Project Order, Variations and Research Progress

Project Title: Groundwater balance in gas development regions of South East South Australia

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

1 Original Project Order

Project Order

Proforma 2018

1. Short Project Title

Groundwater balance in gas development regions of South East South Australia

Long Project Title	Improving hydrogeology and groundwater balance models in the onshore gas development regions of South East South Australia
GISERA Project Number	W.14
Proposed Start Date	6 August 2018
Proposed End Date	31 March 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

Objective

The project aims to conduct a probabilistic assessment of regional scale groundwater balance and improved understanding of groundwater flow regimes in the south east region in relation to proposed onshore gas activities for the Otway Basin. Quantification of potential groundwater balance changes in onshore gas exploration and development areas using the best estimates of probable recharge and discharge rates, current and potential future groundwater stresses can help inform approvals, regulatory decision making, and community understanding on licencing and management measures that are required for optimal use of the resource. This work will build on the knowledge available from SA Department of Environment and Water (DEW) ensuring that the knowledge available from the regional groundwater modelling is leveraged to provide added value in probabilistically assessing the water balance and effects from onshore gas development.

Description

Petroleum and gas operators often extract groundwater in the process of producing petroleum and gas because the water and gas are often intimately connected. This can occur in conjunction with other water uses such as irrigation in the Otway basin. For these reasons community and other stakeholders express significant concerns about the effect the onshore gas industry may have on the environment and water resources.

Conventional petroleum production occurs in much deeper sources and are often separated from surface and groundwater sources by thick layers of impermeable rock. Conventional gas productions are therefore not expected to impact surficial aquifers by inducing drawdown as the gas reservoirs are located in deeper parts of the basin separated by thick layers of impermeable rock. Some amount of water may be used by the industry for operations for which they may be required to apply for a licence for water extraction. Water quantity risks are more likely in southeast SA, only if the conventional gas industry becomes a net user of significant volumes of water depending on the type of resource development. However, understanding the status quo of groundwater resource is important for this region considering the fact that there are multiple competing uses of water (irrigation, forestry, gas) exists and that water levels have been reported to be declining over the years.

Thus, the first objective of the study is to probabilistically quantify the overall water balance of aquifers and groundwater impacts induced by the onshore gas industry in the region by accounting for potential water use by agricultural, forestry and gas industries. Understanding the hydrogeology and status of groundwater resources in areas with existing and potential onshore gas activities is important to ascertain the characteristics of the resource and evaluate any potential changes induced by the industry including effects on “hotspot” areas and significant wetlands. Evidence-based scientific analysis is required to underpin these

assessments which can assist stakeholders make informed decisions about the presence or absence of relative risks to the environment and water resources.

The second objective is to develop a detailed understanding of groundwater flow regimes and flow velocities in these aquifers that can provide the basis for contaminant transport studies in the companion South Australia GISERA water quality research project[1]. A detailed understanding of groundwater flow directions and velocities derived from a groundwater flow model is essential to quantify potential water quality effects induced by different activities associated with onshore gas development.

Methodology

This research will examine groundwater in parts of two major regional aquifers (Doble et al, 2015) – the Tertiary Limestone Aquifer (unconfined) and the Tertiary Confined Sand Aquifer (confined) are important water resources in the southeast SA region. The study will use probabilistic modelling approaches for quantifying water balance in these aquifers. We will also leverage the knowledge from existing conceptual models and regional scale water balance studies. Several groundwater studies have been done previously for the south east SA on a basin-wide scale such as Paydar et al[2] (2009) and Harrington et al[3] (2011) by CSIRO. A more recent study also investigated groundwater recharge in the south east region (Doble et al., 2015[4]). Existing regional scale numerical model (Morgan et al, 2015[5]) developed by the South Australian Government will be used for providing necessary background for modelling analysis undertaken in this project. This component of the study will be undertaken in close coordination with DEW. The lead groundwater modeller of our research team (Rebecca Doble) has been involved with the development of the regional model and is coordinating with the department to ensure that this component is undertaken to derive maximum value out of the available models and avoid duplication of work.

The following activities are planned for the project.

Stakeholder workshop and scenario development

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[1] GISERA SA project order on "Groundwater contamination vulnerability and modelling analysis of onshore gas water quality impacts for southeast SA"

[2] Paydar Zahra, Chen Yun, Xevi Emmanuel and Buettikofer Heinz (2009), Current understanding of the water cycle in the Limestone Coast region

[3] Harrington, N., Lamontagne, S., Crosbie, R., Morgan, L., Doble, R., & Werner, A. (2015). South East Regional Water Balance Project–Phase 2. Project Summary Report. *Goyder Institute for Water Research Technical Report*, *15*, 39.

[4]Doble Rebecca, Pickett Trevor, Crosbie Russell, Morgan Leanne, (2015) A new approach for modelling groundwater recharge in the South East of South Australia using MODFLOW, Goyder Institute for Water Research Technical Report 16/26

[5] Morgan, L., Harrington, N., Werner, A., Hutson, J., Woods, J., & Knowling, M. (2015). South East Regional Water Balance Project–Phase 2. Development of a Regional Groundwater Flow Model. Goyder Institute for Water Research Technical Report, 15.

A ½ - 1 day workshop will be conducted at the beginning of the project to assimilate existing knowledge, available data and models that will provide valuable background for this study. The workshop will initiate a communication platform between the project team and key stakeholders such as, Beach Energy, SA government and CSIRO and University researchers. Stakeholder inputs will also be sought for the development of realistic scenarios for which predictive analysis will be undertaken to investigate water balance changes induced by the irrigation, forestry and gas industries in the subsequent tasks of the project. The objectives of the companion GISERA project on water quality and contamination risks will also be considered.

Development of a fit-for-purpose child model

This study will develop a fit-for-purpose numerical groundwater model. The groundwater model will be used to for investigate the dynamic interactions of different groundwater flow and water balance components such as recharge, surface water - groundwater interaction, natural and anthropogenic discharge including groundwater pumping for irrigation, forestry, stock and domestic needs. Processes will be built into the model to represent groundwater use by the gas industry and test if existing or potential stress induced by gas industry can affect this balance. The model will also establish appropriate spatial and temporal scales to investigate solute transport to feed into the companion GISERA project on water quality impacts.

Model calibration and uncertainty analysis

The groundwater model will be calibrated using available data including water level/ pressure observations and other constraining data comprising estimates of recharge, evapotranspiration and crop water use. The numerical groundwater model will be used in a highly-parameterized uncertainty analysis framework to address the uncertainties and probabilistically quantify water balance changes induced by chosen scenarios of gas development. The uncertainty analysis framework that will be extended and adapted based on extensive previous work undertaken through past GISERA[3, 4, 5] (Sreekanth and Moore, 2015; Sreekanth et al. 2017; Sreekanth et al, 2018) and Bioregional Assessments Programme research projects (Crosbie et al[6], 2016; Peeters et al[7]., 2016)

[6] Crosbie R, Peeters L and Carey H (2016) Groundwater modelling. Submethodology M07 from the Bioregional Assessment Technical Programme. Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia. http://data.bioregionalassessments.gov.au/submethodology/M07.

[7] Peeters L, Pagendam D, Gao L, Hosack G, Jiang W and Henderson B (2016) Propagating uncertainty through models. Submethodology M09 from the Bioregional Assessment Technical Programme. Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia. http://data.bioregionalassessments.gov.au/submethodology/M09.

Water balance analysis

Probabilistic water balance analysis will be undertaken using the calibrated groundwater model to provide a high confidence assessment of current and potential future water balance in the region. The quantification of the water use by the gas industry in relation to other water balance components will also help to quantify potential impacts of the onshore gas industry. Depending on scenarios developed in task 2 the analysis will give a probabilistic quantification of individual project and sector wide contributions and potential cumulative effects of onshore gas, agriculture and forestry industries to the groundwater balance for a selected sub-region in south east SA.

Need & Scope

The Otway Basin in south east South Australia the Upper Mid Tertiary Aquifer and the Lower Tertiary Aquifer are two important regional aquifers that overlay gas reservoirs (separated by large masses of impermeable rock) that are explored for natural gas reserves.

The onshore gas industry of Australia is required to apply for licences for the quantities of water that they may directly or indirectly take, during the operational phase, from aquifers in gas development area. Hence, it is critical to do a quantitative assessment of the water balance and potential risk to farmers' bores and other risk receptors within regions of gas development. The areas where groundwater is already used for irrigation and other purposes may be in a changing state and changes in the climate may also significantly affect the short-term future state of water resources. As the gas industry usually operates for many decades, developing a thorough understanding of the current state of the groundwater resource and assessment of potential future status after the advent of onshore gas industry assessment of changes in groundwater balance is very important.

The study will probabilistically quantify water balance and groundwater flow regimes in existing and potential gas development regions in south east SA including the Hazelgrove and other fields towards south and east of Penola. The models developed in this study will provide the essential tools and precursory knowledge required to analyse potential water quality impacts caused by well integrity, spills and other contamination pathways in the GISERA companion research project[2] on water quality impacts. These two projects are developed in close coordination to maximize use of resources to address the twin goals of water balance and contamination risk assessments. The outcomes of these two GISERA projects will provide the industry, Government and community stakeholders, evidence-based and quantitative assessment of these risks that will aid informed decision making.

5. Project Inputs

Research

The project was developed by researchers of the CSIRO Water Resources Management Program (Sreekanth Janardhanan, Rebecca Doble, Russell Crosbie). The project idea was further developed during the stakeholder consultation workshop and field visits to the southeast SA in April 2018. Stakeholders from South Australia Department of Environment and Water have also been consulted to confirm availability of the regional scale groundwater model and other data sets for this study and to discuss value propositions.

We have discussed the proposal with Juliette Woods, the Principal Groundwater Modeller, Water Science and Monitoring Branch in the DEW. We have mutually agreed to coordinate on this project to ensure complementary efforts by CSIRO and the department modellers across different groundwater modelling initiatives, targeting research objectives in the region. In doing so, a request for the input data and outputs from the SE Regional Scale and Wattle Range models of the SE region developed by DEW has been made available to assist this project, in liaison with their modelling team and through our existing collaboration framework.

DEW has agreed that groundwater modellers currently working on the SE Regional Scale and Wattle Range groundwater models will liaise with CSIRO to maximize the utilization of available knowledge and ensure that the model is useful for DEW purposes.

In addition, upon the suggestion by RRAC, we have invited Wendy Telfer, Manager Planning and Evaluation, SE Region, DEW to participate in the Technical Reference Group to inform the policy perspectives and facilitate uptake of the project findings.

Resources and collaborations

Researcher	Time Commitment (project as a whole)	Principle area of expertise	Years of experience	Organisation
Sreekanth Janardhanan	57 days	Groundwater modelling	11	CSIRO
Rebecca Doble	68 days	Groundwater modelling	14	CSIRO
Russell Crosbie	28 days	Recharge, groundwater modelling	15	CSIRO
Trevor Pickett	50 days	Software engineering	12	CSIRO
Cameron Huddlestone-Holmes	10 days	Onshore gas	13	CSIRO
Collaboration with SA Department of Environment and Water	As required	Groundwater modelling + Policy, Planning and Evaluation	-	SA Department of Environment and Water

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

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Budget Summary

Source of Cash Contributions	2017/18	2018/19	2019/20	% of Cash Contribution	Total
GISERA	-	$204,741.75	$39,785.25	75%	$244,527.00
- SA Government	-	$102,370.88	$19,892.63	37.5%	$122,263.50
- Federal Government	-	$102,370.88	$19,892.63	37.5%	$122,263.50
Total Cash Contributions	**-**	**$204,741.75**	**$39,785.25**	**75%**	**$244,527.00**
Source of In-Kind Contribution	**2017/18**	**2018/19**	**2019/20**	**% of In kind Contribution**	**Total**
CSIRO	-	$68,247.25	$13,261.75	25%	$81,509.00
Total In-Kind Contribution		**$68,247.25**	**$13,261.75**	**25%**	**$81,509.00**

6. Project Impact Pathway

Activities	Outputs	Short term Outcomes	Long term outcomes	Impact
1. Stakeholder consultation workshop	Refined work plan for the project	Improved knowledge on the hydrogeology and conceptual understanding of onshore gas regions of southeast	Improved understanding of water balance in the area to inform water licensing and regulatory measures for the gas industry	The knowledge encapsulated in the groundwater model can be used and progressively improved and adapted for quantitative understanding of environmental effects of onshore gas development – specifically on water quality and quality. The project results and outcomes will be communicated to the community stakeholder which will help the community form use the evidence base provided by the study for forming informed opinions and decisions. The project outcomes will provide evidence base for the community to make informed decisions around gas industry and thus provides valuable guidance around social license to operate and optimal resource development and use for the local economy.
2. Conceptualization and scenario development	A list of scenarios to be run for predicting future states of the water balance components under gas and other developments			
3. Development of a child groundwater model	A fit-for-purpose child model from the existing regional scale groundwater model			
4. Model calibration and uncertainty analysis	Report on stochastic modelling and data-worth analysis	A groundwater model available to use to assess water quality impacts that can be updated progressively as information is available	Publicly available and trusted quantitative analysis of potential water impacts from gas and other industry use in the chosen study area	
5. Water balance analysis	A tabulation of estimates of water balance components with associated uncertainties for the chosen water balance area that encompasses the onshore gas development well fields.			

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	Stakeholder workshop	Rebecca Doble/Russell Crosbie/ Sreekanth Janardhanan /GISERA Comms	6 Aug-2018	31 October 18	None
Task 2	Scenario development	Russell Crosbie/ Cameron Huddlestone-Holmes	6 Aug-18	30 Nov-18	1
Task 3	Groundwater model development	Rebecca Doble	6 Aug-18	28 Feb-19	1,2
Task 4	Model calibration and uncertainty analysis	Sreekanth Janardhanan	1 Sep-18	30 Jun-19	1,2,3
Task 5	Water balance and scenario analysis	Russell Crosbie	1 Jun-19	31 Mar-20	1,2,3,4

Task Description

Task 1

TASK NAME: Stakeholder consultation workshop

TASK LEADERS: Rebecca Doble, Russell Crosbie, Sreekanth Janardhanan, GISERA Comms.

OVERALL TIMEFRAME: August – October 2018

BACKGROUND: The project strongly builds on existing data (SA government, Beach Energy) and models such as the models (SA Government, CSIRO, Flinders) developed and used in the CSIRO projects (GOYDER). To allow an effective integration of these data and models into the work a workshop will be held at the start of the project. The workshop will provide a communication platform between the project team and key stakeholders such as, Beach Energy, SA government and CSIRO and University researchers.

TASK OBJECTIVE: The main objectives of the workshop are;

- to ascertain that all existing data, models and knowledge is adequately incorporated into the project and that key stakeholders have the opportunity to provide additional feedback on the data collection strategy and the modelling approach.
- to review and ascertain the opportunities for using data from existing wells of SA government and the gas industry
- to establish a longer-term connection between the researchers of this new project and the stakeholders and to coordinate interactions and a communication platform that will ascertain close interactions throughout the remainder of the project.

TASK OUTPUTS: Refined work plan for the project

SPECIFIC DELIVERABLES: ½ - 1 day workshop

Task 2

TASK NAME: Conceptualization and scenario development

TASK LEADER: Russell Crosbie, Cameron Huddlestone-Holmes and Sreekanth Janardhanan

OVERALL TIMEFRAME: August – November 2018

BACKGROUND: The scenario development is a vital input for the prediction of future states of groundwater balance components that will be modelled in Task 3. The gas development pathway for the SE will be developed in conjunction with other GISERA projects and combined with any existing projections for changes in other water users going into the future.

TASK OBJECTIVE: The scenario development is a vital input for the prediction of future states of groundwater balance components that will be modelled in Task 3. The gas development pathway for the SE will be developed in conjunction with other GISERA projects and combined with any existing projections for changes in other water users going into the future.

TASK OUTPUTS: A list of scenarios to be run for predicting future states of the water balance components under gas and other developments.

SPECIFIC DELIVERABLES: List of scenarios to be run

Task 3

TASK NAME: Development of a child groundwater model

TASK LEADER: Rebecca Doble

OVERALL TIMEFRAME: August 2018 - February 2019

BACKGROUND: The regional scale groundwater model developed during the Goyder SE project was intended to answer regional scale questions and to provide the boundary conditions for finer scale models that can be built to answer more specific local questions. The existing regional scale groundwater model will provide the boundary conditions for the development of a more detailed child model.

TASK OBJECTIVE: The objective of this task is to build a fit-for-purpose child model from the existing regional scale groundwater model. This new model will be capable of simulating changes in flow and water balance on the scale of 100's of metres which is commensurate with the scale of the gas development as opposed to the existing regional scale model where impacts would not be seen due to the grid resolution. The domain for the child model will be 'cut out' of the existing regional scale model, or based on the Wattle Range model of DEW, ensuring that the model boundaries are compatible to each other and thus tenable for interacting with each other in a loosely-coupled manner. This framework enables CSIRO to leverage the existing model to provide the model inputs, boundary conditions and parameters for the child model while the scale of child model is adapted to answer the specific questions raised by the model objectives.

TASK OUTPUTS: Develop a fit-for-purpose child model from the existing regional scale groundwater model.

SPECIFIC DELIVERABLES: Deliver groundwater model to Task 3.

Task 4

TASK NAME: Model calibration and uncertainty analysis

TASK LEADER: Sreekanth Janardhanan

OVERALL TIMEFRAME: September 2018 – June 2019

BACKGROUND: In this task, the state-of-the-science child groundwater model developed in task 2 will be used in conjunction with the regional scale model for calibration of the model parameters using latest available groundwater data. Depending on the suitability, the model will be calibrated using the PEST suite of software by using highly or parsimoniously parameterized modelling approaches. Un-constrained Monte Carlo simulation or the calibration constrained method called Null-Space Monte Carlo will then be employed, depending on data-availability, to make predictive simulations of groundwater pressure and water level changes.

TASK OBJECTIVE: Calibrate the model basis that can be used to predict groundwater pressure changes and further perform calibration constrained uncertainty analysis to delineate monitoring zones.

TASK OUTPUTS: The task will deliver the modelling and uncertainty analysis framework that is required for probabilistic water balance analysis.

SPECIFIC DELIVERABLES: Report on stochastic modelling and data-worth analysis

Task 5

TASK NAME: Water balance and groundwater impact analysis

TASK LEADER: Sreekanth Janardhanan and Rebecca Doble

OVERALL TIMEFRAME: June 2019 – March 2020

BACKGROUND: Realistic estimates of the ranges of some components of groundwater balance such as the diffuse recharge from rainfall, the amount of storage and the discharge through rivers can be estimated independently for a selected region. For example, long-term mean recharge can be derived from a Chloride mass balance analysis or environmental tracer analysis. The independent water budget estimates forms a key component of a conceptual model and provides context for groundwater modelling to evaluate the effects of anthropogenic and other stressors on the availability and sustainability of resource.

TASK OBJECTIVE: The specific objective of this task is to conduct independent groundwater budget analysis to provide constraints for any subsequent work as it estimates the magnitude of current fluxes. All existing estimates of the water balance components will be collated and reviewed. Posterior distribution of other groundwater flow parameters that are correlated with independently estimated water balance components will be obtained from the calibration and uncertainty analysis undertaken in task 3. The independently estimated water balance components will be integrated in a mass balance calculation in the numerical model. The water balance analysis also help identify important components, processes and stresses of the groundwater system.

TASK OUTPUTS: A tabulation of estimates of water balance components with associated uncertainties for the chosen water balance area that encompasses the onshore gas development well fields. An assessment of the effect of onshore gas induced changes to important receptor locations including significant wetlands in the region

SPECIFIC DELIVERABLES: Historical water balance and analysis of impacts to key receptor locations including significant wetlands

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Project Gantt Chart

Task Leader	Task	FY 2018-19											FY 2019-20								
		Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Rebecca/Russell/ Sreekanth/Comms	**1**																				
Russell/Cameron	**2**																				
Rebecca Doble	**3**																				
Sreekanth Janardhanan	**4**																				
Russell Crosbie	**5**																				

8. Technical Reference Group

The Technical reference group will comprise of:

- South Australian government representatives (e.g. Juliette Woods, the Principal Groundwater Modeller, Water Science and Monitoring Branch, DEW and Wendy Telfer, Manager Planning & Evaluation, SA Region, DEW)
- An academic with experience in groundwater and onshore gas
- An industry representative with local knowledge of SE of South Australia

9. Communications Plan

Stakeholder	Objective	Channel	Timeframe
Stakeholder Consultation Workshop to provide a communication platform between the project team and key stakeholders such as, Beach Energy, SA government and CSIRO and University researchers.	The main objectives of the workshop are: • to ascertain that all existing data, models and knowledge is adequately incorporated into the project and that key stakeholders have the opportunity to provide additional feedback on the data collection strategy and the modelling approach. • to review and ascertain the opportunities for using data from existing wells of SA government and the gas industry • to establish a longer-term connection between the researchers of this new project and the stakeholders and to coordinate interactions and a communication platform that will ascertain close interactions throughout the remainder of the project.	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

10. Budget Summary

Expenditure	2017/18	2018/19	2019/20	Total
Labour	-	$259,989	$45,047	$305,036
Operating	-	$13,000	$8,000	$21,000
Subcontractors	-	-	-	-
Total Expenditure	**-**	**$272,989**	**$53,047**	**$326,036**

Expenditure per Task	2017/18	2018/19	2019/20	Total
Task 1	-	$16,588	-	$16,588
Task 2	-	$32,903	-	$32,903
Task 3	-	$71,472	-	$71,472
Task 4	-	$123,237	-	$123,237
Task 5	-	$28,789	$53,047	$81,836
Total Expenditure	**-**	**$272,989**	**$53,047**	**$326,036**

Source of Cash Contributions	2017/18	2018/19	2019/20	Total
SA Government (37.5%)	-	$102,370.88	$19,892.63	$122,263.50
Federal Government (37.5%)	-	$102,370.88	$19,892.63	$122,263.50
Total Cash Contributions		**$204,741.75**	**$39,785.25**	**$244,527.00**

In-Kind Contribution from Partners	2017/18	2018/19	2019/20	Total
CSIRO (25%)	-	$68,247.25	$13,261.75	$81,509.00
Total In-Kind Contribution from Partners		**$68,247.25**	**$13,261.75**	**$81,509.00**

	Total funding over all years	Percentage of Total Budget
SA Government Investment	$122,263.50	37.5%
Federal Government Investment	$122,263.50	37.5%
CSIRO Investment	$81,509.00	25.0%
TOTAL	**$326,036.00**	

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	Aug-18	Oct-18	2018/19	$12,441.00
Task 2	2.1	Scenario development	GISERA	Aug-18	Nov-18	2018/19	$24,677.25
Task 3	3.1	Groundwater model development	GISERA	Aug-18	Feb-19	2019/20	$53,604.00
Task 4	4.1	Model calibration and uncertainty analysis	GISERA	Sept-18	Jun-19	2019/20	$92,427.75
Task 5	5.1	Water balance analysis and final report	GISERA	Jun-19	Mar-20	2019/20	$61,377.00

11. Intellectual Property and Confidentiality

Background IP (clause 11.1, 11.2)	**Party**	**Description of Background IP**	**Restrictions on use (if any)**	**Value**
				$
				$
Ownership of Non-Derivative IP (clause 12.3)	CSIRO			
Confidentiality of Project Results (clause 15.6)	Project Results are not confidential.			
Additional Commercialisation requirements (clause 13.1)	Not Applicable			
Distribution of Commercialisation Income (clause 13.4)	Not Applicable			
Commercialisation Interest (clause 1.1)	**Party**		**Commercialisation Interest**	
	CSIRO		Not applicable	
	Other		Not applicable	

2 Variations to Project Order

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.

The table below details variations to research Project Order.

Register of changes to Research Project Order

Date	Issue	Action	Authorisation
6/3/19	Delays due in receiving the groundwater model.	Milestone 3 extended by 3 months to May-19.	

3 Progress against project milestones

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.

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 Regional 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.

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Project Schedule Table

ID	Activities / Task Title	Task Leader	Scheduled Start	Scheduled Finish	Predecessor
Task 1	Stakeholder workshop	Rebecca Doble/Russell Crosbie/ Sreekanth Janardhanan /GISERA Comms	6 Aug-2018	31 October 18	None
Task 2	Scenario development	Russell Crosbie/ Cameron Huddlestone-Holmes	6 Aug-18	30 Nov-18	1
Task 3	Groundwater model development	Rebecca Doble	6 Aug-18	31-May-19	1,2
Task 4	Model calibration and uncertainty analysis	Sreekanth Janardhanan	1 Sep-18	30 Jun-19	1,2,3
Task 5	Water balance and scenario analysis	Russell Crosbie	1 Jun-19	31 Mar-20	1,2,3,4

Project Schedule Report

Task 1

TASK NAME: Stakeholder consultation workshop
TASK LEADERS: Rebecca Doble, Russell Crosbie, Sreekanth Janardhanan, GISERA Comms.
OVERALL TIMEFRAME: August – October 2018
BACKGROUND: The project strongly builds on existing data (SA government, Beach Energy) and models such as the models (SA Government, CSIRO, Flinders) developed and used in the CSIRO projects (GOYDER). To allow an effective integration of these data and models into the work a workshop will be held at the start of the project. The workshop will provide a communication platform between the project team and key stakeholders such as, Beach Energy, SA government and CSIRO and University researchers.
TASK OBJECTIVE: The main objectives of the workshop are;

- to ascertain that all existing data, models and knowledge is adequately incorporated into the project and that key stakeholders have the opportunity to provide additional feedback on the data collection strategy and the modelling approach.
- to review and ascertain the opportunities for using data from existing wells of SA government and the gas industry
- to establish a longer-term connection between the researchers of this new project and the stakeholders and to coordinate interactions and a communication platform that will ascertain close interactions throughout the remainder of the project.

TASK OUTPUTS: Refined work plan for the project
SPECIFIC DELIVERABLES: ½ - 1 day workshop

PROGRESS REPORT:

This task has been completed. The workshop was conducted on 22nd Oct, 2018. Participants comprised CSIRO, SA Government and industry representatives. The scope and proposed probabilistic methodology for water balance assessment was presented and discussed. Inputs regarding potential water balance areas around conventional gas development sites were sought from the Government agencies. Opportunities for leveraging existing work and models for providing useful background for the proposed work were also discussed and finalised.

Task 2

TASK NAME: Conceptualization and scenario development
TASK LEADER: Russell Crosbie, Cameron Huddlestone-Holmes and Sreekanth Janardhanan
OVERALL TIMEFRAME: August – November 2018
BACKGROUND: The scenario development is a vital input for the prediction of future states of groundwater balance components that will be modelled in Task 3. The gas development pathway for the SE will be developed in conjunction with other GISERA projects and combined with any existing projections for changes in other water users going into the future.
TASK OBJECTIVE: The scenario development is a vital input for the prediction of future states of

groundwater balance components that will be modelled in Task 3. The gas development pathway for the SE will be developed in conjunction with other GISERA projects and combined with any existing projections for changes in other water users going into the future.
TASK OUTPUTS: A list of scenarios to be run for predicting future states of the water balance components under gas and other developments.
SPECIFIC DELIVERABLES: List of scenarios to be run

PROGRESS REPORT:

This task is complete. The child model area and conceptual model was finalised in consultation with stakeholders. The model extent will be 30 x 30 km, centering just south west of Penola in order to include all three proposed wells in the area. The model will extend down to the bottom of the Dilwyn Sands. Any upward flow pathways from the production zone may be simulated with source or sink cells. Two scenario runs with the model will evaluate the relative water takes by the gas industry in relation to recharge and discharge processes in the area.

Task 3

TASK NAME: Development of a child groundwater model
TASK LEADER: Rebecca Doble
OVERALL TIMEFRAME: August 2018 - February 2019
BACKGROUND: The regional scale groundwater model developed during the Goyder SE project was intended to answer regional scale questions and to provide the boundary conditions for finer scale models that can be built to answer more specific local questions. The existing regional scale groundwater model will provide the boundary conditions for the development of a more detailed child model.
TASK OBJECTIVE: The objective of this task is to build a fit-for-purpose child model from the existing regional scale groundwater model. This new model will be capable of simulating changes in flow and water balance on the scale of 100's of metres which is commensurate with the scale of the gas development as opposed to the existing regional scale model where impacts would not be seen due to the grid resolution. The domain for the child model will be 'cut out' of the existing regional scale model, or based on the Wattle Range model of DEW, ensuring that the model boundaries are compatible to each other and thus tenable for interacting with each other in a loosely-coupled manner. This framework enables CSIRO to leverage the existing model to provide the model inputs, boundary conditions and parameters for the child model while the scale of child model is adapted to answer the specific questions raised by the model objectives.
TASK OUTPUTS: Develop a fit-for-purpose child model from the existing regional scale groundwater model.
SPECIFIC DELIVERABLES: Deliver groundwater model to Task 3.

PROGRESS REPORT:

Groundwater model development is 100% completed. A 'child' numerical groundwater model that encompasses the existing and proposed conventional gas wells in the Penola region has been developed. The model development was based on the regional groundwater model of the Department of Environment and Water for the South East. Vertically the model extends to over 300 m depth from the surface to include the two major aquifers in the region and assess the likelihood of water extraction for conventional gas development negatively impacting the groundwater

resource in the area. The model will be base calibrated and assessed for prediction uncertainties. It will then be used for predictive analysis of potential impacts including drawdown and simulation of flow paths and distances of particles from the gas wells to risk receptors to assess the likelihood of transport of particles from the gas wells to the receptors over a simulation period of 100 years.

Task 4

TASK NAME: Model calibration and uncertainty analysis

TASK LEADER: Sreekanth Janardhanan

OVERALL TIMEFRAME: September 2018 – June 2019

BACKGROUND: In this task, the state-of-the-science child groundwater model developed in task 2 will be used in conjunction with the regional scale model for calibration of the model parameters using latest available groundwater data. Depending on the suitability, the model will be calibrated using the PEST suite of software by using highly or parsimoniously parameterized modelling approaches. Un-constrained Monte Carlo simulation or the calibration constrained method called Null-Space Monte Carlo will then be employed, depending on data-availability, to make predictive simulations of groundwater pressure and water level changes.

TASK OBJECTIVE: Calibrate the model basis that can be used to predict groundwater pressure changes and further perform calibration constrained uncertainty analysis to delineate monitoring zones.

TASK OUTPUTS: The task will deliver the modelling and uncertainty analysis framework that is required for probabilistic water balance analysis.

SPECIFIC DELIVERABLES: Draft chapter on stochastic modelling and data-worth analysis

PROGRESS REPORT:

This task is 100% complete. A novel method for estimating the prior and posterior parameter distributions was implemented for the newly developed child model. Also, a novel tool developed inhouse called netR package (Doble et al, 2017) was implemented to assist in improved calibration of the model. The calibration and uncertainty analysis together provide the probable range of model parameters and inputs that can be used in the scenario analyses for probabilistically quantifying the impacts.

Task 5

TASK NAME: Water balance and groundwater impact analysis

TASK LEADER: Sreekanth Janardhanan and Rebecca Doble

OVERALL TIMEFRAME: June 2019 – March 2020

BACKGROUND: Realistic estimates of the ranges of some components of groundwater balance such as the diffuse recharge from rainfall, the amount of storage and the discharge through rivers can be estimated independently for a selected region. For example, long-term mean recharge can be derived from a Chloride mass balance analysis or environmental tracer analysis. The independent water budget estimates forms a key component of a conceptual model and provides context for groundwater modelling to evaluate the effects of anthropogenic and other stressors on the availability and sustainability of resource.

TASK OBJECTIVE: The specific objective of this task is to conduct independent groundwater budget analysis to provide constraints for any subsequent work as it estimates the magnitude of

current fluxes. All existing estimates of the water balance components will be collated and reviewed. Posterior distribution of other groundwater flow parameters that are correlated with independently estimated water balance components will be obtained from the calibration and uncertainty analysis undertaken in task 3. The independently estimated water balance components will be integrated in a mass balance calculation in the numerical model. The water balance analysis also help identify important components, processes and stresses of the groundwater system.

TASK OUTPUTS: A tabulation of estimates of water balance components with associated uncertainties for the chosen water balance area that encompasses the onshore gas development well fields. An assessment of the effect of onshore gas induced changes to important receptor locations including significant wetlands in the region

SPECIFIC DELIVERABLES: Historical water balance and analysis of impacts to key receptor locations including significant wetlands

PROGRESS REPORT:

This task is 100% complete. The final report is now complete and has been published on the GISERA website.