Curtin University

The Lesueur, SW Hub: Improving seismic response and attributes. Final Report

ANLEC R&D Project 7-0115-0241

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The SW Hub Carbon Capture and Storage (CCS) project is a leading initiative to reduce carbon dioxide emissions in Western Australia. It is a staged project that involves collecting and analysing data and samples from the Lesueur Sandstone formation, to test its feasibility as a CO_2 reservoir. The Lesueur Sandstone lies in the southern Perth Basin and is the type of saline aquifer identified by scientists around the world as a potential CO_2 storage reservoir.

Currently, the SW Hub has been going through a detailed pre-competitive site characterisation. As a part of this process the Harvey 1 stratigraphic well was drilled in 2012 and a 3D seismic survey was acquired in 2013-2014 over a 115 km^2 area in the vicinity of potential future injection sites (Geokinetics, 2014). This survey along with the Harvey 1 well data has been thoroughly analysed in ANLEC R&D Project 7-0314-0231. Since then new sources of the geophysical data became available:

- the new Harvey 2, 3 and 4 wells were drilled and a suite of well-logs have been acquired along with a zero-offset Vertical Seismic Profile (VSP);
- a high-resolution nested 3D seismic surveys around the Harvey 4 well (Urosevic et al., 2014) and, most recently, around the Harvey 3 well (Yavuz et al., 2018)

The objective of the Project 7-0115-0241 (Project) is to fill current information gaps by integrating all available geophysical data. Eventually, we interpreted the data in terms of subsurface distribution of petrophysical properties, relevant for the CO_2 sequestration modelling. These 3D cubes of properties should be used to constrain static and dynamic models, which form a core for feasibility studies of CO_2 sequestration at the SW Hub area.

The analysis started with advanced processing of VSP data. The results of VSP analysis were then used in the reprocessing of the entire 3D seismic dataset plus a composite 2D line that passes in proximity to three Harvey wells and has a relatively dense and uniform distribution of source-receiver offsets. Both of these datasets were then used for stochastic seismic inversion. Underpinning all of these analyses are well logs, which are comprehensively analysed in a separate report corresponding to the Milestone 6 of the Project (Pervukhina et al., 2018) which is also attached to this report.

The main findings of the overall study are as follows:

VSP data in the Harvey 2, 3 and 4 wells are of variable quality but sufficient to estimate vertical velocities for constraining the tomographic velocity model for surface seismic data. Anomalous

seismic attenuation (Q=30) is observed in the Yalgorup Member, while the contribution of scattering attenuation is minimal.

A composite line was created through the volumes, which incorporates a previously acquired 2D line with full complement of offsets and passes in proximity to the Harvey 1, 3 and 4 wells. This allowed building a relatively detailed velocity model that provided a sufficiently high quality seismic common-offset gathers and allowed the application of a stochastic Amplitude versus Offset (AVO) inversion. However, this inversion was still anchored at a single well (the Harvey 1 well) as other wells are too shallow for characterisation of the Wonnerup section. In order to validate the results, we compared them with the logs of the Harvey 3 well, which served as a blind test well. The match with this blind well is reasonably good. However, it is unclear if these results could be deemed reliable at such great distances from the Harvey 1 well. In addition, the results are limited to the composite seismic line.

The most comprehensive analysis was performed on the Geokinetics (2014) seismic volume, involving the stochastic rock physics inversion. To this end, the entire volume was first completely reprocessed. This allowed us to produce images far superior to those produced previously, with better reflection continuity and fault delineation. Furthermore, tomographic velocity analysis was undertaken to produce the velocity model for both final imaging and inversion.

The deterministic inversion of the Geokinetics 3D data showed very large uncertainty and hence requires a priori constraints. Hence, a quantitative interpretation workflow was developed, which implemented the Bayesian approach to stochastic seismic inversion. This workflow incorporates prior understanding of the subsurface features. Hence, the inversion gave us an opportunity to test if several geologically plausible hypotheses are consistent with seismic data.

The output of the inversion was controlled by (1) initial model and (2) our subjective estimate of the uncertainty of the initial model, well data and seismic amplitudes. The workflow involved a joint kinematic/amplitude inversion since the initial subsurface seismic model was based on high-resolution velocity analysis that captures both the loading trends derived from the well data and lateral variations of the seismic properties. Given the facies classification in the wells and correlation with petrophysical parameters, we converted the reference inversion output into reservoir characteristics.

The main findings are:

1. Despite the limitations of the Geokinetics (2014) 3D seismic, the inversion confidently delineates the Yalgorup/Wonnerup interface;

2. As expected, this horizon corresponds to the rapid transition of the impermeable rocks to reservoir sandstone. While the probability of the baffles exceeds 70%, it is never close to 100%, and thus, permits lateral discontinuity of the sealing interface along the horizon;

3. Within the sufficient seismic quality areas, we observed two seismic lithology types within Wonnerup:

   a. intense layering in the deeper parts towards western edge of the survey

   b. uniform reservoir – the most typical appearance.

4. We suggest that the quiescent Wonnerup Member may be due to the overlapping depth trends of the reservoir/baffles facies types, so they become seismically indistinguishable. Validation of this suggestion requires additional well information.