Project Order

Proforma 2018

1. Short Project Title

Onshore gas and water contamination: causes, pathways and risks

Long Project Title	Onshore gas water quality impacts for southeast SA: Groundwater contamination pathways, vulnerability and modelling analysis
GISERA Project Number	W.13
Proposed Start Date	1 July 2018
Proposed End Date	30 June 2020
Project Leader	Sreekanth Janardhanan

2. GISERA Region

- ☐ Queensland
- ☐ New South Wales
- ☐ Northern Territory
- ☒ **South Australia**
- ☐ Western Australia
- ☐ Victoria

3. GISERA Research Program

- ☒ **Water Research**
- ☐ GHG Research
- ☐ Social & Economic Research
- ☐ Biodiversity Research
- ☐ Agricultural Land Management Research
- ☐ Health Research

4. Project Summary

Objectives

The risk of contaminants from onshore gas activities and sources migrating to groundwater resources and groundwater dependent receptors depends on the likelihood of the confluence of three core events: contamination events (source activation); the presence of a causal pathway; and the susceptibility of water sources and receptors to be impacted by such events. This study has formed three objectives around better understanding these events to achieve a realistic quantification of groundwater contamination risks in gas development areas of southeast SA:

1) Identification of causal pathways and risk factors associated with onshore gas activities that can result in potential contamination events (source and pathway index) by taking into consideration regulatory controls and industry best practice for realistic quantification of residual risks
2) Relative assessment of the vulnerability of water resources (groundwater aquifers, SW resources connected to groundwater and wetlands) and water dependent receptors to contamination risks using spatial modelling techniques considering several confounding factors like depth to water table, recharge, soil properties, aquifer properties and slope (receptor vulnerability index)
3) Provide realistic estimates of the likelihood of contaminants migrating and reaching valuable economic and environmental receptors in onshore gas development areas for combinations of a high source and pathway index and a high vulnerability index using probabilistic modelling and uncertainty analysis.

Description

There are several activities and causal pathways associated with the onshore gas development that can lead to water contamination risks. SA EPA[1] (2014), based on stakeholder consultations, have identified onshore gas as a water quality hazard in the Penola area.Recent CSIRO research (Mallants et al., 2017a[2], b[3]) have identified two broad categories of contamination migration pathways. These are: 1) pathways related to

[1] SA EPA (2014) South East Regional Groundwater Quality Monitoring, Evaluation and Reporting Program, Environment Protection Authority, 21st Oct, 2014

[2] Mallants D, Bekele E, Schmid W and Miotlinski K 2017, *Human and environmental exposure conceptualisation: Soil to shallow groundwater pathways*, Project report prepared by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) as part of the National Assessment of Chemicals Associated with Coal Seam Gas Extraction in Australia, Commonwealth of Australia, Canberra.

[3] Mallants D, Apte S, Kear J, Turnadge C, Janardhanan S, Gonzalez D, Williams M, Chen Z, Kookana R, Taylor A, Raiber M, Adams M, Bruce J, Prommer H 2017, *Deeper groundwater hazard screening research*, prepared by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Canberra.

surface handling of drilling fluids including surface pathways (surface runoff), soil and shallow groundwater pathways and 2) pathways related to drilling itself involving deeper groundwater pathways.

The contamination events resulting from these two categories can include accidental or flood-induced surface spillage of contaminants, vertical leakage of poor quality water from holding ponds, loss of drilling fluids in groundwater formations during drilling, migration of groundwater and dissolved chemicals through leaky wells, poor-integrity water bores, leaks in underground seals, natural or reactivated faults, and migration of geogenic contaminants up a poor-integrity wellbore. Depending on the nature of causal pathways of contamination from the onshore gas activities, this study will establish appropriate spatial and process modelling tools for evaluating the likelihood of potential contamination of water resources and receptors associated with the likely causal pathways in chosen areas of southeast SA where onshore gas activity is currently existing or planned in the near future.

Methodology

The first major activity in the proposed study is identification and conceptualization of contamination sources and pathways and characterization of groundwater vulnerability in the gas development areas of southeast SA to produce a realistic assessment of contamination risks in the areas of proposed/existing gas development. SA EPA (2014) have identified areas of petroleum exploration and development and are developing groundwater monitoring programs for these areas.

In this first activity we identify the relative risks of groundwater contamination based on two risk factors a) the likelihood of the presence of contaminant source and causal pathway, and b) the relative vulnerability of the water source and receptors to contamination. Combining these risk factors leads to a more realistic characterisation of the level of risk of contamination (e.g., high or low). It can be viewed much like the Swiss Cheese analogy where risks are determined by defence mechanisms stacked side by side, in which the risk of a hazard becoming a reality is mitigated by the differing layers and types of defences. A high likelihood of a causal pathway may exist around a storage pond (source) near a gas well field. While the likelihood of activation of causal pathway is high at this location, the actual classification of groundwater contamination risk into high or low depends also on the presence of confounding factors such as a shallow groundwater system and a conductive vadose zone at this location that determine the magnitude or the impact (consequence).

The second major activity builds on the first one, by simulation of travel paths, travel times and distances using a numerical groundwater flow and advective transport model. The travel paths, times and distances will be simulated for a very long time (e.g. 10,000 years) to investigate the likelihood of contaminant particles reaching risk receptors. The model simulation analysis will adopt probabilistic methods that help quantify the uncertainties and enables the estimation of potential impacts with a high degree of confidence. The fate of likely contaminants as they travel through these pathways to the receptors will be evaluated by accounting for their dilution and attenuation characteristics. These activities will build on existing knowledge generated by recent studies. A brief description of specific tasks associated with these two activities is provided in the following sub-sections with specific deliverables detailed in Section 7.

Causal pathways workshop and scenario development

Previous related studies have applied risk-based approaches to assess the relative likelihood of water contamination causal pathways from onshore gas activities (Mallants et al.[1], 2017a, b; NCGRT[4], 2016; Jacobs[5], 2016). SA Environmental Protection Authority (EPA) is responsible for protection of water quality and have established groundwater quality monitoring evaluation and reporting program for the South East NRM region (SA EPA[6], 2014). Jacobs (2016) undertook a hydrogeological risk assessment for the southeast SA. They identified the relative likelihood of contamination pathways that could be activated in onshore gas development areas. The NCGRT (2016) study identified that infiltration from surface spills has the greatest risk for groundwater contamination. Similarly, Jacobs (2016) associated highest risk ratings with the potential spill of surface contaminants migrating to the Tertiary Unconfined Aquifer. These studies will be critically reviewed with their findings potentially adopted, where appropriate, during this work specially to prioritize the selection of causal pathways and scenarios to be modelled. A ½ - 1-day workshop will be conducted to assimilate and synthesise the knowledge from past studies to bring together multi-disciplinary expertise and create conceptual models for plausible causal pathways for contamination.

Scenarios will be developed and prioritized based on residual risks (versus inherent risks). Characterization of residual risks will be undertaken after taking into consideration the SA state regulatory controls of onshore gas activities, and associated industry standards and compliance. A ranking of the residual risks can be undertaken by accounting for the management practices that are underpinned by regulation resulting in a realistic compilation of possible and probable pathways for contaminant migration. The SA Government has developed comprehensive risk-based criteria to assess the level of environmental impact of activities associated with petroleum development (DMITRE[7], 2013, SA EPA, 2014). The scenarios developed here for assessment will be further refined in coordination with the groundwater vulnerability analysis undertaken in the following task.

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[4] NCGRT(2016), Quantitative assessment of the likelihood of adverse water resource impacts from gas production from unconventional reservoirs, National Centre for Groundwater Research and Training

[5] Jacobs (2016) Hydrogeological risk assessment – unconventional gas well – South East, Department of State Development

[6] SA EPA (2014) South East Regional Groundwater Quality Monitoring, Evaluation and Reporting Program, Environment Protection Authority, 21st Oct, 2014

[7] DMITRE (2013), Criteria for classifying the level of environmental impact of regulated activities: requirement under Part 12 of the Petroleum and Geothermal Act 2000, Petroleum and Geothermal Regulatory Guidelines 004, Energy Resources Division, V1.0 Department of Manufacturing, Innovation, Trade, Resources and Energy South Australia, Adelaide.

Groundwater vulnerability analysis using spatial modelling

Groundwater vulnerability to contamination depends on many natural resource characteristics such as depth to groundwater, soil properties, aquifer characteristics, recharge rates, slope, and impacts of vadose zone processes. All these parameters, attributes and processes influence the 'dilution' and 'attenuation' of contaminants, which greatly affects the level of risk.

Established methods for regional scale screening of groundwater contamination risks belong to either index-based, statistical, or process-based analysis (Nixdorf et al.[8], 2018). A previous study (Jacobs, 2016) conducted for the southeast region applied aquifer vulnerability analysis for the southeast region. They considered three aspects to characterize aquifer vulnerability: groundwater confinement, overlying strata, and depth to groundwater. In our study, we propose to consider more comprehensively the confounding factors using methods like DRASTIC developed by the US EPA (Nixdorf et al, 2018). While the DRASTIC method is most suitable for contamination from the surface, we propose to develop an appropriate adaptation of this method for the groundwater vulnerability analysis considering broader scenarios of contamination sources in deeper systems.

Model development for simulation of water quality impacts

Previous studies (Jacobs[3], 2016) have applied analytical methods for estimation of travel times of contaminants in the aquifers of the southeast region. While such methods provide quick estimates of travel times and distances, they are underpinned by simplifying assumptions such as homogeneity and isotropy of the aquifer. More realistic estimation of the travel paths, travel times and travel distances require methods that use numerical models for groundwater flow and transport that can account for more realistic characterization of the regional groundwater system. We have demonstrated the utility and flexibility of such methods in our recent studies for GISERA (Sreekanth and Moore, 2015[9]; Sreekanth et al, 2018[10]), and the Federal Department of the Environment and Energy (Mallants et al.[11], 2017). Transport of contaminants in the vadose zone resulting from surface contamination will be simulated using similar methods (Mallants et

[8] Nixdorf, E., Sun, Y., Lin, M., & Kolditz, O. (2017). Development and application of a novel method for regional assessment of groundwater contamination risk in the Songhua River Basin. *Science of the Total Environment*, *605*, 598-609.

[9] https://gisera.csiro.au/project/high-performance-groundwater-modelling/

[10] https://gisera.csiro.au/project/assessment-of-water-quality-risk-to-farmers-bores-and-spatial-design-of-groundwater-monitoring-networks/

[11] http://www.environment.gov.au/system/files/resources/370d0bcd-8fe2-436f-88d7-1c3361ef8cd5/files/deeper-groundwater-hazard-screening-research.pdf

al., 2017c[12]). These methods are tenable for undertaking a comprehensive uncertainty analysis that enables quantification of the impacts and water quality risks with a high degree of confidence.

Water quality impacts and uncertainty analysis
In this study, we propose to apply probabilistic methods for simulation of particle travel times and distances using advective transport modelling to quantify the risk of contaminant particle migration that can result in potential adverse impacts to groundwater resources, and/or surface water resources, and/or water-dependent receptors. The probabilistic approach will account for aleatory uncertainty (uncertainty due to natural variation, for example in the hydraulic characteristics of the groundwater system), as well as epistemic uncertainty (uncertainty due to lack of knowledge, for example, the likelihood of cement failure in a gas well).

Epistemic uncertainty can cause considerable variability in contamination risks depending on the causal pathway and the location at which a contamination source is activated. For example, contamination risks are higher when spillage or leakage occurs at a location where water table is close to the surface as compared to another location where groundwater table is deeper. In our study, the use of groundwater vulnerability analysis along with the probabilistic modelling of water quality impacts for the most likely scenarios and causal pathways would account for uncertainties, comprehensively characterize risk, and quantifies the likelihood of extreme impacts. In the end, we will have widespread knowledge of any probabilities of water contamination risk from gas development and production activities.
As described earlier, the water quality impact analysis will be prioritized based on the residual risk characterized for distinct activities and hazards to provide realistic assessment of potential extreme impacts.

Need & Scope

Under the Environment Protection Act of SA (EPA[13], 1993) pollution of groundwater is an offence and responsibility of site contamination is assigned to the polluter. The Australian gas industry is bound by regulation to apply best practice engineering design for the drilling, maintenance and closure of onshore wells and other related activities. However, events and activities that lead to contamination through the two broad pathways described earlier have been reported in many onshore gas developments around the world. The water quality changes need not necessarily be caused via the introduction of external substances like fuels or drilling fluids, but also by geogenic contaminants that can be mobilized by pressure changes. For example, water with high salinity from a gas bearing formation may flow into a beneficial aquifer through a pathway induced through a leaky well when an upward gradient exists. Hence, it is critical to do a quantitative assessment of the potential water quality impacts to high value water resources and water-

[12] Mallants D, Simunek J, van Genuchten MTh, Jacques D 2017c, Using Hydrus and its Modules to Simulate the Fate and Transport of Coal Seam Gas Chemicals in Variably-Saturated Soils. Water *9*(6), 385; doi:10.3390/w9060385
[13] https://www.epa.sa.gov.au/files/12558_sc_overview_info.pdf

dependent receptors such as farmers' bores within regions of gas developments. Such an assessment will need to consider the likelihood and spatial proximity of a wide range of risk receptors in gas development areas to potential contaminant pathways.

Even when a causal pathway does exist, contamination risk is non-existent if receptors are absent within the vicinity of a potential source. The groundwater vulnerability and modelling analysis is included in the scope of this study to identify and readily exclude receptors that have zero risk of contamination. For other receptors, the probabilistic simulation and analysis will help quantify the probable extreme impacts that would enable prioritisation monitoring and management measures. For example, the probabilistic simulation of travel paths and travel times would help in delineating zones within the region where water quality should be monitored for early detection of any adverse changes in water quality to minimize the potential impacts to farmers' bores and other risk receptors.

5. Project Inputs

Research

Activities and pathways that can trigger potential for groundwater and surface water contamination and related risks in onshore gas development areas have been identified in past studies around the world. Recent studies undertaken by CSIRO (Mallants et al., 2017a, b), NCGRT[3] (2016), and others (SA EPA, 2014; Jacobs[3], 2016) provide an excellent foundation for hydrogeological risk assessments and water quality impact analyses. In our studies, we will review these studies, and when appropriate, select the relevant scenarios for a detailed modelling analysis that is based on the knowledge acquired from the past studies in conjunction with our own spatial analyses of groundwater vulnerability. We will utilise the groundwater model developed in the companion GISERA project[14] and build on additional particle path and travel time simulation models to investigate the likelihood of migration of contaminant particles to important water sources that are used by the community and water dependent risk receptors. Modelling of the unsaturated zones will also be undertaken to investigate plausible scenarios of contamination resulting from potential surface spills.

The project was developed by CSIRO researchers (Sreekanth Janardhanan, David Rassam, Rebecca Doble, James Kear, Dirk Mallants, Russell Crosbie) in consultation with other stakeholders.

[14] GISERA SA project on Hydrogeology and groundwater balance in gas development areas of southeast SA

Resources and collaborations

Researcher	Time Commitment (project as a whole)	Principle area of expertise	Years of experience	Organisation
Sreekanth Janardhanan	45 days	Groundwater modelling	11	CSIRO
Dennis Gonzalez	45 days	Spatial Analysis	9	CSIRO
David Rassam	50 days	Unsaturated zone transport modelling	22	CSIRO
Rebecca Doble	11 days	Groundwater modelling	14	CSIRO
Russell Crosbie	10 days	Groundwater vulnerability analysis	15	CSIRO
James Kear	5 days	Well integrity	9	CSIRO
Cameron Huddlestone-Holmes	5 days	Onshore gas	13	CSIRO
Dane Kasperczyk	5 days	Geomechanics	5	CSIRO
Dirk Mallants	15 days	Transport modelling	22	CSIRO
Dan Gladish	5 days	Statistical analysis	5	CSIRO
Dan Pagendam	5 days	Statistical analysis	11	CSIRO

Subcontractors (clause 9.5(a)(i))	Time Commitment (project as a whole)	Principle area of expertise	Years of experience	Organisation
N/A	-	-	-	-

Budget Summary

Source of Cash Contributions	2017/18	2018/19	2019/20	% of Cash Contribution	Total
GISERA	-	$124,314.75	$83,847.75	75%	$208,162.50
- SA Government	-	$62,157.38	$41,923.88	37.5%	$104,081.25
- Federal Government	-	$62,157.38	$41,923.88	37.5%	$104,081.25
Total Cash Contributions	**-**	**$124,314.75**	**$83,847.75**	**75%**	**$208,162.50**
Source of In-Kind Contribution	**2017/18**	**2018/19**	**2019/20**	**% of In kind Contribution**	**Total**
CSIRO	-	$41,438.25	$27,949.25	25%	$69,387.50
Total In-Kind Contribution	**-**	**$41,438.25**	**$27,949.25**	**25%**	**$69,387.50**

6. Project Impact Pathway

<table>
<tr><th>Activities</th><th>Outputs</th><th>Short term Outcomes</th><th>Long term outcomes</th><th>Impact</th></tr>
<tr><td>Causal pathway workshop</td><td>Elicitation of contamination causal pathways arising from the onshore gas activities</td><td rowspan="3">Knowledge generated by the integration of causal pathways, their spatial attribution in relation to regions with distinct classification of groundwater vulnerability which enables to 1) prioritize of impact assessments 2) identification of relatively low, moderate and high-risk areas in the region</td><td rowspan="3">The regulatory agencies will be able to use knowledge generated on risk of water quality impacts to inform regulatory decision making. They can glean additional information on which zones are at relatively higher and lower risks of contamination and can inform their approval processes for licensing and make good arrangements</td><td rowspan="6">Assessment of potential water quality risks, potentially impacted areas and likelihood can prepare regulatory agencies and industry alike with improved knowledge and measures for preventing and mitigating outcomes from undesirable events reducing societal concerns, environmental impacts and improved organisational management</td></tr>
<tr><td>Contamination casual pathways and scenario</td><td>Shortlist of scenarios to be modelled</td></tr>
<tr><td>Groundwater vulnerability analysis</td><td>Risk classes for groundwater contamination vulnerability</td></tr>
<tr><td>Model development</td><td>Numerical models that encapsulate the flow and transport processes</td><td rowspan="3">Provides tangible information on what are the likely distances and times over which potential water quality impacts may occur from onshore gas related activities in the southeast</td><td rowspan="2">Predictive analysis of likelihood and potential extent of undesirable events like water contamination can help the community make informed opinion/decisions around social license to operate.</td></tr>
<tr><td rowspan="2">Water quality impacts and uncertainty analysis</td><td rowspan="2">Analysis of scenarios resulting from plausible pathways that have a likelihood of impacting water resource and water dependent risk receptors</td></tr>
<tr><td>The outputs of the project will provide industry with insights about where, when and how to best manage environmental impacts arising from water contamination risks</td></tr>
</table>

7. Project Plan

Project Schedule

ID	Activities / Task Title (should match activities in impact pathway section)	Task Leader	Scheduled Start	Scheduled Finish	Predecessor
Task 1	Causal pathway workshop	Sreekanth Janardhanan	1 July 2018	30 October 2018	
Task 2	Contamination causal pathways and scenario development	Sreekanth Janardhanan/ James Kear/ Cameron Huddlestone-Holmes	1 August 2018	31 January 2019	1
Task 3	Spatial analysis and groundwater vulnerability	Russell Crosbie/Dennis Gonzalez	1 August 2018	30 June 2019	1
Task 4	Model development	David Rassam /Sreekanth Janardhanan	1 September 2018	31 August 2019	1,2
Task 5	Water quality impacts and uncertainty analysis	Sreekanth Janardhanan/David Rassam	1 September 2019	28 February 2020	1,2,4
Task 6	Journal papers	Sreekanth Janardhanan	1 March 2020	30 June 2020	1,2,3,4,5

Task Descriptions

Task 1
TASK NAME: Causal pathway workshop
TASK LEADER: Sreekanth Janardhanan/Rebecca Doble/James Kear/Cameron H-H/David Rassam/Dirk Mallants
OVERALL TIMEFRAME: July – October 2018
BACKGROUND: Disciplinary expertise in onshore gas, well engineering, hydrogeology, water quality, unsaturated and saturated zone transport modelling need to be integrated for comprehensively conceptualize the causal pathways for water quality risks of onshore gas development. The half-day workshop will provide a common platform for researchers from multiple disciplines to interact and elicit the water quality causal pathways and conceptualize scenarios that need to be investigated using modelling techniques in this project. The workshop will also ascertain that regulatory controls and industry nest practice management measures are accounted for when developing scenarios for modelling-based analysis.
TASK OBJECTIVES: Integration of multi-disciplinary expertise in onshore gas, well engineering, groundwater and modelling to develop conceptual models of causal pathways
TASK OUTPUTS AND SPECIFIC DELIVERABLES: Conceptual model of causal pathways

Task 2
TASK NAME: Contamination causal pathways and scenarios
TASK LEADER: Sreekanth Janardhanan/James Kear/ Cameron Huddlestone-Holmes
OVERALL TIMEFRAME: August 2018 – January 2019
BACKGROUND: There can be a number of causal pathways that can potentially result in groundwater and/or surface water contamination as a result of onshore gas activities. A risk-based approach is required to identify the causal pathways that required detailed modelling analysis to investigate potential impacts to water resources and water dependent assets.
TASK OBJECTIVES: Following on from the causal pathway workshop, this task will identify a selection of causal pathways that required modelling analysis. Realistic scenarios will be developed in conjunction with groundwater vulnerability analysis undertaken in task 3.
TASK OUTPUTS AND SPECIFIC DELIVERABLES: Scenarios for model-based water quality impact analysis; causal pathway chapter for the final report.

Task 3
TASK NAME: Spatial analysis and groundwater vulnerability
TASK LEADER: Russell Crosbie/Dennis Gonzalez
OVERALL TIMEFRAME: August 2018 – June 2019
BACKGROUND: Contamination risks depend not only on the causal pathways that lead to water sources, but also on the physical characteristics of the groundwater source and environment. For example a surface spill of a contaminant poses higher risk at locations where the water table is shallower and the soil properties permit high recharge rates. The severity of the risk is also influenced by proximity and value of important assets and receptors to sources of contamination.
TASK OBJECTIVES: This task will develop and apply a spatial analyses techniques which helps to evaluate groundwater vulnerability in the gas development region in conjunction with the causal pathways and risk receptors.
TASK OUTPUTS AND SPECIFIC DELIVERABLES: Maps of groundwater vulnerability in relation to causal pathways and risk receptors; model development chapter for the final report

Task 4
TASK NAME: Model development
TASK LEADER: David Rassam/Sreekanth Janardhanan
OVERALL TIMEFRAME: September 2018 – August 2019
BACKGROUND: A few different modelling techniques are envisaged for the quantitative simulation of contaminant travel times, distances and velocities in unsaturated and saturated soil media.
TASK OBJECTIVES: In this task we will develop a suite of models that can be applied for contaminant transport simulation, particle travel times, distances and velocities. These modelling tools will be developed in such a way that epistemic and aleatory uncertainties can be readily accounted for in the scenario analysis undertaken in task 5.
TASK OUTPUTS AND SPECIFIC DELIVERABLES: Particle path and travel time simulators, unsaturated and saturated zone advective transport models that can be coupled with groundwater flow and surface water – groundwater interaction models.

Task 5

TASK NAME: Water quality risks and uncertainty analysis

TASK LEADER: Sreekanth Janardhanan/David Rassam

OVERALL TIMEFRAME: September 2019 – February 2020

BACKGROUND: While uncertainties in the predictions made using environmental models are inevitable, models can often be used to test hypotheses about potential negative effects caused by resource development. Using probabilistic screening analysis it is often possible to exclude with high confidence many assets and risk receptors from potential water quality impacts from onshore gas activity causal pathways

TASK OBJECTIVES: Using the screening modelling tools and groundwater vulnerability analysis, undertake scenario analysis to identify potential water quality impacts through selected causal pathways. This task also helps to classify zones within gas development areas and pertaining receptors into distinct risk categories.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: Water quality risk analysis for the receptors; Final report

Task 6

TASK NAME: Journal papers

TASK LEADER: Sreekanth Janardhanan

OVERALL TIMEFRAME: March – June 2020

BACKGROUND: A few multi-disciplinary approaches are being integrated for water quality impact and risk analysis in this project.

TASK OBJECTIVES: Write the journal papers on methods and case studies

TASK OUTPUTS AND SPECIFIC DELIVERABLES: Journal papers.

Project Gantt Chart

Task Leader	Task	FY 2018-19												FY 2019-20											
		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Sreekanth J	**1**																								
Sreekanth J et al	**2**																								
Dennis Gonzalez	**3**																								
David R/Sreekanth	**4**																								
Sreekanth J/David R	**5**																								
Sreekanth J	**6**																								

8. Technical Reference Group

The Technical reference group will comprise three members yet to be determined:

- A member of South Australian government (e.g., the Department of Environment Water and Natural Resources)
- An academic with experience in groundwater and onshore gas research
- An industry representative with local knowledge of SE of South Australia

9. Communications Plan

Stakeholder	Objective	Channel	Timeframe
Causal pathway workshop – internal CSIRO	The main objectives of the workshop are integration of multi-disciplinary expertise in onshore gas, well engineering, groundwater and modelling to develop conceptual models of causal pathways	Workshop	At commencement of project
Government and Industry	To facilitate a deeper understanding of research findings and implications for policy, programs, planning, and other initiatives	Knowledge transfer session	Towards completion
Wider public	To communicate key messages from the research	Fact sheets	Towards completion
Scientific community	To communicate scientific findings	Journal publication	At completion

10. Budget Summary

Expenditure	2017/18	2018/19	2019/20	Total
Labour	-	$149,753	$105,297	$255,050
Operating	-	$16,000	$6,500	$22,500
Subcontractors	-	-	-	-
Total Expenditure	**-**	**$165,753**	**$111,797**	**$277,550**

Expenditure per Task	2017/18	2018/19	2019/20	Total
Task 1	-	$14,602	-	$14,602
Task 2	-	$23,390	-	$23,390
Task 3	-	$61,328	-	$61,328
Task 4	-	$66,433	$34,966	$101,399
Task 5	-	-	$56,468	$56,468
Task 6	-	-	$20,363	$20,363
Total Expenditure	**-**	**$165,753**	**$111,797**	**$277,550**

Source of Cash Contributions	2017/18	2018/19	2019/20	Total
SA Government (37.5%)	-	$62,157.38	$41,923.88	$104,081.25
Federal Government (37.5%)	-	$62,157.38	$41,923.88	$104,081.25
Total Cash Contributions	**-**	**$124,314.75**	**$83,847.75**	**$208,162.50**

In-Kind Contribution from Partners	2017/18	2018/19	2019/20	Total
CSIRO (25%)	-	$41,438.25	$27,949.25	$69,387.50
Total In-Kind Contribution from Partners	**-**	**$41,438.25**	**$27,949.25**	**$69,387.50**

	Total funding over all years	Percentage of Total Budget
SA Government Investment	$104,081.25	37.5%
Federal Government Investment	$104,081.25	37.5%
CSIRO Investment	$69,387.50	25.0%
TOTAL	**$277,550**	

Task	Milestone Number	Milestone Description	Funded by	Start Date (mm-yy)	Delivery Date (mm-yy)	Fiscal Year Completed	Payment $ (excluding CSIRO contribution)
Task 1	1.1	Stakeholder workshop	GISERA	Jul-2018	Aug-2018	2018/19	$10,951.50
Task 2	2.1	Causal pathways and scenario development chapter as milestone report	GISERA	Aug-2018	Jan-2019	2018/19	$17,542.50
Task 3	3.1	Spatial analysis chapter as milestone report	GISERA	Aug-2018	Jun-2019	2018/19	$45,996.00
Task 4	4.1	Model development chapter as milestone report	GISERA	Sep-2018	Aug-2019	2019/20	$76,049.25
Task 5	5.1	Final report	GISERA	Sep-2019	Feb-2020	2019/20	$42,351.00
Task 6	6.1	Journal papers	GISERA	Mar-2020	June-2020	2019/20	$15,272.25

11. Intellectual Property and Confidentiality

<table>
<tr><td rowspan="3">Background IP (clause 11.1, 11.2)</td><td>Party</td><td>Description of Background IP</td><td>Restrictions on use (if any)</td><td>Value</td></tr>
<tr><td></td><td></td><td></td><td>$</td></tr>
<tr><td></td><td></td><td></td><td>$</td></tr>
<tr><td>Ownership of Non-Derivative IP (clause 12.3)</td><td colspan="4">CSIRO</td></tr>
<tr><td>Confidentiality of Project Results (clause 15.6)</td><td colspan="4">Project Results are not confidential.</td></tr>
<tr><td>Additional Commercialisation requirements (clause 13.1)</td><td colspan="4">Not Applicable</td></tr>
<tr><td>Distribution of Commercialisation Income (clause 13.4)</td><td colspan="4">Not Applicable</td></tr>
<tr><td rowspan="3">Commercialisation Interest (clause 1.1)</td><td colspan="2">Party</td><td colspan="2">Commercialisation Interest</td></tr>
<tr><td colspan="2">CSIRO</td><td colspan="2">Not applicable</td></tr>
<tr><td colspan="2">Other</td><td colspan="2">Not applicable</td></tr>
</table>