Australia's National
Science Agency

GISERA | Gas Industry Social and Environmental Research Alliance

Project Order

Short Project Title

Methane contributions from holding ponds – a desktop study

Long Project Title	Methane contributions from holding ponds – a desktop study to identify emissions potential and controls in CSG holding ponds and aquatic systems in Queensland
GISERA Project Number	G.9
Start Date	25/07/2022
End Date	30/11/2022
Project Leader	Kaydy Pinetown

GISERA State/Territory

- [x] Queensland
- [ ] New South Wales
- [ ] Northern Territory
- [ ] South Australia
- [ ] Western Australia
- [ ] Victoria
- [ ] National scale project

Basin(s)

- [x] Adavale
- [ ] Amadeus
- [ ] Beetaloo
- [ ] Canning
- [ ] Western Australia
- [ ] Carnarvon
- [ ] Clarence-Morton
- [x] Cooper
- [ ] Eromanga
- [x] Galilee
- [ ] Gippsland
- [ ] Gloucester
- [ ] Gunnedah
- [ ] Maryborough
- [ ] McArthur
- [x] North Bowen
- [ ] Otway
- [ ] Perth
- [ ] South Nicholson
- [x] Surat
- [ ] Other (please specify)

GISERA Research Program

- [ ] Water Research
- [ ] Health Research
- [ ] Biodiversity Research
- [ ] Social & Economic Research
- [x] Greenhouse Gas Research
- [ ] Agricultural Land Management Research
- [ ] Other (please specify)

1. Project Summary

With substantial ongoing community concerns about fugitive methane emissions from onshore natural gas production, accurately accounting for, locating and mitigating sources of unintended releases of methane are critical to reducing the potential climate impacts from natural gas production (e.g., U.S. Methane Emissions Reduction Action Plan, 2021). International, Australian and CSIRO's GISERA research into a range of different emission sources (by process or sector) have been categorised and reported on through various channels to increase knowledge and reduce uncertainty in industry-wide methane fugitive emissions (for comprehensive information head to https://gisera.csiro.au/research/greenhouse-gas-and-air-quality/methane-seepage-in-the-surat-basin/). Methodologies for the identification and quantification of infrastructure leakage of fugitive emissions have provided accurate input parameters for calculation of industrial emissions for methane for Commonwealth Government's National Greenhouse Gas Inventory, particularly for fugitive emissions from infrastructure (Ong et al, 2017). However, there remain significant knowledge gaps in our understanding of the contribution to methane emissions from coal seam gas (CSG) water holding ponds. This project will commence the reduction in this uncertainty through a desktop survey, identification of knowledge gaps, collation of existing company data and development of a field survey program that will reduce uncertainty of the potential contributions to emissions from water holding ponds. The outcomes of this project will be used to design future data collection approaches and a preferred methodology for accurately quantifying methane emissions for water holding ponds in Queensland. This will ensure complete coverage of all aspects of natural gas production for fugitive emissions in the National Greenhouse Gas Inventory and will contribute to enhanced community understanding of the level of risk to potential climate impacts from natural gas production in Queensland.

2. Project description

Introduction

Quantifying and reporting emissions is becoming more rigorous and specific in the context of global efforts to become Net Zero. Australia aims to achieve net zero emissions by 2050 (Australia's long-term emissions reduction plan, 2021). This has been echoed globally, and as well as ongoing work to reduce carbon dioxide emissions, there is renewed focus on fugitive methane emissions in the light of the U.S. Methane Emissions Reduction Action Plan (2021) and related Global Methane Pledge (https://www.ccacoalition.org/en/resources/global-methane-pledge).

Some fugitive emission processes are highly variable, uncertain and difficult to measure, making estimates potentially contentious. In the case of water holding ponds, there has until recently, been little published or discoverable information. This project aims to better understand the contribution

of potential fugitive emissions from holding ponds relative to other aspects of CSG activities, and also put the data in context of the scale of natural methane from water bodies.

The need for "Transparency and disclosure of actionable data" (US Methane Emissions Reduction Action Plan, 2021), means that defining methane sources is very important to the overall management of methane as a major greenhouse gas. In Australia, the Commonwealth Government has identified water holding ponds as a significant source of uncertainty in calculating fugitive emissions from natural gas production. While some sources of methane have been measured with detail and high levels of accuracy, in particular for fugitive emissions in natural gas infrastructure (Ong et al, 2017 and other reports by CSIRO's GISERA) in Queensland, New South Wales and Northern Territory, there are gaps in knowledge, or only limited quantified data and detail for other sources that could be quantitatively significant. Communities living alongside CSG operations want to be assured that all emissions from natural gas production are comprehensively accounted for. One gap that contributes to uncertainty in GHG emissions accounts relates to water holding ponds for CSG onshore gas production operations.

The question around the contribution of holding ponds to emissions was highlighted recently in the Australian public domain as a result of a publication in 2021 by Neininger *et al.* and an international team of collaborators. The paper on "CSG industry methane emissions in the Surat Basin, Australia: Comparing airborne measurements with inventories" used airborne measurements to measure emissions from a coal seam gas field in the Surat Basin. The authors compared the results with both international oil and gas field data with current and a historical series of measurements for central Queensland. Their conclusion was that there were missing elements in the emissions inventories and raised concerns that other potential contributors of methane emissions may have previously been overlooked, such as water holding ponds. The paper was taken up by media outlets and presented in the media (ABC 7:30 Report).

Both the published study and the work proposed for this project addresses the following community concerns:

- GHG emissions and air quality have been consistently ranked highly in GISERA Surveys of community concerns of natural gas development over a number of years

- Internationally, there has been increased focus on methane fugitives (e.g., U.S. Methane Emissions Reduction Action Plan, 2021) and COP 26 actions and pledges.

The Neininger *et al.* (2021) paper also:

- Cast doubt on the accuracy of some emissions measurements

- Cast doubt on who the major producers and contributors to emissions are

- Asked which methods are most accurate and how are they validated/calibrated

The paper also claimed that:

- Emissions from holding ponds were larger than expected, relative to other fugitive sources
- Plumes were observed but not previously measured on the ground or incorporated to regional measurements.

Previously, it had been anticipated that the contribution to fugitive methane emissions from holding ponds would be small, relative to other GHG emissions from pipelines or compression units; however, there appears to be only limited publicly available information on actual volumes, the range and type of measurements, and their diurnal and seasonal behaviour.

The objective of this study is to conduct a detailed desktop study to close the knowledge gap on the contributions of holding ponds (partly through comparison with aquatic systems such as natural terrestrial water bodies) to determine an additional aspect of methane fugitive emissions from natural gas production. As there are limited data so far on emissions from CSG holding ponds, the project will also seek to evaluate quantified information from similar natural water bodies to GHG emissions. This will provide some adjacent information on the relative contributions and key controls on the rates of emissions from aquatic systems such as lakes, ponds and pools. If emission levels appear significant for holding ponds or natural equivalents, the study will identify an analytical investigative field strategy to quantify emissions over time to add to existing CSG holding pond data. This desktop study will also consider what data exists with companies on this topic, what knowledge gaps still exist and how emissions can be managed or mitigated through additives and treatments. New information gained from this project will contribute directly to improved accuracy in the Commonwealth Government's National Greenhouse Gas Inventory.

Some data and measurements for holding ponds that have been published by Ong et al, (2017) for NSW examples range from 3-40 kg/day methane. The measurements are broad in range. Currently, any data published elsewhere lack harmonisation and are presented in different units of measurement, with flux and concentration data, over minutes, hours, days and other cycles. This illustrates the need for more measurements and harmonising existing and new data to better set context for how significant emissions contributions from holding ponds may be.

Researchers have developed methods and approaches to accurately quantify fugitive emissions from CSG and other gas production infrastructure onshore in Australia. Some of this work previously conducted by GISERA can be found here https://gisera.csiro.au/research/greenhouse-gas-and-air-quality/methane-seepage-in-the-surat-basin/. Previous work undertaken by CSIRO's GISERA also notes that "The median fugitive emissions from measurements of CSG wells in Queensland and NSW is less than 1kg/day with 1% of wells releasing 63 kg/day. Well completion and work-over

measurements show releases of 200 kg/day and 20 t/day, respectively. Measurements made at a CSG water treatment plant were between 18 and 32 kg/day and from a CSG compression plant, emissions were 780 kg/day. (See: https://gisera.csiro.au/fugitive-methane-emissions-factsheet/). This project will determine where along this range of sources water holding ponds lie in terms of their fugitive emissions.

In brief, work conducted by CSIRO's GISERA has consistently shown that Australian measurements of fugitive emissions are far lower than equivalent infrastructure in the US. This is due in part to the newer infrastructure and more robust state government environmental regulation that has come after lessons learned in the US. However, water holding ponds and terrestrial aquatic bodies have not undergone the same thorough investigation, and so significant knowledge gaps remain.

This project will aim to focus on finding quantitative data on fugitive methane emissions from wastewater treatment facilities. The greatest uncertainty in contribution is from the initial raw water holding ponds closest to the inlet from the well production and separator on the left of both examples in Figure 1. On the right-hand side of both examples, Figure 1, are the cleaned and beneficial reuse water and the residual brine ponds. As industry routinely measures the waters sent to beneficial re-use, the team may review the publicly available information, but based on the flow charts (Figure1) it is unlikely that any gaseous emissions would remain at that point of any quantitative significance. The review of literature, incorporating company and publicly available data, will reduce uncertainty as to the methane contributions from holding ponds, set in the context of natural water bodies and benchmarked alongside other CSG fugitive emissions already well quantified. This evaluation will allow for the identification of appropriate analytical methods and sampling campaigns to be able to quantify methane as well as potential controls (organic, inorganic and microbial species) that can control emissions over time.

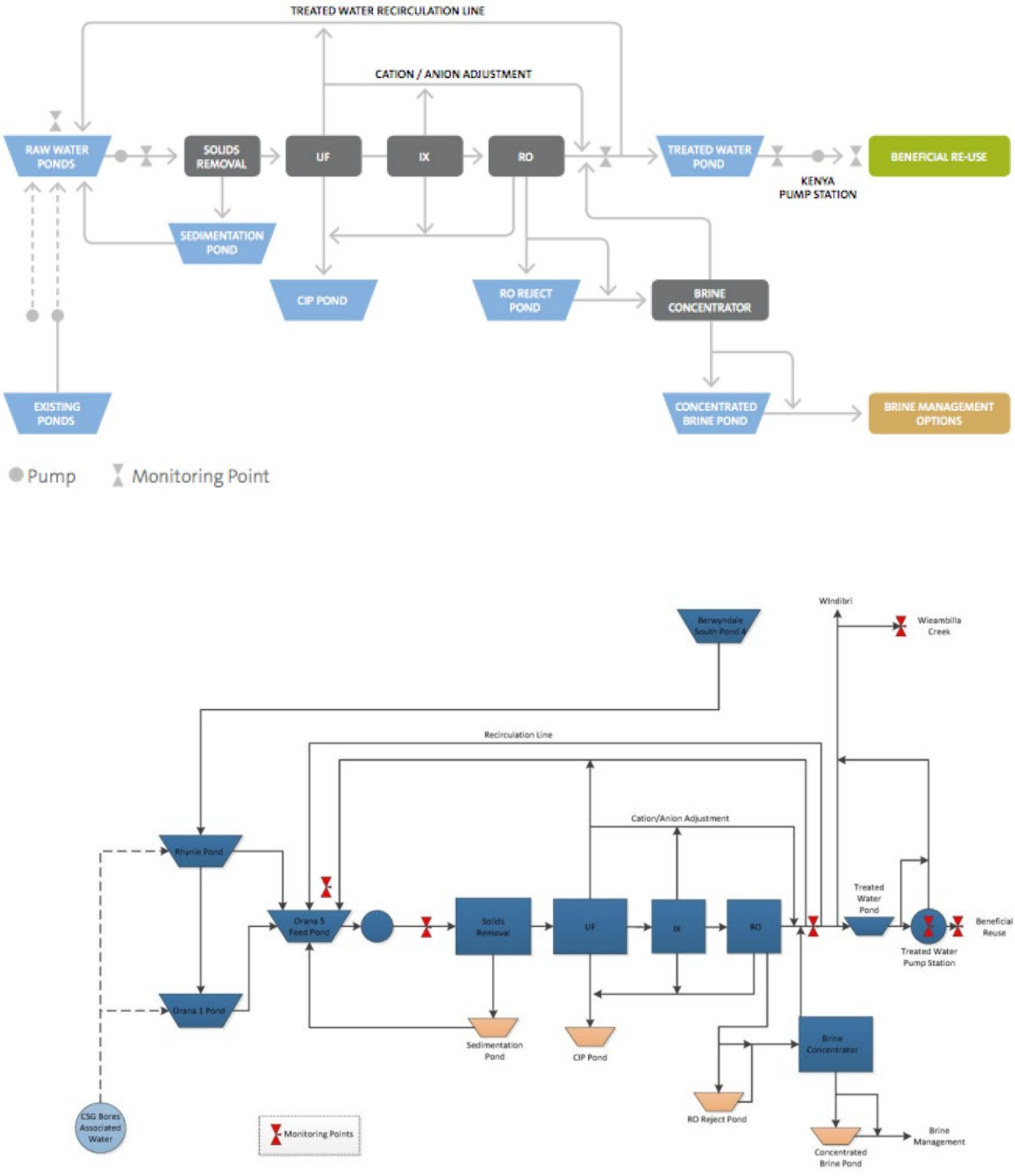

Figure 1 Upper figure of a schematic of a CSG water treatment plant (Queensland Gas Company, 2013; link here) and lower figure of the Kenya Water Treatment Facility (https://www.sunwater.com.au/wp-content/uploads/Home/Customer/Water-Quality/Chinchilla_Quarterly_Report_Q1_2015.pdf

Prior Research

There is little information on emissions from industrial waterbodies such as CSG holding ponds, so a detailed study is necessary to quantify the range of emissions, and the potential controls on these emissions, so that they can be managed and mitigated if required. Limited existing data and publications on emissions from aquatic systems such as freshwater lakes and ponds indicate they may be a significant natural source of methane. However, there is a degree of uncertainty around the scale of these emissions over time.

A few examples of information from a range of terrestrial water bodies and aquatic systems are as follows:

- Berlin in Germany: Total CH_4 emission from 32 water bodies in Berlin over four seasons is 2,600 t CH_4 per year. Small water bodies (area < 1 ha) typically located in urban green spaces were identified as emission hotspots (Herrero Ortega et al. 2019).
- Silkeborg in Denmark: Total urban ponds emit approximately 38,000 t CO_2 equivalent per year based on CH_4 and CO_2 emissions from 37 ponds in Silkeborg over four seasons (Audet et al. 2020).
- Uppsala in Sweden: A total emission of 83,000 t CO_2 equivalent per year in Sweden was estimated based on 40 urban ponds in Uppsala (Peacock et al. 2019).
- Lake Erie in North America: A total emission of 500,000 t CO_2 equivalent per year from Lake Erie with a surface area of 25,700 km^2 (Fernandez et al. 2020).
- Malden in the Netherlands: An emission of 3.4 kg CO_2 equivalent per year was estimated from one urban pond with an area of 4635 m^2 in Malden, the Netherlands (van Bergen et al. 2019).

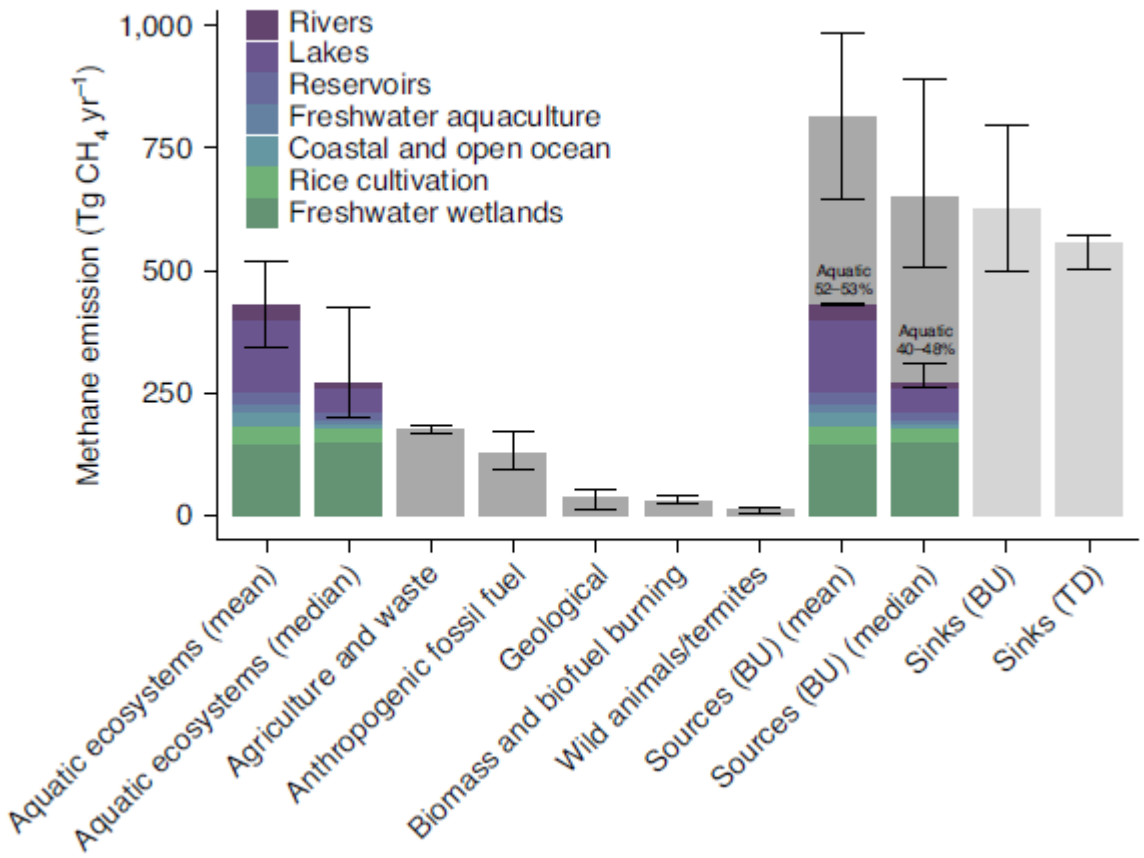

Figure 2 Range of data reported by Rosenstreter et al (2021) showing the range of methane emissions from aquatic systems. Previously it had been assumed that water bodies provided only minor inputs relative to agriculture etc.

Rosenstreter et al (2021) have consolidated a range of data from aquatic systems, both natural terrestrial systems and other types, and noted that the contribution of methane from these systems are greater than previously anticipated (Figure 2).
Methane emissions from the CSG holding ponds are not well characterised and to date, only one CSG holding pond in Queensland has been documented:

- Condamine Catchment, Surat Basin: A continuous mobile methane survey reported an area of elevated methane with a peak concentration of 2.107 ppm and a width of 2.3 km adjacent to a CSG pond in the downwind direction, whereas the background methane concentration was 1.774 ppm in the region (Iverach et al. 2015).

Therefore, the contribution of holding ponds to greenhouse gas emissions in respect of CSG operations are not well represented in the literature and so can only be inferred. This project aims to more thoroughly evaluate the potential for holding ponds to emit greenhouse gases and how that might vary over time. It will be important to establishing the potential holding pond emissions in Queensland relative to other international examples, so it is critical that well designed field work and

sampling campaigns are conducted in the future to measure the emissions response in unique Australian settings.

In a number of workshops facilitated by GISERA, repeated requests have come from Commonwealth Government Representatives on the need to quantify the contribution of holding ponds in CSG operations to methane emissions. CSG operations are known to be large producers of water. From previous GISERA work, these waters may contain inorganic components such as particulates and clays from the formation being produced, dissolved minerals and elements, and organic components such as coal particles, dissolved hydrocarbons including gaseous species, and depending on depths and temperature conditions, the potential for active microbial communities. These fluids may directly contribute towards GHG emissions from exsolution or ebullition of gas as the water reaches the surface. However, there is potentially a large carbon loading in the fluids that can react or be consumed to alter the contribution of GHGs. As noted, several times, the overall information is limited, and not collected in a systematic, harmonised, or detailed manner. Work by Neininger et al (2021) in collaboration with B. Kelly of UNSW, and discussions with Prof. Kelly have provided further insight into their observations and the team feels that there is a gap in measuring discrete holding ponds to be added to the overall inventory.

Relevant State/Territory Government independent reviews

GHG emissions associated with CSG exploration and production have been identified as a major public concern by independent reviews of the CSG industry in Queensland:

- *https://www.stateoftheenvironment.des.qld.gov.au/pollution/greenhouse-gas-emissions;*
- *https://www.qao.qld.gov.au/reports-resources/reports-parliament/managing-coal-seam-gas-activities;*
- *https://cabinet.qld.gov.au/documents/2016/Oct/RevGasComm/Attachments/Report.PDF*.

This has been confirmed by CSIRO's GISERA's recent stakeholder survey, conducted in 2021 where GHG emissions have been noted to be particularly important to the community.

Need & Scope

The quantities of water involved in CSG extraction can be significant with produced water volumes being greatest during the initial stages of well development. An early precursor to this proposed literature review and information described above has begun to reveal that waterbodies are likely to be significant contributors to global GHG emissions. In the case of CSG holding ponds, this could be from direct operations, mobilising dissolved organic and inorganic carbon, microbial activity and other

chemical responses. However, there is a massive data and knowledge gap as few measurements have been reported in regions where CSG operations occur.

Emissions from CSG holding ponds may represent a significant, but as yet unidentified, contributor to GHG emissions source that has not been included in industry estimates of fugitives. The potential for a gap between the use of top-down versus bottom-up inventory and accounting mechanisms also pose a challenge. Since the characteristics of produced water are highly variable in terms of their geologic origin, geographic setting, chemical make-up, and host microbiomes, a comprehensive study is required to understand the potential of these water bodies to contribute to fugitive emissions generated from CSG.

This study will:

- Develop a synthesis of current and emerging literature on natural and other terrestrial slow moving aquatic bodies (ponds, pools or lakes) relating to GHG emissions
- Collate and analyse existing company and publicly available data on methane emissions from water holding ponds
- Define appropriate sampling methodologies and protocols for both the GHG and associated geomicrobiological information that may impact the production or consumption of emissions in holding ponds
- Develop a field campaign strategy that would quantify methane emissions and their controls
- Conduct a first pass assessment of potential mitigation methods

Methodology

This desktop study aims to fill knowledge gaps in fugitive methane emissions from CSG water holding ponds and benchmark these against natural aquatic systems, by

- Reviewing the growing literature on water holding ponds and natural water bodies, such as terrestrial ponds, lakes or pools, to provide context on relative contributions, harmonise any data identified for comparative purposes

- Collating data from industry and publicly available datasets.

- Developing an emissions monitoring strategy for the ponds (i.e., sampling protocols and analytical methods)

- Designing field surveys to obtain information on controls (diurnal, seasonal and operational factors as well as water chemistry, residual hydrocarbons, particulate materials and microbiological controls)

- Providing a robust sampling workflow to assess contributions from water storage and handling treatments at CSG sites.

- Examining potential mitigation strategies for fugitive emissions reductions from water holding ponds.

This project closes a knowledge gap so that the scale of methane emissions can be better understood, monitored and mitigated. In the context of all potential methane emissions sources, understanding relative contributions from CSG operations will be important context for the community, so that major emissions points can be better identified, quantified, and managed for the future.

GHG emissions from CSG holding ponds are likely to be affected by numerous factors, including water volumes and chemistry, carbon content, nutrient availability, and microbial community composition, as well as climatic conditions in the various regions of Australia in which they are located. These data are not readily available in one place and are held in various public databases, published studies and in datasets held by industry/government. The project will develop options for closing knowledge gaps and propose future research and requirements for monitoring of CSG holding ponds. Any field campaigns and proposals will be developed at the end of this project as a new proposal.

Outcome: A comprehensive scientific report and communication activity to stakeholders that advances the understanding of the potential extent of GHG emissions from holding ponds and how it compares to other structures and sites as discussed above. The report will also identify appropriate tools and methodologies to quantify methane emissions from holding ponds and natural water bodies, so that generation mechanisms and controls can be identified. A set of field campaign activities will be developed so that at a future stage relevant data can be collected for holding ponds and natural water bodies in Queensland.

3. Project Inputs

Resources and collaborations

Researcher	Time Commitment (project as a whole)	Principle area of expertise	Years of experience	Organisation
Linda Stalker	5 days	Gas geochemistry and stable isotopes, monitoring and verification, organic geochemistry	+30 years	CSIRO
Kaydy Pinetown	25 days	Gas reservoir characterisation, coal and organic rock characterisation, emissions assessment	+20 years	CSIRO
Se Gong	20 days	Organic and biogeochemistry	+15 years	CSIRO
David Midgely	5 days	Microbial ecology, bioinformatics	+15 years	CSIRO
Emma Crooke	14 days	Biogeochemistry and microbiology	+15 years	CSIRO
Richard Schinteie	14 days	Biogeochemistry and microbiology	+15 years	CSIRO

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

Technical Reference Group

The project will establish a Technical Reference Group (TRG) that will include the project leader and a group of different stakeholders as appropriate which may include:

- Australia Pacific LNG representative
- QGC representative
- Origin Energy representative
- Shell representative
- Arrow Energy representative
- UQ's Centre for Natural Gas representative
- Office of Groundwater Impact Assessment representative
- QLD Government representative

5. Project Plan

Project Schedule

ID	Activities / Task Title	Task Leader	Scheduled Start	Scheduled Finish	Predecessor
Task 1	Desktop study of methane contributions from holding ponds	Linda Stalker	25 July 2022	30 November 2022	N/A

Task description

Task 1: Desktop study of methane contributions from holding ponds

OVERALL TIMEFRAME: July 2022 - November 2022

BACKGROUND: To assess the significance of methane emissions from CSG water holding facilities in context of other emissions from the onshore gas industry and aquatic systems and natural water bodies, a survey of available literature and industry data will be conducted, identifying key controls, and assessing best analytical protocols to quantify emissions in the field.

TASK OBJECTIVES: Conduct data discovery through a literature survey of holding pond GHG emissions. This will include a review of emissions from holding ponds and water treatment facilities, and other potential operational sources. A review of emissions from other natural aquatic systems (e.g., lakes, ponds, pools) will also be conducted. Aspects such as the seasonal and diurnal controls on holding pond emissions will be assessed. The task will reduce uncertainty as to whether methane emissions from holding ponds are quantitatively significant and close a major knowledge gap. An assessment of best practise analytical methods will be conducted with a view to developing a scientific field campaign workflow for future project investigations and data collection in Queensland.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: Review completed, and outputs are used to reduce uncertainty surrounding the potential for methane emissions from holding ponds in Queensland.

6. Budget Summary

Expenditure	2021/22	2022/23	2023/24	2024/25	2025/26	Total
Labour	$0	$123,739	$0	$0	$0	$123,739
Operating	$0	$13,600	$0	$0	$0	$13,600
Subcontractors	$0	$0	$0	$0	$0	$0
Total Expenditure	**$0**	**$137,338**	**$0**	**$0**	**$0**	**$137,338**

Expenditure per task	2021/22	2022/23	2023/24	2024/25	2025/26	Total
Task 1	$0	$137,338	$0	$0	$0	$137,338
Total Expenditure	**$0**	**$137,338**	**$0**	**$0**	**$0**	**$137,338**

Source of Cash Contributions	2021/22	2022/23	2023/24	2024/25	2025/26	Total
Federal Govt (53%)	$0	$72,789	$0	$0	$0	$72,789
APLNG (20%)	$0	$27,467	$0	$0	$0	$27,467
QGC (7%)	$0	$9,614	$0	$0	$0	$9,614
Total Cash Contributions	**$0**	**$109,870**	**$0**	**$0**	**$0**	**$109,870**

In-Kind Contributions	2021/22	2022/23	2023/24	2024/25	2025/26	Total
CSIRO (20%)	$0	$27,467	$0	$0	$0	$27,467
Total In-Kind Contributions	**$0**	**$27,467**	**$0**	**$0**	**$0**	**$27,467**

	Total funding over all years	Percentage of Total Budget
Federal Government investment	$72,789	53%
APLNG investment	$27,467	20%
QGC investment	$9,614	7%
CSIRO investment	$27,467	20%
Total Expenditure	**$137,338**	**100%**

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	Desktop study of methane contributions from holding ponds	GISERA	Jul-22	Nov-22	2022/23	$109,870

1. 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 13.1)	**Party**		**Commercialisation Interest**	
	CSIRO		N/A	
	APLNG		N/A	
	QGC		N/A	

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