Project Order, Variations and Research Progress

Project Title: Characterising the regional fluxes of methane seepage in the Surat Basin, Queensland

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

1 Original Project Order

Project Order

Proforma 2012

1. Short Project Title (less than 15 words)

Methane seepage fluxes, Surat Basin, Queensland

Long Project Title	Characterising the regional fluxes of methane seepage in the Surat Basin, Queensland
GISERA Project Number	Gas 1315
Proposed Start Date	June 2013
Proposed End Date	June 2015
Project Leader	Damian Barrett

2. GISERA Research Program

- [ ] Biodiversity Research
- [ ] Marine Research
- [ ] Land Research
- [ ] Water Research
- [ ] Social & Economic Research
- [x] GHG Research

3. Research Leader, Title and Organisation

Prof Damian Barrett
CSIRO Land and Water
Black Mountain Laboratories
Canberra, ACT, 2601

4. Summary (less than 300 words)

This research proposal aims to address significant uncertainties associated with background seepage of methane and its detection and measurement in the Surat Basin, Queensland. By seepage we refer to the diffusive flux of methane to the atmosphere through the land surface and water bodies, the localised flux of methane *via* connectivity pathways consisting of leads, faults and outcrops and the flux from agricultural wells and bores. It does not consider the fugitive emissions of methane occurring as part of open cut and underground coal mines or emissions occurring from infrastructure (wells, compressors, associated water reticulation, or gas pipelines) associated with CSG production.

The research will provide:

(1) A desktop review and analysis of remote sensing imaging and direct detection (ground based flux) methods to quantify methane sources and fluxes;

(2) A field trial of methods at (a) a remote sensing pilot site, and (b) a ground based direct detection and monitoring pilot site. The remote sensing pilot will test the acceptable method(s) developed in Task 1 for deployment within a defined test area and ability to detect methane seeps more broadly in the Upper Condamine River catchment. The ground detection and monitoring pilot will test *in situ* measurement of on-ground methane fluxes at up to two pilot sites. Isotopic chemical tracers will assist in distinguishing coal methane seeps from biogenic methane sources. Each pilot is contingent on results from Task 1 and the client's input at decision points in the project; and,

(3) broad scale application of methods to a larger region in the Upper Condamine River catchment. This research will provide baseline monitoring data of methane seepage fluxes over different seasons. The final design is contingent on results from Tasks 1 and 2, their successful application and the client's input at decision points.

The following table provides a summary of the aims, methods, outputs and outcomes of this project:

Research Aim	Research Methods	Outputs	OUTCOMES
Year 1			
Task 1. A literature review of the science on all methods and technologies of CH_4 measurement in light of their applicability to quantifying fluxes and their variations at a range of spatial and temporal scales in the Surat Basin, Queensland.	Desktop study of scientific literature with, potentially, limited numerical modeling using synthetic or limited datasets to demonstrate feasibility of methods and their applicability to the measurement of diffuse CH_4 fluxes from a range of potential sources (including but not confined to terrestrial outcrops, preferential pathways, alluvium losses, river fluxes, biogenic sources, agricultural wells, and other infrastructure not part of CSG development fields).	A report advising on the scientific capabilities of all forms of CH_4 detection and measurement methodologies to be used in the Surat Basin to quantify fluxes and sources of background emissions.	A comprehensive assessment of the application of methods of CH_4 detection and measurement to an important sedimentary basin in which CSG development is underway.
Task 1.The development of agreed plans for a pilot program for measuring CH_4 fluxes on at least one study site.	Scoping of a pilot program of application of methods for CH4 flux measurement and its sources.	The report is to include a plan for deployment of these activities as part of a pilot study (Task 2) and year one of an ongoing baseline-monitoring program (Task 3).	A fully scoped plan for analysis of CH4 fluxes and sources for an important sedimentary basin in which CSG development is underway.
Task 2. Based on successful development of a plan pilot program, deploy appropriate technology for the measurement and sourcing of CH_4 from sources in the Surat Basin.	Deploy CH_4 measurement technologies as agreed in Task 1 (including, but not limited to, FTIR spectroscopy, laser, atmospheric concentration measurement, inverse atmospheric transport modeling, eddy covariance measurement, Flux chamber measurement, hyperspectral imaging, and/or isotope sampling) at pilot test site(s). Establish value of applied methodologies and identify uncertainties/gaps in their application. Scope plan for deployment of methods for one year to establish baseline monitoring	A report on the application of specified CH_4 methods at the pilot test site(s), the value of measurements and analysis and recommendations for development of the pilot test into a baseline-monitoring program.	A scientifically defensible pilot program to demonstrate the value of application of CH_4 measurement methodologies in the Surat Basin for the purpose of developing a long term monitoring program as CSG development occurs.
Year 2			
Task 3. Based on successful demonstration of value of the pilot program, deploy appropriate technology for CH_4 measurement and sourcing for the purpose of initiating a baseline monitoring study.	Application of the demonstrated methods to long term monitoring conditions. Analysis of the variation in CH4 fluxes from various sources in time and space. Analysis of the attribution of sources of CH4 fluxes to biogenic/thermogenic origins. An assessment of the value of baseline monitoring of background CH_4 fluxes.	A report on the long-term application of specified technologies for measurement of CH_4 fluxes and their sources in the Surat basin, Queensland, including an assessment of the degree of variation in fluxes on a range of space and time scales and specifications for ongoing operation of a baseline monitoring program.	The foundation of a baseline monitoring program, its methods and quantified uncertainties that will underpin an ongoing, long term monitoring program for the Surat Basin.

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

Expenditure	2011/12 Year 1	2012/13 Year 2	2013/14 Year 3	2014/15 Year 4	2015/16 Year 5	Total
Labour			471,837	822,706		1,294,543
Operating			267,000	123,000		390,000
Total Costs						
CSIRO			738,837	945,705		1,684,543
Total Expenditure			**738,837**	**945,706**		**1,684,543**

Expenditure per Task	2011/12 Year 1	2012/13 Year 2	2013/14 Year 3	2014/15 Year 4	2015/16 Year 5	Total
Task 1			111,553			
Task 2			627,284			
Task 3				945,706		
Task 4						
Task 5						
Total Expenditure			**738,837**	**945,706**		**1,684,542**

Cash Funds to Project Partners	2011/12 Year 1	2012/13 Year 2	2013/14 Year 3	2014/15 Year 4	2015/16 Year 5	Total
CSIRO			537,755	583,952		1,121,707
Total Cash to Partners			537,755	583,952		1,121,707

Source of Cash Contributions	2011/12 Year 1	2012/13 Year 2	2013/14 Year 3	2014/15 Year 4	2015/16 Year 5	Total
Australia Pacific LNG (on behalf of APPEA)			537,755	583,952		1,121,707
Total Cash Contributions			**537,755**	**583,952**		**1,121,707**

In- Kind Contribution from Partners	2011/12 Year 1	2012/13 Year 2	2013/14 Year 3	2014/15 Year 4	2015/16 Year 5	Total
CSIRO			201,082	361,753		562,835
Total In- Kind Contribution from Partners			**201,082**	**361,753**		**562,835**

	Total funding over all years	Percentage of Total Budget
Australia Pacific LNG (on behalf of APPEA) investment	$1,121,707	66.6%
CSIRO Investment	$562,835	33.4%
Total Other Investment		
TOTAL	**$1,684,542**	**100%**

Task	Milestone Number	Milestone Description	Funded by	Participant Recipient	Start Date (mm- yy)	Delivery Date (mm- yy)	Fiscal Year	Fiscal Quarter	Payment $
Task 1	1.1	Report on review and analysis of literature on detecting and measuring diffuse sources of methane seeps and proposal for discrete testing at pilot sites in Task 2	GISERA	CSIRO	1.07.2013	31.08.2013	2013/14	1	$74,937
Task 2	2.1	Remote sensing pilot study	GISERA	CSIRO	1.09.2013	30.03.2014	2013/14	3	$81,701
Task 2	2.2	Ground detection pilot study	GISERA	CSIRO	1.10.2013	30.06.2014	2013/14	4	$399,116
Task 3	3.1	Remote sensing baseline study	GISERA	CSIRO	1.07.2014	30.06.2015	2014/15	4	$162,319
Task 3	3.2	Ground detection baseline study	GISERA	CSIRO	1.07.2014	30.06.2015	2014/15	4	$403,634

6. Other Researchers

Researcher	Time Commitment (project as a whole)	Principle area of expertise	Years of experience	Organisation
Damian Barrett	0.05	Environmental science and resources sector	>20	CSIRO
Stuart Day	0.30	Methane sensing and detection	25	CSIRO
David Etheridge	0.50	Atmospheric trace gas composition and fluxes	20	CSIRO
Brad Sherman	0.20	Methane flux measurement in aquatic environments	>12	CSIRO
Ashok Lumar	0.40	Atmospheric transport modelling	20	CSIRO
Zoe Loh	0.40	Concentration measurements and interpretation	5	CSIRO
Colin Allison	0.35	Isotopes and tracers	20	CSIRO
Cindy Ong	0.30	Remote sensing	>20	CSIRO
Andrew Roger	0.10	Remote sensing	11	
Mark Dell 'Amico	0.25	Methane sensing and detection	25	CSIRO
Robyn Fry	0.1	Methane emissions	10	CSIRO
Steve Zeglin	0.30	High level skills in flux tower deployment and operation, and related soil and atmospheric measurements	>30	CSIRO
Eva van Gorsel	0.25	Micrometeorology and fluxes	15	CSIRO
Technical Assistant	0.80	Remote atmospheric monitoring, calibrations, data management	5-20	CSIRO

7. GISERA Objectives Addressed

This research will determine the flux and sources of background seeps of methane to the atmosphere which is an important determinant of the GHG footprint and a baseline for estimation of fugitive emissions from industry

8. Program Outcomes Achieved

See section 13

9. Program Outputs Achieved

Details are provided in *Section 15. Project Objectives and Outputs*

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

There is currently no information on the size and source of background methane seepage to the atmosphere from the Surat Basin. This project will provide important baseline information on the characteristics and magnitude of methane seepage.

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

The outputs of this project form the basis of a further project on estimation of methane fugitive emissions by coal seam gas development in the Surat Basin, Queensland.

12. Project Development

The Jurassic and Permian coal beds of eastern Australia have become an increasingly significant source of Australian gas production. Geochemical and isotope data indicate that the considerable stores of methane in these shallow coal seams are the result of CO_2-reduction methanogenesis from microbial activity occurring since uplift of eastern Australian geologic basins during the late Cretaceous and Tertiary (Faiz and Hendry 2006). The known 2P gas reserves in these seams amount to over 35,000 PJ, of which ~92% occur in the Surat and Bowen Basins (Kaye et al 2012).

Methane is a powerful 'greenhouse' gas contributing more than 20 times the global warming potential of CO_2 on a per mass basis. It is the most abundant organic compound in the earth's atmosphere. The total annual source of methane to the atmosphere is estimated to be about 580 Tg/year (Denman et al, 2007) largely from wetlands, lakes, rice cropping and ruminant animal production, biomass burning, landfill, and waste with about 6% from coal mining activities. Natural geological sources may account for about 10% of the total methane source (Lassey et al., 2007; Etiope et al., 2008).

Important geological sources of methane enter the atmosphere through natural seeps and fissures occurring in terrestrial and marine settings. The potential natural sources of methane to the atmosphere from sedimentary basins include surface exposed outcrops of shale and near-surface coal and *via* connectivity pathways along faults, cleavages, and alluvial sediments associated with rivers. 'Background' methane fluxes (i.e. those not associated with the CSG production) occur through biogenic processes in wetlands, swamps, rivers, and dams. In some locations, further background sources of methane are agricultural bores, feed lots, old exploration wells, landfill, wastewater and biomass burning. Fluxes from all of these sources are often episodic, ephemeral and difficult to observe.

It is possible that, in the Surat Basin, Queensland, all of these sources of methane to the atmosphere exist and it is important to be able to distinguish among them to determine those potentially susceptible to CSG production. Baseline data on the fluxes, sources, pathways and variations in natural methane seeps is required to separate 'background' or 'baseline' emissions from other human induced variation in methane emissions particularly in gas production regions such as the Surat Basin. Any perceived variation in methane production from seeps in this region are potential conflict points with communities and hence risks to the gas sector's production if there is a perception, even incorrectly, that the industry is responsible for this variation.

This project will address pathways of methane emissions that are considered 'non-anthropogenic'; that is, natural connectivity between coal seams and coal bearing aquifers and the atmosphere as a result of links occurring between these sources and the surface and will separate these sources of methane from biogenic sources such as decomposition of organic matter and feed lots. It will also consider methane emissions from agricultural wells. Consideration of the impacts of CSG field development on potential connectivity and preferred pathways of methane to the atmosphere will be part of future studies and their mitigation and are not considered in this study. Detection and quantification of fugitive emissions from CSG production will be part of another study to be undertaken by CSIRO (Day et al 2012).

Currently, there is virtually no information on baseline methane seeps in the Surat and no existing study has examined the impacts of coal seam gas development on these background fluxes of methane. Nor have these studies investigated potential impacts of gas field development (both positive and negative) on these fluxes.
This project aims to generate for the first time a comprehensive quantitative estimate of baseline methane emissions from soils, rivers and agricultural infrastructure at a regional scale in the Surat Basin. The project is designed in Tasks that increment knowledge toward this aim. Both the client and research agency have input into decisions during the project on the emphasis and timing of Tasks. The approach is to examine a range of methods and their applications in a phased manner. At the conclusion of the two years, the result will be a comprehensive study of the location and flux of methane seeps (terrestrial and aquatic), the governing processes and sources of methane and the establishment of a baseline against which ongoing monitoring can occur.

13. Project Objectives and Outputs

The three Tasks of this research program build a hierarchy of knowledge whereby later Tasks use information and understanding developed in the earlier Tasks to underpin further work.

The **first Task** consists of a survey, review and analysis of literature on methane detection and measurement. The literature will be assessed on its applicability to develop customised methods for application to the task of quantifying methane sources and fluxes from seeps in the Surat Basin. Utilising the collective, internationally recognised skills within CSIRO, methods for remote sensing imaging, spectroscopy, atmospheric concentration, flux and source detection will be reviewed and a best strategy based on these methods will be proposed for deployment in the Surat Basin in Tasks 2 and 3. Proposals for limited discrete testing of remote sensing and ground detection methods at pilot sites will be completed and evaluated by the client. From this, agreement will be reached on how to proceed with either a remote sensing pilot, a ground detection pilot or both in Task 2. The proposals will include a review of methods for monitoring fluxes to determine baseline sources and potential natural variation. A report will advise on the best methods for deployment of a pilot study flux and establishment of a broader scale application of methods.

The **second Task** will utilise the strategy from Task 1 to deploy a pilot study of methane sources in the Surat basin. The pilot study will be field trial(s) of (a) a remote sensing pilot, and/or (b) a ground based detection and monitoring pilot. The remote sensing approach will test laser and imaging methods. The ground based detection will test the use of atmospheric concentration and flux measurements as inputs to determine the capability of atmospheric transport modelling to determine fluxes of methane on a range of spatial scales. Limited ground based gas geochemistry sampling for isotopic analyses and dissolved methane concentrations will be used to determine whether pilot site methane losses are of biogenic or coal origin and potentially assist with locating the source of the methane.

Finally, the **third Task** will apply a broad scale application of methods to assess regional methane sources (based on Task 2 results) based on remote sensing methods. An option exists to apply these methods to develop a survey of regional methane sources within the Surat basin from which a register of methane sources would be developed for the Condamine. Ongoing ground based monitoring of pilot sites will provide a baseline of methane seepage fluxes and their seasonal variations as the basis of an ongoing monitoring program.

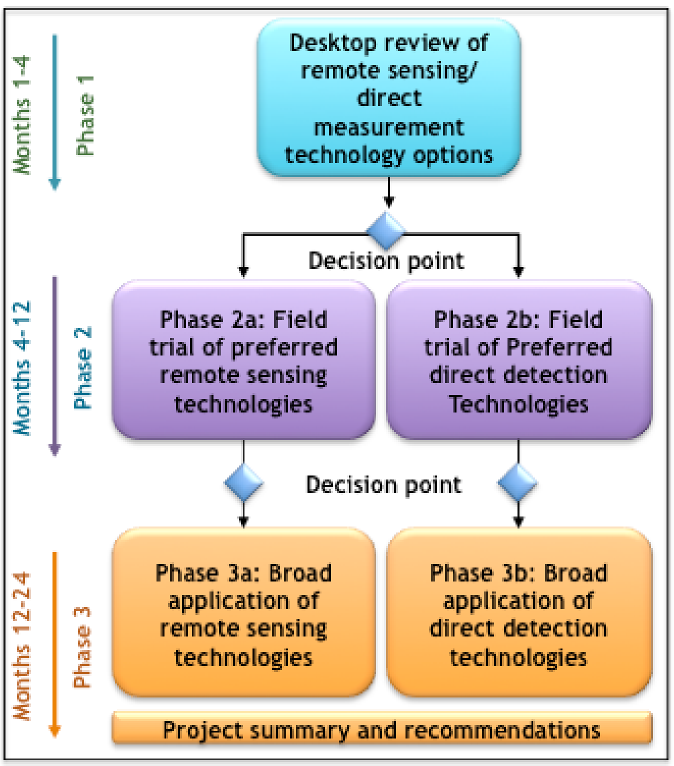
14. Project Plan

The program of work applies existing CSIRO capability to review methods and develop an integrated measurement program of methane sources and fluxes. CSIRO already has expertise in this domain through a well established program of work on coal seam methane fugitive emissions for the coal mining industry and more recently work on fugitives related to coal seam gas production.

The proposed work involves a comprehensive analysis of methane sensing and measurement methods followed by implementation of measurement activities at pilot sites and extensive deployment within the Surat Basin.

The **aim** of this research program is:

To refine methods of methane detection, locate existing significant seeps, identify sources of methane, characterize the flux of gas and develop a scientifically robust baseline of methane fluxes from seeps.



The challenge is to identify methane that has migrated from a coal seam reservoir to the surface *via* seepage and separate these fluxes from other sources (e.g. biogenic methane). The research is designed to proceed in three Tasks with decision points separating each Task. The decision point is designed to ensure shared negotiation/decision making occurs between the Research Advisory Committee, APLNG and CSIRO prior to embarking on Tasks 2 and 3 in order to ensure deliverables are aligned with the best deployment of methods. The decision points also take into account the exploratory nature of the research in recognition of the significant uncertainties surrounding background methane seepage in the Surat Basin. It is possible that parts of Tasks 2 and 3 could be undertaken in a parallel fashion based on mutual agreement between APLNG and CSIRO.

14.1 Project Schedule

ID	Task Title	Task Leader	Scheduled Start	Scheduled Finish	Predecessor
Task 1	Review & analysis of literature	Stuart Day	1 July 2013	31 August 2013	
Task 2	Pilot study	Damian Barrett	1 October 2013	30 June 2014	
Task 3	Baseline study	Damian Barrett	1 July 2014	30 June 2015	

14.2.1 TASK NAME:

Task 1: Survey, review and analysis of literature

14.2.2 TASK LEADER:

Stuart Day

14.2.3 OVERALL TIMEFRAME:

It is proposed to finish Task 1 in 4 months.

14.2.4 BACKGROUND:

The first Task consists of a literature review and analysis of methane detection and measurement methods with the aim of tailoring a set of methods to the specific problem of locating and quantifying methane seeps in the Surat Basin. The review will also consider the sensitivity of methods to the task of detecting and quantifying fluxes. This Task will reduce the very significant uncertainties associated with this problem and provide a sound basis for Tasks 2 and 3. The review will include two components: (a) remote sensing methods (FTIR and laser spectroscopy and hyperspectral imaging/spectroscopy methods) and (b) direct ground based detection (mobile Piccaro CRDS analyser + GPS). The most suitable approach will depend on the type of sources (terrestrial or aquatic), the flux and area of seepage and the resulting atmospheric concentrations (under differing meteorological conditions). Existing remote measurement methods for methane detection work well for concentrated point sources (e.g. pipeline leaks) but function poorly when used to detect and measure diffuse low concentration fluxes such as seeps. The research task being tackled in this project is to design, tailor, develop and adapt methods to this problem.

14.2.5 TASK OBJECTIVE:

Review and analyse literature on methane detection and measurement. Development of tailored methods for application at pilot sites in the Surat Basin, Queensland.

14.2.6 TASK OUTPUTS:

The output from Task 1 will be a report containing proposals for discrete testing of methods at pilot sites for use in Task 2 and the design of measurement protocols to quantify the variability in baseline sources and ongoing monitoring at monitoring sites.

14.3.1 TASK NAME:

Task 2: Field trial of methane detection at pilot sites
Task 2.1: Remote Sensing method pilot study
Task 2.2: Ground detection pilot study

14.3.2 TASK LEADER:

Damian Barrett

14.3.3 OVERALL TIMEFRAME:

It is proposed that Task 2 be undertaken over 8 months and be finished at 12 months.

14.3.4 BACKGROUND:

Task 2 consists of utilising knowledge gained in Task 1 to deploy methods at pilot test sites. Prior to deployment at pilot sites, model testing is required to ensure the best application of methods. Due to the highly uncertain nature of methane seeps in this region, a significant amount of interpretation and testing of numerical models will be required as part of the review process. It is important that characterization of the drivers of methane fluxes and their response processes can be understood and interpreted by source modelling. The review of methods will consider the measurements and numerical modelling requirements for work undertaken at three scales or ‘footprints’ of methane loss to the atmosphere:

1) Localised (1 – 10 m) flux chamber measurements and interpretation of methane sources
2) Landscape (100 – 1000 m) eddy covariance measurements from which methane fluxes are determined
3) Regional (100 – 10,000 m) inverse derivation of methane fluxes using atmospheric transport modeling methods based on the observed concentrations.

The pilot studies will be applied to methane sources using a combination of methods identified, developed, tested and refined in Task 1 and model testing in Task 2. Ground based methods potentially include atmospheric concentration measurements with accompanying meteorology and chamber measurements to both calculate fluxes and obtain samples for pilot isotopic analyses.

14.3.5 TASK OBJECTIVE:

Task 2.1 a remote sensing pilot
The remote sensing pilot will examine Fourier Transform Infrared (FTIR) spectroscopy, Laser spectroscopy and hyperspectral imaging/spectroscopy methods to determine suitability for ground based or airborne measurements of seeps. A range of new, cheaper sensors are appearing on the market and these will be evaluated along with existing methods to determine best approach for this application. This will require resolving a suite of technical difficulties and questions associated with each method and testing them against diffuse, low concentration sources of methane in the atmosphere.

Task 2.2 a ground detection pilot.

The on-ground pilot will utilise observations of atmospheric methane concentration as data constraints in models to determine fluxes from locations and their potential variation in response to known drivers. Inverse methods will be trialled at these pilot sites to obtain best estimates of source fluxes of methane and their variability. Inverse modelling is the most scientifically rigorous approach to examining the mechanisms driving variation in background methane fluxes. The modelling undertaken will form the bases for a scientifically robust interpretation of measurements and longer application of methods in Task 3 to establish baseline fluxes and their variations.

If the pilot site consists of methane fluxes from water bodies, the work will build on existing research undertaken in CSIRO in the Condamine River. Methane fluxes from aquatic systems with free water surfaces (e.g. river weir pools, farm dams) will be quantified using floating chambers used in one of two modes:

1) For low fluxes typical of natural waters the head-space gas is recirculated through a high precision gas analyser (Picarro CRDS) following the protocols used by CSIRO for similar research in water supply reservoirs;
2) For high fluxes (i.e. vigorous bubbling), a once-through system currently being developed and trialled by CSIRO will be employed in which gas captured by a chamber is diluted by ambient air drawn through the chamber and subsequently analysed using a high precision gas analyser.

Initial sampling is to be conducted at a coarse spatial resolution to identify important spatial gradients in fluxes. Subsequent sampling will be undertaken at higher spatial resolution to reduce uncertainty in the overall areal mean flux to within satisfactory levels. Adequate characterisation of instantaneous fluxes from a weir pool experiencing decomposition of catchment-supplied organic matter can be completed in 1-2 days of sampling (depending on spatial scale; 1 day of sampling should be sufficient for volumes < 2000 ML). Characterisation of seasonal variability requires 3 to 4 sampling experiments and would be undertaken in Task 3. Interannual variability is likely to be very high in systems subject to flooding on an irregular basis as flood waters will supply large amounts of organic matter that will degrade rapidly over the first year but may continue to fuel methanogenesis at a lower rate for several years. Characterising interannual variability would require ongoing monitoring following Task 3.

At the pilot sites, flux chamber measurements, combined with **limited** isotopic analyses will be used to differentiate reservoir methane from other potential sources. Once started the isotope observations will enable planning for potentially more detailed sampling based on cost and importance (in Task 3). More extensive sampling and detailed work is planned in Task 3 depending on results from the pilot sites. Terrestrial sites may include soil-air space sampling and soil water sampling. Aquatic sites will include chamber measurements of fluxes, samples of bubble methane and associated samples of river water to measure dissolved methane concentrations. The geochemistry of these samples will assist with establishing sources of methane and flux measurements will determine quantities of methane generated per unit time.

Measurements of samples will consist of limited isotopic composition (such as $^{13}CH_4$, CH_3D, $^{14}CH_4$), CH_4 concentration in air, soils, water and direct from source, and a suite of geochemical elements as potential tracers to identify sources.

In aquatic sites, we will also conduct the following sampling and measurements:

- Collect and analyze (by ICPMS) water samples for basic geochemical constituents to characterize possible groundwater exchanges with the river.
- Collect and analyze water samples for 13C isotopes, alkalinity and TIC.
- Collect gas samples and analyze for composition (C_1-C_5, O_2+Ar, N_2, CO_2, $d^{13}C$ - CH_4, d^2D - CH_4)
- Collect and analyze water samples to characterize the spatial variability of dissolved methane and compute any associated fluxes.

14.3.6 TASK OUTPUTS:

Report on application of methods at pilot sites and recommendations for establishing baseline measurements

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14.4.1 TASK NAME:

Task 3: Broad scale application of methane detection

14.4.2 TASK LEADER:

Damian Barrett

14.4.3 OVERALL TIMEFRAME:

It is proposed that Task 3 will be undertaken over 12 months and begun at the end of the first year to coincide with the culmination of the pilot remote sensing imaging of seeps.

14.4.4 BACKGROUND:

The third Task will extend the tested remote sensing methods from Tasks 1 and 2 at a more broad scale in the Surat Basin (Upper Condamine River catchment) to assess regional methane sources and fluxes. Using the most suitable remote sensing methodology from Task 1 and 2, a survey to cover the Surat Basin will be undertaken to enable identification of the location of sources of methane. The survey method will need to be sufficiently wide and frequent to ensure that all material sources of methane are located and documented. If successful this approach would allow development of a register of methane sources. The register of significant methane sources provides further information for a baseline to establish ongoing monitoring or for more intensive examination of selected locations in the future. The approach and methods will be developed in consultation with industry representatives to ensure the measurement program compliments existing sampling already undertaken by industry and to meet industry needs.

14.4.5 TASK OBJECTIVE:

The third Task will also extend monitoring at the aforementioned pilot sites in order to begin developing an ongoing set of baseline measurements used to determine day-to-day, season-to-season and year-to-year variation in methane fluxes. This activity will reduce the considerable uncertainties associated with background methane fluxes in the Surat Basin and contribute to the establishment of a sound baseline. This component extends and refines the direct concentration and flux measurement techniques developed and applied in Task 2.

14.4.6 TASK OUTPUTS:

Report on development of baseline measurements and plan for ongoing monitoring

14.9 SPECIFIC DELIVERABLES

The scientific review in Task 1 will provide robust knowledge as to the best selection of detection and measurement methods for this particular region.

The data provided by this project will provide an important baseline data set that allows an objective, quantitative comparison of methane fluxes and concentrations to be undertaken in the future as CSG production in the Surat Basin accelerates.

Outcomes from this work to APLNG, the CSG sector and communities include a comprehensive and scientifically rigorous analysis of background methane fluxes and the establishment of a baseline for an important part of the Surat Basin, Queensland, in which CSG development is occurring and against which ongoing monitoring can conducted.

Through this program of research, a critical unknown in CSG production will be reduced thereby contributing to maintaining and improving environmental stewardship by the industry.

References used in Task section:

Day S, Connell L, Etheridge D, Norgate T and Sherwood N (2012) Fugitive greenhouse gas emissions from coal seam gas production in Australia. CSIRO Australia, 27 pp.

Denman, K. L., et al. (2007), Couplings between changes in the climate system and biogeochemistry, in Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, edited by S. Solomon et al., chap. 7, pp. 499 – 587, Cambridge Univ. Press, Cambridge, U.K.

Etiope, G., K. R. Lassey, R. W. Klusman, and E. Boschi, 2008: Reappraisal of the fossil methane budget and related emission from geologic sources. *Geophysical Research Letters 35: L09307*., **35**, L09307.

Faiz M and Hendry P (2006) Significance of microbial activity in Australia coal bed methane reservoirs – A review. *Bulletin of Canadian Petroleum Geology*. 54, 261 – 272

Kaye L, Barrett DJ, Vink S, Roux E, Murray C-E, White J, Robbins S (2012) Coal Seam Gas, Coal and Agriculture: Water Implications. Report for ACARP Project C21006. *Australian Coal Association Research Program*. 139 pp.

Lassey, K. R., Etheridge, D. M., Lowe, D. C., Smith, A. M., Ferretti, D. F. Centennial evolution of the atmospheric methane budget: what do the carbon isotopes tell us?. Atmospheric chemistry and physics. 2007; 7:2119-2139.

15. Budget Justification

The budget for this project has been agreed between APPEA, APLNG and CSIRO. APPEA identified the project as one of particular public and industry interest and has, on behalf of the industry and via APLNG, contributed whole-of-industry funds to the project. APPEA funds appear 'via APLNG' because APLNG is a member of GISERA, APPEA is not. The Research Advisory Committee and Management Committee have approved this budget.

16. Project Governance

The project leaders and APPEA/APLNG representatives will meet at least 1 month prior to delivery of milestone reports to discuss project management issues and no less than on six monthly intervals. There are three 'decisions points' in the project plan that enable input from industry representatives, the GISERA Research Advisory Committee and CSIRO researchers as to the specific direction of research work conducted in this project. Decisions will be made by mutual agreement between researchers and industry representatives, and will be offered for and will require ratification by the GISERA Research Advisory Committee.

17. Communications Plan

GISERA will manage communications in accordance with GISERA's Alliance Agreement (available at: http://www.gisera.org.au/contract.html) and Communications Strategy.

18. Risks

Capacity to deliver this project will be managed by CSIRO. Risks in delivery will be mitigated using the breadth of skills across the organisation. Communication risks will be mitigated by adherence to the communications protocols outlined in the GISERA Communications Strategy and the GISERA Alliance Agreement. CSIRO will undertake all project management tasks and will consult with APLNG on decisions points and contingencies in the work program.

Gas Industry
Social & Environmental
Research Alliance

19. Intellectual Property and Confidentiality

Background IP (clause 10.1, 10.2)	Party	Description of Background IP	Restrictions on use (if any)	Value
	CSIRO	All atmospheric transport modelling, inverse modelling methods, prior remote sensing methods for methane detection, CH_4 flux measurement methods (aquatic and terrestrial) and eddy covariance techniques used in this study.	None	$
				$
Ownership of Non-Derivative IP (clause 11.3)	CSIRO			
Confidentiality of Project Results (clause 15.6)	Project results are not confidential.			
Additional Commercialisation requirements (clause 12.1)	Not applicable			
Distribution of Commercialisation Income (clause 1.1)	Not applicable			
Commercialisation Interest (clause 1.1)	**Party**		**Commercialisation Interest**	
	APLNG		None	
	CSIRO		None	

20. Approval from Project Parties

In signing this Document you are committing your organisation to provide the specified personal and the required in-kind contributions.

Australia Pacific LNG

SIGNED for and on behalf of)
)
by) Dan O'Sullivan ....

in the presence of)

....
Signature of witness

KRISTEN FORBES .
....
Name of witness

CSIRO

SIGNED for and on behalf of)
)
by) ....
in the presence of)

....
Signature of witness

THERESE NILE
....
Name of witness

Gas Industry Social & Environmental Research Alliance

2 Variations to Project Order

Changes to research Project Orders are approved by the GISERA Director, acting with authority provided by the GISERA Management Committee or Research Advisory Committee, in accordance with the GISERA Agreement (http://www.gisera.org.au/contract.html).

The table below details variations to research Project Order.

Register of changes to Research Project Order

Date	Issue	Action	Authorisation
07/05/14	Finalising phase 2 work program was completed end of March 2014.	Milestone 2.1 will be pushed back to Sept 2014.	
07/05/14	Finalising phase 2 work program was completed end of March 2014.	Milestone 2.2 will be pushed back to Nov 14.	
07/05/14	Finalising phase 2 work program was completed end of March 2014.	Milestone 3.1 will be pushed back to Nov 2015.	
07/05/14	Finalising phase 2 work program was completed end of March 2014.	Milestone 3.2 will be pushed back to Nov 15.	
18/12/14	As a result of the decision to have phase 2 report reviewed externally, delivery date to be pushed back.	Milestone 2.2 will be pushed back to February 2015.	
24/07/15	Phase 3 will be extended over 3 years with annual reviews on progress. Will provide project with opportunity to establish a longer and more significant set of baseline measurements than originally planned.	Milestone 3.1 due in Nov 15, milestone 3.2 due in Nov 16 and milestone 3.3 will be due in Nov 17.	

3 Progress against project milestones

Progress against milestones are approved by the GISERA Director, acting with authority provided by the GISERA Management Committee or Research Advisory Committee, in accordance with the GISERA Agreement (http://www.gisera.org.au/contract.html).

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

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

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

Project Schedule Table

ID	Task Title	Task Leader	Scheduled Start	Scheduled Finish	Predecessor
Task 1	Review & analysis of literature	Stuart Day	1 July 2013	31 August 2013	N/A
Task 2.1	Remote sensing pilot study	Stuart Day	1 Sept 2013	8 Sept 2014	Task 1
Task 2.2	Ground detection pilot study	Stuart Day	1 Oct 2013	28 Feb 15	Task 2
Task 3.1	· The continuous monitoring results – installation, commissioning and operation of the two field stations. · Preliminary data available.	Stuart Day	Jul 2014	Nov 15	
Task 3.2	□Modelled development and analysis of continuous data. □Periodic monitoring and field validation □Trial of remote sensing technologies.	Stuart Day	1 Dec 15	Nov 16	
Task 3.3	□Delivery of final report for Remote sensing baseline study and Ground detection baseline study	Stuart Day	1 Dec 16	Nov 17	

Project Schedule Report

Task 1.

TASK NAME: Survey, review and analysis of literature

TASK LEADER: Stuart Day

OVERALL TIMEFRAME: 2013

BACKGROUND: The first Task consists of a literature review and analysis of methane detection and measurement methods with the aim of tailoring a set of methods to the specific problem of locating and quantifying methane seeps in the Surat Basin. The review will also consider the sensitivity of methods to the task of detecting and quantifying fluxes. This Task will reduce the very significant uncertainties associated with this problem and provide a sound basis for Tasks 2 and 3. The review will include two components: (a) remote sensing methods (FTIR and laser spectroscopy and hyperspectral imaging/spectroscopy methods) and (b) direct ground based detection (mobile Piccaro CRDS analyser + GPS). The most suitable approach will depend on the type of sources (terrestrial or aquatic), the flux and area of seepage and the resulting atmospheric concentrations (under differing meteorological conditions). Existing remote measurement methods for methane detection work well for concentrated point sources (e.g. pipeline leaks) but function poorly when used to detect and measure diffuse low concentration fluxes such as seeps. The research task being tackled in this project is to design, tailor, develop and adapt methods to this problem.

TASK OBJECTIVE: Review and analyse literature on methane detection and measurement. Development of tailored methods for application at pilot sites in the Surat Basin, Queensland.

TASK OUTPUTS: The output from Task 1 will be a report containing proposals for discrete testing of methods at pilot sites for use in Task 2 and the design of measurement protocols to quantify the variability in baseline sources and ongoing monitoring at monitoring sites.

PROGRESS REPORT

The final draft report was submitted to APPEA on 18 December 2013. The literature review has gone through the mandatory internal review process and is now publicly available on the GISERA website http://www.gisera.org.au/publications/tech_reports_papers/ghg-emission-proj-1-lit-review.pdf.

Task 2.1.

TASK NAME: Remote Sensing method pilot study

TASK LEADER: Stuart Day

OVERALL TIMEFRAME: 2014

BACKGROUND: Task 2 consists of utilising knowledge gained in Task 1 to deploy methods at pilot test sites. Prior to deployment at pilot sites, model testing is required to ensure the best application of methods. Due to the highly uncertain nature of methane seeps in this region, a significant amount of interpretation and testing of numerical models will be required as part of the review process. It is important that characterization of the drivers of methane fluxes and their response processes can be understood and interpreted by source modelling. The review of methods will consider the measurements and numerical modelling requirements for work undertaken at three scales or 'footprints' of methane loss to the atmosphere:

1) Localised (1 – 10 m) flux chamber measurements and interpretation of methane sources
2) Landscape (100 – 1000 m) eddy covariance measurements from which methane fluxes are determined
3) Regional (100 – 10,000 m) inverse derivation of methane fluxes using atmospheric transport modeling methods based on the observed concentrations.

The pilot studies will be applied to methane sources using a combination of methods identified, developed, tested and refined in Task 1 and model testing in Task 2. Ground based methods potentially include atmospheric concentration measurements with accompanying meteorology and chamber measurements to both calculate fluxes and obtain samples for pilot isotopic analyses.

TASK OBJECTIVE: The remote sensing pilot will examine Fourier Transform Infrared (FTIR) spectroscopy, Laser spectroscopy and hyperspectral imaging/spectroscopy methods to determine suitability for ground based or airborne measurements of seeps. A range of new, cheaper sensors are appearing on the market and these will be evaluated along with existing methods to determine best approach for this application. This will require resolving a suite of technical difficulties and questions associated with each method and testing them against diffuse, low concentration sources of methane in the atmosphere.

TASK OUTPUTS: Report on application of methods at pilot sites and recommendations for establishing baseline measurements

PROGRESS REPORT

The interim report for Phase 2 (which only relates to the remote sensing component) has been through the mandatory internal review and was submitted to APPEA on 11 November 2014.

Task 2.2

TASK NAME: Ground detection pilot study

TASK LEADER: Stuart Day

OVERALL TIMEFRAME: It is proposed that Task 2 be undertaken over 8 months and be finished at 12 months.

BACKGROUND: Task 2 consists of utilising knowledge gained in Task 1 to deploy methods at pilot test sites. Prior to deployment at pilot sites, model testing is required to ensure the best application of methods. Due to the highly uncertain nature of methane seeps in this region, a significant amount of interpretation and testing of numerical models will be required as part of the review process. It is important that characterization of the drivers of methane fluxes and their response processes can be understood and interpreted by source modelling. The review of methods will consider the measurements and numerical modelling requirements for work undertaken at three scales or 'footprints' of methane loss to the atmosphere:

1) Localised (1 – 10 m) flux chamber measurements and interpretation of methane sources
2) Landscape (100 – 1000 m) eddy covariance measurements from which methane fluxes are determined

3) Regional (100 – 10,000 m) inverse derivation of methane fluxes using atmospheric transport modeling methods based on the observed concentrations.

The pilot studies will be applied to methane sources using a combination of methods identified, developed, tested and refined in Task 1 and model testing in Task 2. Ground based methods potentially include atmospheric concentration measurements with accompanying meteorology and chamber measurements to both calculate fluxes and obtain samples for pilot isotopic analyses.

TASK OBJECTIVE: The on-ground pilot will utilise observations of atmospheric methane concentration as data constraints in models to determine fluxes from locations and their potential variation in response to known drivers. Inverse methods will be trialled at these pilot sites to obtain best estimates of source fluxes of methane and their variability. Inverse modelling is the most scientifically rigorous approach to examining the mechanisms driving variation in background methane fluxes. The modelling undertaken will form the bases for a scientifically robust interpretation of measurements and longer application of methods in Task 3 to establish baseline fluxes and their variations.

If the pilot site consists of methane fluxes from water bodies, the work will build on existing research undertaken in CSIRO in the Condamine River. Methane fluxes from aquatic systems with free water surfaces (e.g. river weir pools, farm dams) will be quantified using floating chambers used in one of two modes:

1) For low fluxes typical of natural waters the head-space gas is recirculated through a high precision gas analyser (Picarro CRDS) following the protocols used by CSIRO for similar research in water supply reservoirs;
2) For high fluxes (i.e. vigorous bubbling), a once-through system currently being developed and trialled by CSIRO will be employed in which gas captured by a chamber is diluted by ambient air drawn through the chamber and subsequently analysed using a high precision gas analyser.

Initial sampling is to be conducted at a coarse spatial resolution to identify important spatial gradients in fluxes. Subsequent sampling will be undertaken at higher spatial resolution to reduce uncertainty in the overall areal mean flux to within satisfactory levels. Adequate characterisation of instantaneous fluxes from a weir pool experiencing decomposition of catchment-supplied organic matter can be completed in 1-2 days of sampling (depending on spatial scale; 1 day of sampling should be sufficient for volumes < 2000 ML). Characterisation of seasonal variability requires 3 to 4 sampling experiments and would be undertaken in Task 3. Interannual variability is likely to be very high in systems subject to flooding on an irregular basis as flood waters will supply large amounts of organic matter that will degrade rapidly over the first year but may continue to fuel methanogenesis at a lower rate for several years. Characterising interannual variability would require ongoing monitoring following Task 3.

At the pilot sites, flux chamber measurements, combined with limited isotopic analyses will be used to differentiate reservoir methane from other potential sources. Once started the isotope observations will enable planning for potentially more detailed sampling based on cost and importance (in Task 3). More extensive sampling and detailed work is planned in Task 3 depending on results from the pilot sites. Terrestrial sites may include soil-air space sampling and soil water sampling. Aquatic sites will include chamber measurements of fluxes, samples of bubble methane and associated samples of river water to measure dissolved methane concentrations. The geochemistry of these samples will assist with establishing sources of methane and flux measurements will determine quantities of methane generated per unit time.

Measurements of samples will consist of limited isotopic composition (such as 13CH4, CH3D, 14CH4), CH4 concentration in air, soils, water and direct from source, and a suite of geochemical elements as potential tracers to identify sources.

In aquatic sites, we will also conduct the following sampling and measurements:

- Collect and analyze (by ICPMS) water samples for basic geochemical constituents to characterize possible groundwater exchanges with the river.
- Collect and analyze water samples for 13C isotopes, alkalinity and TIC.
- Collect gas samples and analyze for composition (C1-C5, O2+Ar, N2, CO2, d13C - CH4, d2D - CH4)

Collect and analyze water samples to characterize the spatial variability of dissolved methane and compute any associated fluxes.

TASK OUTPUTS & SPECIFIC DELIVERABLES: Report on application of methods at pilot sites and recommendations for establishing baseline measurements

PROGRESS REPORT

The final report for Phase 2 (which includes the remote sensing and ground detection components) has been through the compulsory internal review. It is available on the GISERA website for viewing GHG Emission_Methane seeps_stage 2 report.