to schedule.
     - Project is expected to continue to deliver according to plan.
     - Milestone payment is approved.
   - Amber:
     - Milestone largely met according to schedule.
     - Project has experienced delays or difficulties that will be overcome by next milestone, enabling project to return to delivery according to plan by next milestone.
     - Milestone payment approved for one amber light.
     - Milestone payment withheld for second of two successive amber lights; project review initiated and undertaken by GISERA Director.
   - Red:
     - Milestone not met according to schedule.
     - Problems in meeting milestone are likely to impact subsequent project delivery, such that revisions to project timing, scope or budget must be considered.
     - Milestone payment is withheld.
     - Project review initiated and undertaken by GISERA Research Advisory Committee.

2. Progress Schedule Reports outline task objectives and outputs and describe, in the 'progress report' section, the means and extent to which progress towards tasks has been made.

Project Schedule Table

ID	Task Title	Task Leader	Scheduled Start	Scheduled Finish	Predecessor
1	Scoping meeting and research plan	Peter Dillon	Dec-11	Jun-12	-
2	Lab study aquifer hydraulic characterisation	Saeed Torkzaban	Feb-12	Mar-13	1
3	Model development and field trial	Saeed Torkzaban	Oct-12	Jul-14	1, 2 part
4	Results, training, papers and proposal	Saeed Torkzaban	Apr-14	Jul-15	2, 3 part

GISERA Gas Industry Social & Environmental Research Alliance

Project Schedule Report

Task 1.

TASK NAME: Scoping meeting and research plan

TASK LEADER: Peter Dillon

OVERALL TIMEFRAME: Dec 2011 – June 2012

TASK OBJECTIVES: Establish research plan and coordinate with current activities to maximise research opportunities generated by the current work program.

SPECIFIC DELIVERABLE: Report on aquifers that were selected for testing, likely candidate for field testing of injection, and an outline of the proposed lab test methodology.

PROGRESS REPORT:

Regular meetings with representatives of Australia Pacific LNG were held and the lab experimental program to establish research priorities (sites/ aquifers/ waters) was discussed and agreed upon. A report of the literature review and laboratory methodology on clogging processes was produced and shared with Australia Pacific LNG. CSIRO liaised with Australia Pacific LNG on the design of monitoring program for trials and CSIRO will be briefed on progress with the injection trials.

Task 2.

TASK NAME: Lab study aquifer hydraulic characterisation

TASK LEADER: Saeed Torkzaban

OVERALL TIMEFRAME: Feb 2012 – March 2013

TASK OBJECTIVE: Develop laboratory measurement methods to establish hydraulic conductivity changes in core materials due to using re-injection water of different qualities. This needs to account for secondary porosity and confining pressures.

SPECIFIC DELIVERABLE: Report on aquifer core hydraulic testing giving comparisons with traditional tests and field data (pumping tests, down-hole flow meter and geophysical logs) and discussion on how to deal with dual porosity in a systematic framework.

PROGRESS REPORT:

An experimental setup has been designed and developed to systematically study the various mechanisms of well clogging and to test a range of parameters such as water quality, sediment mineralogy, and flow rate. The lab experiments were delayed until all the facilities such as core holder, pump, pressure transmitters were delivered and set up. Meanwhile, several initial experiments were undertaken at the department of petroleum engineering of the University of Adelaide. Observations suggest that the potential for clogging due to clay mobilization is very significant. More experiments are planned and will commence in March.

Task 3.

TASK NAME: Model development and field trial

TASK LEADER: Saeed Torkzaban

OVERALL TIMEFRAME: Oct 2012 – July 2014

CSIRO | Australia Pacific LNG | QGC A BG Group business | AGL Energy in action | origin | Santos We have the energy.

TASK OBJECTIVE: Develop a conceptual model of clogging and unclogging in injection wells accounting for physical, chemical and biological processes. This will take account of literature and experience in MAR, secondary recovery in oil drilling, brine disposal and water filtration treatments. Apply the model to laboratory studies (in Task 2).

SPECIFIC DELIVERABLE: Report that includes a literature review, basis for model, model description and its ability to predict at core scale. The report will also include description of injection trials undertaken, which provides field data on near-well permeability declines and increases.

PROGRESS REPORT:

Extensive laboratory experiments have been conducted to understand clogging and unclogging process due to the release and transport of in situ colloids (e.g. clay and silica particles) resulting from water injection with various chemical qualities into core samples from intended aquifer sites. A mathematical model was developed and employed to simulate colloid release, transport, retention at pore constrictions which may cause clogging and unclogging in injection wells. Comparison of the fitted and experimentally measured colloid release curves and the core permeability showed a good agreement, indicating that the essential physics of the problem was captured by the model. Our experimental and modelling results indicated that only a small fraction of colloid deposit on the grain surfaces contributed to colloid release at any given change in chemical and hydrodynamic conditions. The water-sensitivity of the core samples was found to depend on the presence of multivalent cations (Ca^{2+} and Mg^{2+}) in the native groundwater and the interlayer of clay minerals. It was also found that there exists a critical salt concentration (CSC) in the injecting water below which clay release and clogging may begin.
A draft report on clogging project progress was submitted to Origin Energy on 19 September 2014.

Task 4

TASK NAME: Results, training, papers and proposal

TASK LEADER: Saeed Torkzaban

OVERALL TIMEFRAME: April 2014 – July 2015

TASK OBJECTIVES: Apply the model to an appropriately monitored field injection trial to assess performance of the model in predicting clogging and unclogging of the injection well, ideally with water of different qualities. Provide training to Australia Pacific LNG staff in use of the model and data requirements.

TASK OUTPUTS: Report on application of model to field trial with at least two water qualities. Other outputs include two journal papers on methodology and model, training materials for Australia Pacific LNG and documented progress meetings with the project reference panel each year.

PROGRESS REPORT:

This milestone is 100% complete.
The final report on the laboratory experiments, modelling study, a guideline for the field application for assessing the clogging potential during re-injection of CSG associated water has been completed and available for viewing on the GISERA website Understanding and quantifying clogging and its management during re- injection of CSG water permeates, brines and blends.