The South West Hub In-Situ Laboratory – A Unique Multi-Level Completion for CO₂ Injection Testing and Monitoring

Karsten Michael¹ Arsham Avijegon¹ Ludovic Ricard¹ Tess Dance¹ Claudio Delle Piane¹ Barry Freifeld² Mark Woitt² Linda Stalker¹ Jo Myers³ Marina Peruvkhina¹ Laurent Langhi¹ Allison Hortle¹ Don Geeves¹ Stefan Finsterle²

¹CSIRO Energy, 26 Dick Perry Avenue, Kensington, WA 6151, Australia
²Class VI Solutions Inc., Oakland, CA, USA
³CSIRO Wealth from Oceans, Australia

Abstract

The In-Situ Laboratory Project entails completing and instrumenting an existing well and injecting a small volume of CO₂ for testing purposes into an interval of the Lesueur Formation at the South West Hub project in Western Australia. The project commenced in the middle of October 2016 and is scheduled to run until the end of April 2019, with hydraulic testing and CO₂ injection planned between June – November 2017. The purpose is to aid demonstration of the commercial viability of geologically storing carbon and contribute to broadening the portfolio of globally evaluated geological settings for storage via testing of a different geological depositional environment. The project will develop the first part of an enduring research facility at the South West Hub to enable further research of a geological environment that has more uncertainty than many other current projects; i.e. in the case of the South West Hub there is uncertainty around the extent of a regional seal.

The project activities will lead to the design, procurement and deployment of surface and bottomhole equipment to enable testing to be conducted in the Lesueur Formation using the Harvey 4 well that was drilled as part of the South West Hub CCS Project. A range of small-scale well tests will be designed and conducted to confirm the functionality of the newly deployed equipment. In addition, results of the tests will help to reduce some of the previously identified uncertainty regarding the containment and CO₂ migration behaviour.

Based on currently available data and considering the requirements for the In-Situ Lab project, Harvey 4 was identified as the preferred candidate in which a unique five-level bottomhole assembly will be installed for monitoring and testing purposes. The Harvey 4 well will be completed with multiple packers, flow control equipment and instrumentation to allow selective water testing and CO₂ injection into each of the 5 perforated intervals (Figure 1). Two of the five perforated intervals are planned in the Yalgorup Member of the Lesueur Formation and three in the underlying Wonnerup Member. The completion will include fiber optic instrumentation to monitor for seismic events and P/T gauges to monitor temperature/ pressure changes when producing formation water and injection of CO₂ into the formation. The completion will include geophone and will also be equipped with dual downhole fluid samplers both which are positioned within the Wonnerup Member. The system will allow long term fluid sampling using small amounts of N₂ to pump the fluid samples to surface
Completion of the various intervals will be followed up by flowing these units for clearing the perforations of any fines accumulations, which will also give an assessment of the overall permeability, skin and productivity of each interval. This information will be used for better constraining the modelling parameters for the subsequent testing.

No thick contiguous low permeability barriers were identified in the Wonnerup Member and injected CO$_2$ is assumed to largely migrate upwards vertically under buoyancy, more or less unimpeded. Still, the Wonnerup Member is of considerable thickness and it is important to measure vertical migration velocity and residual saturation along the migration path. The concept of the vertical migration test is to inject CO$_2$ at the bottom interval and let it migrate vertically upward, dominantly under buoyancy drive. The vertical migration of CO$_2$ is monitored indirectly through pulsed neutron logging and possibly VSP, as well as directly through sampling from the perforated intervals above. The appropriate distance between perforation intervals depends on the CO$_2$ injection volume, the time available for the test, as well as the degree of heterogeneity and permeability anisotropy.

Shale layers and palaeosols in the Yalgorup Member are expected to act as seals or baffles. The effectiveness of their sealing capacity will be assessed through vertical interference tests across individual and/or a series of shale layers by injection/production of formation water. A potential test interval would be across the Wonnerup-Yalgorup boundary, with completions in sandstone units in the uppermost Wonnerup Member and above the first shale layer in the Yalgorup Member. A water test using pressure measurements will determine the absolute vertical permeability and hydraulic continuity of the palaeosols. It should be noted that given the uncertainty with respect to hydraulic characteristics and continuity of palaeosols it is a possibility that a) pressure impacts will not be observed during the test due to an unexpectedly high sealing capacity of the palaeosols or b) pressure impacts will be measured almost instantly if the palaeosols are discontinuous in the tested intervals. Both cases would provide useful qualitative information regarding the containment characteristics of the Yalgorup Member, however the respective test could not be used to interpret specific hydraulic properties.

The main technical risk is the hydraulic isolation of each completion interval, particularly for the vertical interference test. Additional risks are due to the lack of previous hydraulic testing and the inherent uncertainty regarding a) continuity and hydraulic properties of the palaeosols, b) degree of compartmentalization/aquifer support, c) producibility/injectivity of the completion intervals and d) impact of heterogeneity on the migration behavior of CO$_2$. Operational constraints include surface storage availability for produced water, costs for CO$_2$ transport and surface storage, as well as time available for testing and monitoring. The current plan includes up to 1200 m$^3$ of water production and up to 1000 tonnes of CO$_2$ injection.
Figure 1. Log interpretation of sandstone- and shale-dominated zones in the Wonnerup and Yalgorup members in Harvey 4 (left) and schematic of proposed well tests (right).