Australia's National
Science Agency

GISERA | Gas Industry Social and Environmental Research Alliance

Progress report

Assessment of faults as potential connectivity pathways

CSIRO | Australia Pacific LNG | QGC | origin | Santos | NSW Government | Australian Government Department of Industry, Science, Energy and Resources | Supported by Government of South Australia | Queensland Government | Northern Territory Government

Progress against project milestones

Progress against milestones/tasks are approved by the GISERA Director, acting with authority in accordance with the 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 is withheld.
  - 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 by GISERA Director.

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

TASK NUMBER	TASK DESCRIPTION	SCHEDULED START	SCHEDULED FINISH	COMMENT
1	Compilation of historic data and reinterpretation of existing seismic surveys	Jul-19	Aug-20	
2	Site reconnaissance and synoptic river sampling, including planning	Jul-19	Oct-19	
3	Surface geophysical survey and groundwater sampling, including planning	Oct-19	Aug-20	
4	Environmental tracer laboratory analysis	Oct-19	Aug-20	
5	Data interpretation, integration and report writing (including peer reviews)	Jul-20	Dec-20	Data interpretation and integration complete. The draft report will be submitted for peer review on 5 November 2021. Public release is expected before calendar year end'

Project schedule report

TASK 1: Compilation of historic geological mapping, geological structural and hydrochemical data and reinterpretation of existing seismic surveys

BACKGROUND

This task builds up on previous work, including the studies by Cresswell (2014), Raiber and Suckow (under review)) and Suckow et al. (under review)). The various hydrochemical datasets will be integrated with the geological mapping, 3D geological models and current structural framework to support the development of a preliminary conceptual model of the region and identification of potential anomalies in the datasets. The anomalies may indicate the occurrence of preferential flow pathways in areas where geological faults are expected to be present.

A subset of the approximately 2600 km of 2D geophysical seismic data that is publicly available will be reinterpreted. Existing seismic surveys were run as part of petroleum exploration studies.

These studies focus on the deep subsurface, and as a result, these seismic surveys may lack resolution in the shallow subsurface. The raw data of a selected subset of seismic survey will be reprocessed to filter noise and enhance possible structural features positioned in the top 500 m of the geological profile.

TASK OBJECTIVES

The main purpose of this task is the identification of gaps in the current knowledge of faults and their role to potential fluid transport from the coal seams to near surface environmental assets and the selection of sites for further field investigations. A preliminary conceptual model of the groundwater system will be developed using existing geological and water geochemical data, including dissolved methane concentration associated with different hydrostratigraphic units.

The hydrochemical datasets will be interpreted in the context of the geological framework available for the region with a focus on the proximity to geological structures such as fault zones and lineaments to be further confirmed by the reinterpretation of the seismic survey data to identify the tendency for the occurrence of faults that extend to near surface.

TASK OUTPUTS AND SPECIFIC DELIVERABLES

A preliminary conceptual model to support the selection of sites for field shallow geophysical survey and selection of existing bores for groundwater sampling will be developed.

PROGRESS REPORT

Geophysical company HiSeis has been engaged for reinterpretation of one seismic line, approximately 8700m long, to assess the feasibility of the proposed approach. The reprocessing involved application of multiple seismic migration algorithms, resulting in an improved characterisation of the geometry of aquifers and aquitards in the shallow subsurface (<250 m). The results also successfully demonstrated the usefulness of the methodology in determining whether deep seated geological structures extend to near the surface and confirming if smaller-scale shallow structural features (faults or fractures) are present that have not been identified by the traditional data processing algorithms presented in the reports that are publicly available; a selection of several potential additional seismic lines was conducted, including the sourcing of a wide range of associated data files from the DIGS website to complete the reinterpretation of an additional seismic line with the assistance of HiSeis' geophysicists. This task was critical to confirm the possible lateral continuity (to the north and south) of faults identified on the vertical plane of the initial re-processed seismic line. From the integration of these features in the context of the 3D geological model and hydrochemical and tracer data, the final goal is to confirm whether such faults may comprise connectivity pathways in this sedimentary basin. Data compilation on NSW DIGS for these lines showed that although interpreted geophysical sections for selected lines are publicly available, the raw (field) data are not publicly available for some lines, as confirmed with the Geological Survey of NSW. These seismic surveys were conducted in 1998 on behalf of Source Energy and in 2004 on behalf of Eastern Star Gas, the previous operators of PEL238.

We have received the required seismic raw data from Santos in mid-October 2020, and HiSeis has in late- December (18th of December) completed re-processing of the selected additional seismic line. The results of this re-processing will be integrated with the results from environmental tracer analysis and shallow geophysical surveys throughout the next months.

With completion of the re-processing of the second seismic line, this milestone is completed.

TASK 2: Site reconnaissance trip and synoptic river sampling

BACKGROUND

Although previous work was conducted in relation to geology and water chemistry in this region, much of that work focussed on the deeper compartments of the subsurface. However, evidence exists that suggests that faults are present in the shallow subsurface and there is therefore a need to better characterise the geometry and potential fault-induced connectivity pathways. It is generally accepted that a multidisciplinary approach that considers independent lines of evidence is required to identify potential environmental assets that may be impacted by CSG activities in the vicinity of the potential faulting zones. Furthermore, it is critical to integrate existing expert knowledge into the planning of fieldwork and conceptualisation of the aquifer/aquitard systems.

This reconnaissance trip will allow us to engage with experts on the geology and hydrogeology of the Narrabri area. We will invite experts from industry, academia (UNSW), state and federal government agencies (e.g. NSW Department of Industry Lands and Water, Geoscience Australia and ANSTO) and a representative from private land holders to join us in the field and visit the area where previous work suggested that there may be geological structures present. This will include visiting important geological features as well as environmental assets (e.g. Bohena Creek). Together with the experts and with the information from Task 1, we will identify the most appropriate locations for the geophysical field surveys (Task 3). As part of this reconnaissance trip, we will also collect surface water samples from Bohena Creek (subject to flow conditions) for a suite of hydrochemical and environmental tracers, with a focus on those parameters (e.g. dissolved methane, 222Rn and noble gases) that are sensitive for detection of a contribution of upwards flux from deeper formations.

TASK OBJECTIVES

Undertake a field reconnaissance trip and engage with local experts to identify most suitable areas for geophysical surveys. Collect surface water samples from Bohena Creek at approximately six sites for environmental tracer analysis (subject to flow conditions).

TASK OUTPUTS AND SPECIFIC DELIVERABLES

A memorandum summarizing expert views on geological structures, preliminary site selection for geophysical surveys and sampling of surface water of Bohena Creek.

PROGRESS REPORT

A preliminary field reconnaissance trip was undertaken on the 2nd September to identify suitable lines for geophysical surveys. This involved the identification of public roads and cultural features such as power lines or underground pipelines which could interfere in the acquisition and interpretation of the electromagnetic data to be collected. The reconnaissance trip also involved the identification of sites where historic seismic survey lines, as these can provide an independent line of evidence as well as verification of the access to the existing groundwater monitoring network for groundwater sampling under Task 3.

Based on this initial field reconnaissance survey, a preliminary number of geophysical survey lines were identified, and the Task 3 fieldworks have been booked for late 2019. The suitability of the proposed geophysical survey lines to address the projects objectives have been currently discussed with the technical experts. Due to the on-going drought in NSW, no surface water samples could have been collected so far. Subject to the presence of surface water in the Bohena Creek during the execution of Task 3, water sampling may occur during that field mobilisation.

TASK 3: Surface geophysical survey and groundwater sampling

BACKGROUND

The expression of geological faults in the shallow subsurface or at the surface can be initially inferred from the interpretation of the regional geomorphology using aerial photographs, existing LiDAR data, existing 3D geological models and satellite images. An initial assessment of aerial images of the proposed study area suggests that reaches of Bohena Creek are relatively straight lines over several km's, and these very closely follow the orientation of mapped structural lineaments that are likely associated with deep seated faults. Furthermore, irregular formation tops in stratigraphic and exploration wells have been observed underneath Bohena Creek.

The predominant high resolution geophysical method proposed in this study is the CSAMT, which has been extensively employed in mineral exploration (Hu et al., 2013), environmental, engineering problems (He et al., 2006) and groundwater investigation (Fu et al., 2013; Yan-ling et al., 2018). This method presents many logistical advantages when compared to other resistivity methods, resulting in extended field survey areas with relatively short periods of time by using a multi-channel receiver. TEM will also be used as a complementary tool to the CSAMT, particularly to assist in reducing the uncertainty of data collected by the primary method.

Groundwater sampling at approximately eight selected bores will be performed for laboratory analysis of parameters as described in task 4. The sites selection will be based on the findings from this task combined with information gathered during task 2 and existing data compiled under task 1.

TASK OBJECTIVES

The main objectives of the high-resolution geophysical investigation is to confirm the position of geological structures within the 500 m interval, characterise their geometry (azimuth and dip) and extent in a series of 2D sections. The proposed geophysical methods will provide valuable evidence on whether identified structures correspond to an extension of deep seated faults and their likelihood to connect near the surface environmental assets (groundwater dependent ecosystems and shallow groundwater private bores) to the deep coal seams that may potentially correspond to environmental stressors following gas development activities. It is important to highlight that the geophysical survey comprises one line of evidence that is expected to be combined and supported by the findings of the environmental tracers. The latter will help to ascertain if geological structures are likely to be conductive to flow migration.

TASK OUTPUTS AND SPECIFIC DELIVERABLES

The outputs of both geophysical investigation methods will be presented as 2D vertical sections of interpolated values of ground resistivity. The preliminary findings from the geophysical survey together with historic evidence will be presented in a brief memorandum.

PROGRESS REPORT

This milestone is complete.

- The project team conducted a field geophysical survey in late January/early February 2020. One transient electromagnetic (TEM) survey line (approximately 4200 metres) was successfully completed with the assistance of a subcontractor's field crew and equipment. Due to severe thunderstorms followed by increased risk of flooding in the Pilliga Forest region, the survey had to be discontinued before all the works could be completed.
- In early December 2020, the project team completed the groundwater sampling. They collected groundwater samples from 11 monitoring bores within the proposed gas development area for a wide range of environmental tracers. In addition, six groundwater samples from operating CSG wells were collected.
- Following the groundwater sampling campaign, a window of opportunity to complete the final surface geophysical survey was in early to mid-December 2020; however, extremely high temperatures (~44 degrees) resulted in an elevated bushfire risk in the Pilliga Forest, and the team therefore had to postpone the survey further. Discussions with the subcontractor throughout early 2021 confirmed that due to other commitments in other states, they could not commit to a date within the required timeframe (by mid-2021). It was therefore agreed not to proceed with the second survey with the original subcontractor.
- The project team sought for alternative TEM geophysical survey providers and identified an alternative subcontractor. The setup of this survey would be different from the previous TEM survey, and it focusses on the upper ~80-100 m of the subsurface. Due to the different setup, which involves continuously driving the signal emitter and receptor sensors along the road, it was anticipated that it would be possible to survey considerably more lines (up to about 40 km's/day). This would allow to conduct multiple shallow east-west transects, allowing to enhance the understanding of a possible vertical continuity of geological structures to the shallow subsurface.

TASK 4: Environmental tracer laboratory analysis

BACKGROUND

To further verify if connectivity between deeper and shallow formations occurs in the Narrabri region, groundwater samples from shallow bores (i.e. bores screened within the alluvial aquifer or the shallow parts of the Pilliga Sandstone) will be analysed for parameters such as helium and dissolved methane. Some of the methods previously used for identification of connectivity are limited. For example, detection limit of major or minor ions towards influx of groundwater from deeper formations via fractures and faults or aquitard leakage is in the range of 5-10% admixture of deep water (e.g. fluoride concentration in the Maules Creek Formation range from 6-12 mg/L and below detection limit to 1.5 mg/L in the Pilliga Sandstone; Raiber and Suckow, 2019). In contrast, helium can indicate admixtures in the per mil range because deeper aquifers (e.g. Black Jack Group and Maules Creek Formation) are likely to contain up to a factor 1000 more helium than the shallower aquifers (e.g. Pilliga Sandstone, Orallo Formation and alluvium). Helium therefore is a much more sensitive parameter for upward flowing groundwater and will provide more robust indications of cross formational flow.

TASK OBJECTIVES

Laboratory analysis of noble gas (He, Ne, Ar, Kr, Xe including 3He/4He), 222Rn, dissolved methane (concentrations and isotopes), other selected hydrochemical and isotopic tracers, including stable isotopes of water and strontium, tritium and carbon-14.

TASK OUTPUTS AND SPECIFIC DELIVERABLES

Analytical results of noble gases and other selected environmental tracers will be obtained, providing new evidence on the potential hydrogeological connectivity between deep and shallow aquifers.

PROGRESS REPORT

This milestone is complete. The analysis of the ground water samples collected (hydrochemistry, stable isotopes, strontium isotopes, noble gases, methane isotopes and groundwater age tracers) as part of this field sampling campaign, have been completed.

Variations to Project Order

Changes to research Project Orders are approved by the GISERA Director, acting with authority, in accordance with the GISERA Alliance Agreement. Any variations above the GISERA Director's delegation require the approval of the relevant GISERA Research Advisory Committee.

The table below details variations to research Project Order.

Register of changes to Research Project Order

DATE	ISSUE	ACTION	AUTHORISATION

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GISERA is a collaboration between CSIRO, Commonwealth and state governments and industry established to undertake publicly-reported independent research. The purpose of GISERA is to provide quality assured scientific research and information to communities living in gas development regions focusing on social and environmental topics including: groundwater and surface water, greenhouse gas emissions, biodiversity, land management, the marine environment, and socio-economic impacts. The governance structure for GISERA is designed to provide for and protect research independence and transparency of research.