



NORWEST ENERGY NL

A CASE STUDY

- *REDUCED TOTAL WATER CONSUMPTION VIA UTILISING RECYCLED FLOWBACK FLUID IN SUBSEQUENT STAGES OF HYDRAULIC FRACTURE STIMULATION PROGRAM*
- *MEASURED FRACTURE HEIGHT GROWTH AND PROPAGATION DISTANCES VIA STATE-OF-THE-ART TECHNOLOGIES*

EP413

ARROWSMITH-2 WELL

ONSHORE NORTHERN PERTH BASIN

WESTERN AUSTRALIA

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INTRODUCTION

Norwest Energy NL ('Norwest') is a junior exploration company listed on the Australian Securities Exchange for over 20 years. Norwest has a portfolio of permits located within the northern Perth Basin of Western Australia.

EP413 is one such project, located on Crown Land and covering an area of 508.3km². The nearest township of Eneabba located 30km to the south.

The AS-2 drilling and hydraulic fracture stimulation program was conducted between 2011-2014. This well was drilled as a pilot well to test the unconventional formations within EP413. Norwest was subject to intense scrutiny and oversight by the Regulator throughout this program. Coupled with a world-class technical program, Norwest was able to deliver a project that met all regulatory requirements including health, safety and environmental targets.

This project has provided a foundation upon which Norwest and its Joint Venture partners AWE Limited and Bharat PetroResources Ltd (Bharat) can continue to explore for unconventional resources in the northern Perth Basin. It has provided the unique opportunity to involve the Indian Government in an unconventional resource exploration program in Western Australia, via their wholly-owned company Bharat, with their financial and technical commitment to the project highly valued.

It was vitally important that Norwest undertook comprehensive stakeholder engagement with all relevant stakeholders throughout the project lifecycle, and in particular prior to the hydraulic fracture stimulation program. The stakeholder engagement program was extensive, providing information and education materials to the relevant parties. Public meetings, company website materials, flyers, media advertisements and other means were all employed to inform all relevant parties.

Additionally, Norwest has a policy for employing local people, contractors and businesses wherever possible, and has spent over \$5M in the local community since 2011.

Norwest has developed a strong relationship with the Amangu Traditional Owners and seeks their assistance in conducting all necessary Heritage Surveys and related activities within the permit boundaries.

It became apparent early in the project development phase that baseline studies data would be invaluable in demonstrating the high degree of environmental management standards adhered to across this program. Supporting this concept, Norwest participated in a comprehensive baseline studies consortium with other northern Perth Basin operators, the Department of Mines and Petroleum, the University of Western Australia, and CSIRO. This dataset has proven useful in liaising with all project stakeholders, with the long-term results showing no impact from hydraulic fracture stimulation whatsoever.

This document provides an overview of the Arrowsmith-2 hydraulic fracture stimulation program, with one highlight being the demonstrated use of recycled flowback fluids in subsequent stages providing a 50% reduction in water consumption across the program. A second highlight is the use of tracer beads and logging technologies to measure fracture height growth and propagation distances near the wellbore.

TECHNICAL PROGRAM

Arrowsmith-2 (AS-2) was drilled as a vertical pilot well in 2011 to specifically target and test unconventional prospects. The formations of interest formed a gross column of over >1000 metres thickness, at a depth of 2240-3301m below the surface.



Figure 1 AS-2 well location

Due to the results of the AS-2 drilling program, the decision was made to extend the evaluation to include hydraulic fracture stimulation.

This project was regulated under the *Petroleum and Geothermal Resources Act 1967* and administered by the Department of Mines, Industry Regulation and Safety (previously Department of Mines and Petroleum). The *Guide to the Regulatory Framework for Shale and Tight Gas in Western Australia: A Whole-of-Government Approach* provided the legislation governing the hydraulic fracture stimulation program.

Documents required for development and submission included the Environmental Plan, Well Management Plan, Safety Management System, Emergency Response Plan and Oil Spill Contingency Plan.

After a rigorous regulatory approvals process, the hydraulic fracture stimulation program commenced in mid-2012.

Rigorous regulatory approvals process undertaken prior to commencement with safety, environment and technical regulatory audits conducted throughout project lifecycle

A summary of the Evaluation Plan for AS-2 is provided as Figure 2.

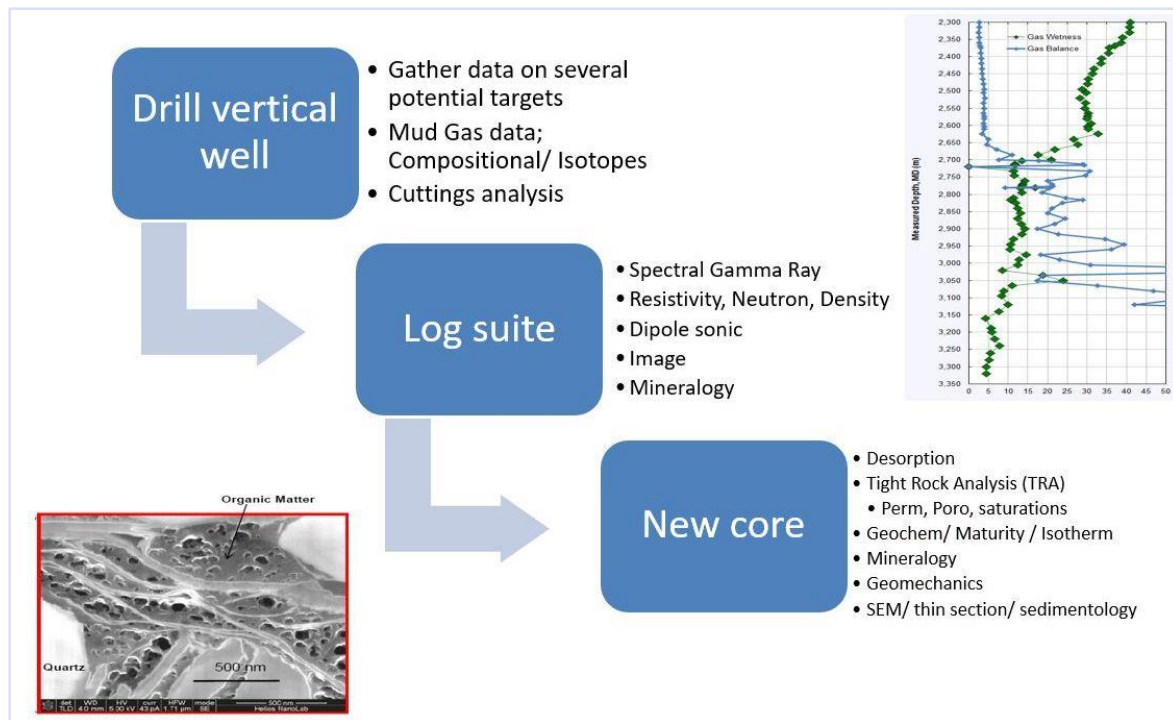


Figure 2. Evaluation Plan for AS-2

The AS-2 hydraulic fracture stimulation program consisted of 5 stages (Refer Figure 3).

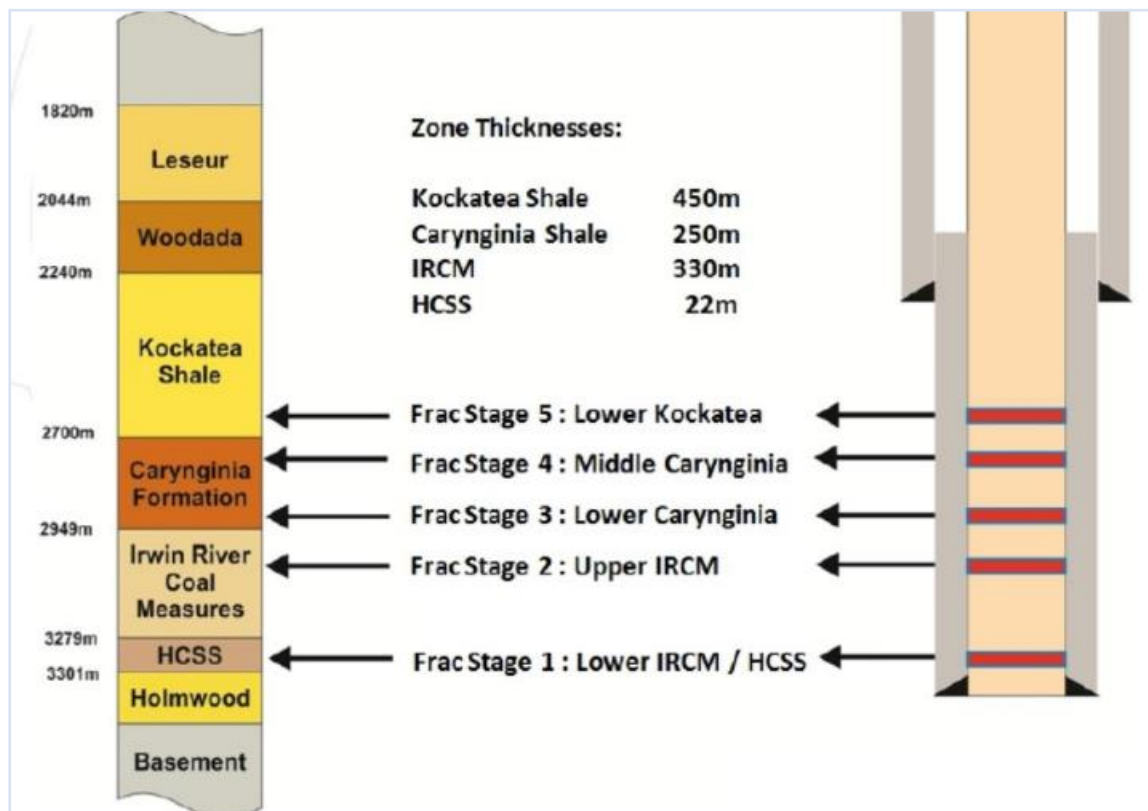


Figure 3 Formations of interest in EP413

Fracture Modelling

One important aspect of the technical program was to understand the extent of the fracture network created during hydraulic fracture stimulation.

Data obtained during the fracture stimulation stages was incorporated into a computer simulation model, enabling design modifications to be made for subsequent stages in the program. This calibrated model gave indications for both fracture height growth and penetration into the formations (Refer Figure 4). Induced fractures were projected to create a half-length of 700m, with the majority of proppant placement within the first 200m of the wellbore. The fracture height was projected to predominantly grow downwards with the height growth projected to be less than 17 metres.

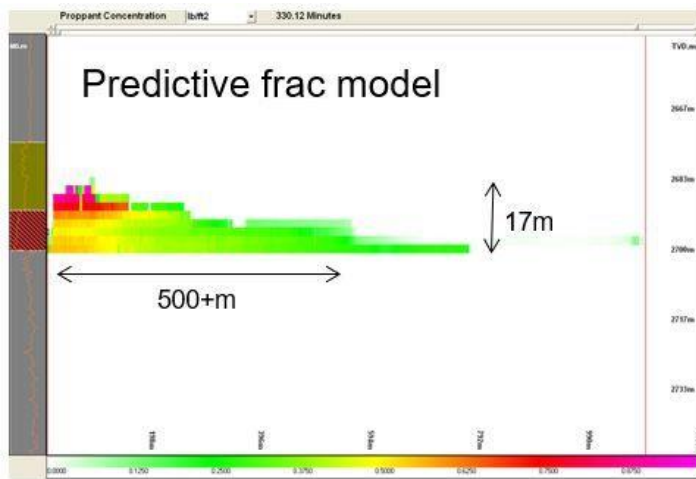


Figure 4 Simulation model output showing fracture height growth and penetration, along with proppant concentration

Tracer Technology

To fully understand fracture propagation and formation penetration, a proppant tracing technology was utilised at AS-2 (ProTechnics 2018). This process involved the precise injection of a small quantity of uniquely identifiable tracer beads into the hydraulic fracture stimulation fluid system.

A post-fracture stimulation gamma ray log was then run to precisely identify and quantify the tracer bead placement in the completion operation (CoreLab 2018). This process provided direct measurements to develop and refine completion procedures and processes to optimise production, and to understand fracture height and propagation.

Arrowsmith-2 Stage 2 - IRCM

Red colour depicts fracture placement, fracture height and proppant placement

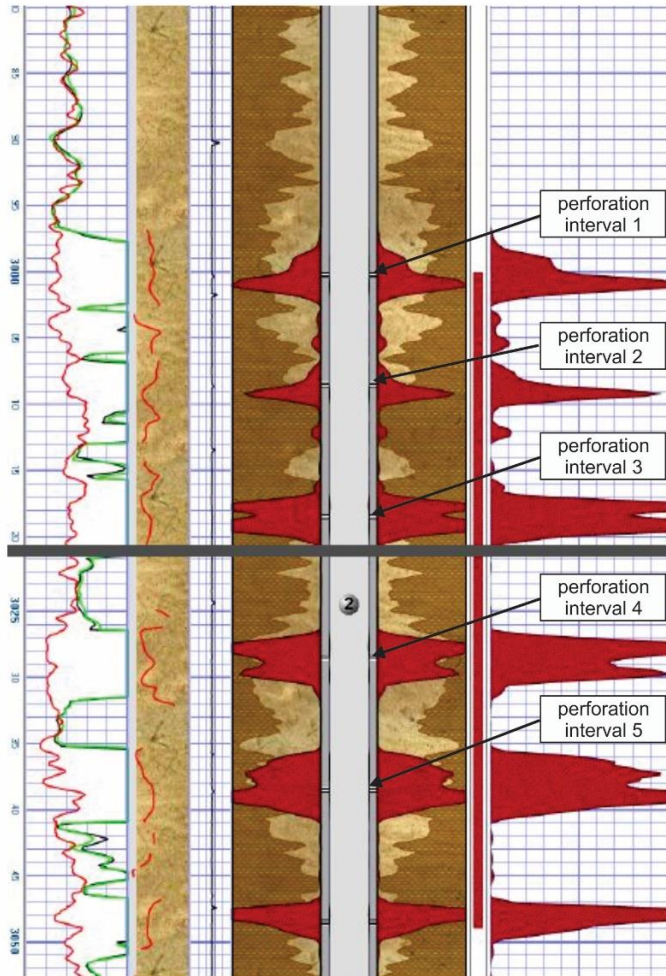


Figure 5 depicts the Spectrascan log for stage 2 of the Arrowsmith-2 hydraulic fracture stimulation program.

The six perforation intervals are shown in this image.

The hydraulic fracture stimulation fluid and proppant were pumped into the formation through these small perforations.

The red colour in Figure 5 depicts where the proppant (sand) was placed during the fracture stimulation.

These results provided direct measurements to develop and refine subsequent completion procedures.

However even more importantly, it demonstrated that vertical fracture growth was limited to within the target formation.

Figure 5 Arrowsmith-2 well Spectrascan gamma ray log output defining fracture height and proppant placement

Evaluation demonstrated that vertical fracture growth was limited to the targeted formations and with induced fracture height <17 metres

Well Integrity

AS-2 was designed and constructed with multiple casing strings satisfying industry standards (Refer Figure 6).

Appendix I - Downhole Diagram

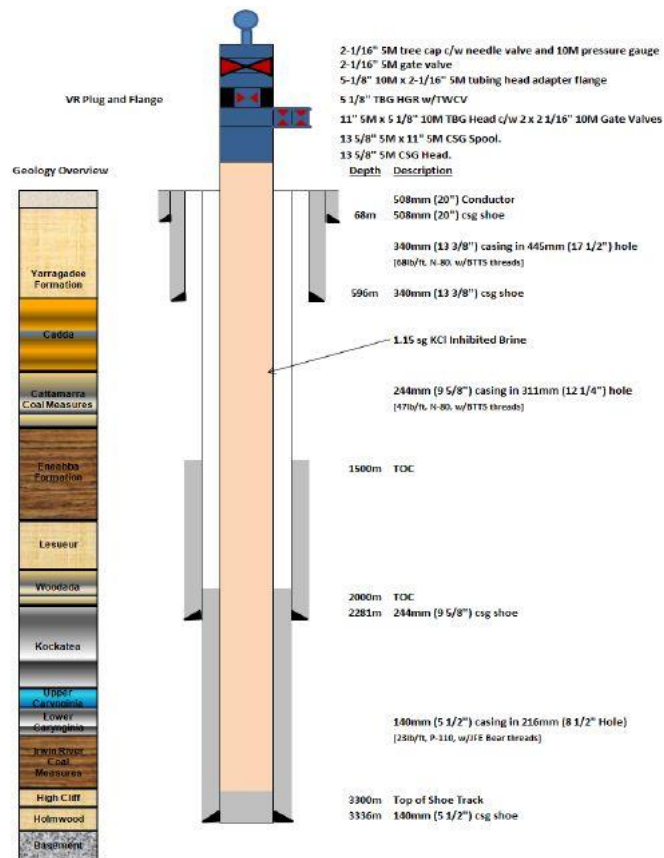


Figure 6 AS-2 Well Design

A Well Management Plan with a specific section on well integrity was developed, submitted and approved by the Regulator.

During the drilling and completing of the well, cement was injected through the wellbore and up the annulus between the steel casing and the formation, providing an additional layer of separation between the AS-2 wellbore and surrounding environment. This implementation followed the specific parameters set during the well design process, and adhering to all necessary regulations on well construction.

Pressure testing and validation against the design criteria were undertaken during the program to confirm well design specifications had been met.

Prior to the stimulation program, a cement bond log (CBL) was run on the AS-2 well. This log provided evidence that the cementing job had been successful, and well integrity confirmed. A sample of the CBL is provided in Figure 7 below.

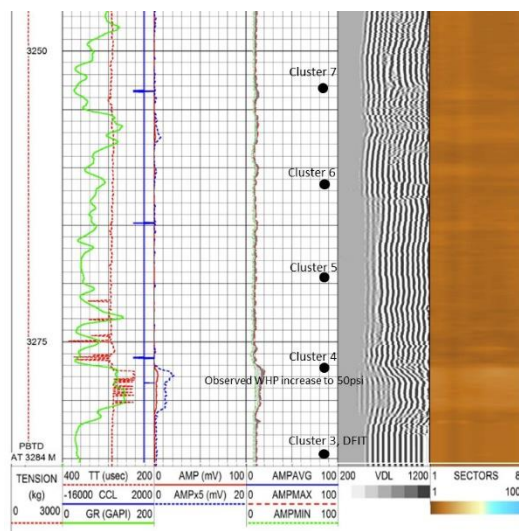


Figure 7 Stage 1 cement bond log (CBL)

Ongoing Pressure Monitoring

Norwest continues to conduct 6 monthly monitoring of wellhead and production tree pressure to ensure well integrity is maintained, with inspection reports required to be submitted to the Regulator.

Security measures have been implemented to ensure the wellhead cannot be tampered with, and a security fence is in place around the wellhead, located inside a fenced off location with padlocked gates and signage in place to deter entry.

Cement Bond Log demonstrates well integrity

WATER USAGE

The water used at the AS-2 project was extracted from a water well situated in EP413, under a water licence provided by the Department of Water.

A highlight of the AS-2 program was the water-saving methodology that was implemented.

During flow back of stage 1 of the Arrowsmith-2 five stage fracture stimulation programme it was observed that the flow back water salinities were relatively low when compared to returned fluids data from the US with concentrations between 15 and 20,000 ppm and a pH of between 7.5 and 8.5.

A forward plan was implemented to test the potential for utilising the returned water in subsequent stages of the programme in consideration for future unconventional gas appraisal and development activity in the area.

Two days after completion of the Arrowsmith-2 stage 2 fracture stimulation treatment, flow back water samples were acquired and sent to a 3rd party laboratory for analysis, where a full compositional analysis was undertaken. In addition to confirming the flow back water salinities & pH that were being measured on site, this testing was also designed to test for other flow back water potential contaminants that may result in the flow back water being unsuitable for reuse on subsequent fracture stimulation stages on the well.

The results were favourable and with DMIRS approval the stage 3 fracture stimulation treatment was designed utilising a 50:50 blend of fresh water and flow back water. The stage 3 treatment was

conducted however at 2/3rds of the way through the treatment the decision was made to revert to utilising 100% fresh water to negate the potential the flow back water was causing the higher than anticipated treating pressures, which was subsequently proven to not be the case. Stages 4 and 5 were both then successfully completed utilising a 50:50 blend of fresh water and flow back water to prove that flow back water could be successfully reused on fracture stimulation activity in the area to minimise the amount of fresh water required.

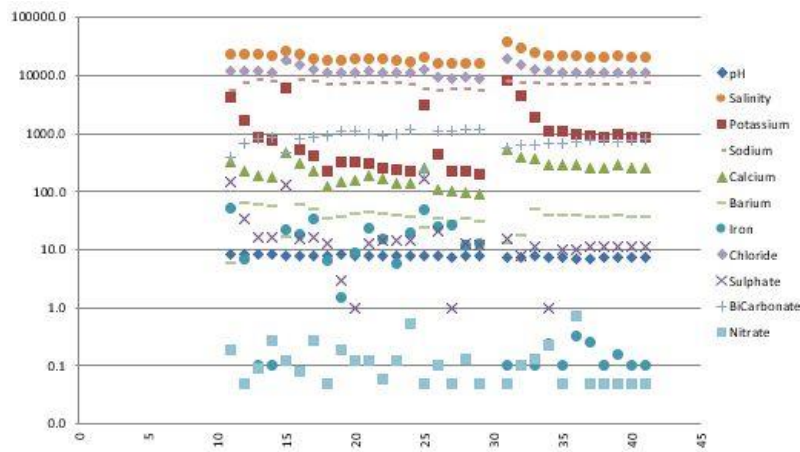


Figure 8 Example of flowback fluid analysis

Recycling of Flowback Water represented 50% reduction in water use

Baseline Studies

In 2014, a consortium of northern Perth Basin operators was established, with the purpose of creating a dataset of baseline values of environmental indicators and monitoring techniques used during development of tight gas resources in the northern Perth Basin. The consortium was made up of AWE Limited, Origin Energy, Latent Petroleum, the Department of Mines and Petroleum, the University of Western Australia and Norwest Energy, with the study led by CSIRO.

The study included a desktop study of groundwater monitoring data, monitoring of the water well at AS-2 and water wells within other operators' permits.

Additionally, a vehicle mounted picaro system measuring atmospheric levels of methane gas was undertaken in November 2015 (Figure 9). The survey covered 1588km in 5 days, stopping periodically to measure wind speed and direction, and to take flux measurements. The findings of the survey were that methane levels across the transect were within expected background levels.



Figure 9 Vehicle-mounted Picaro system measuring methane emissions

These baseline studies were vital in gaining community trust and support, by demonstrating that unconventional resource extraction does not show any evidence of methane emissions or have adverse effects on groundwater .

A more complete overview is provided by an APPEA journal publication (Hortle et al. 2017).

Seismic Monitoring

Norwest also participates in an ongoing seismic monitoring program led by the Seismology Research Centre (SRC) (www.src.com.au), with an onsite seismic monitor operating near the AS-2 well location since mid-September 2014 (Figure 10).



Figure 10 Seismic monitoring station at AS-2 location

Using the data collected by Geoscience Australia in conjunction with the northern Perth Basin Seismic Network, SRC has developed an historic earthquake catalogue. (Refer Figure 11). There were 63 earthquakes recorded within the region during the reporting period, with none in the vicinity of AS-2.

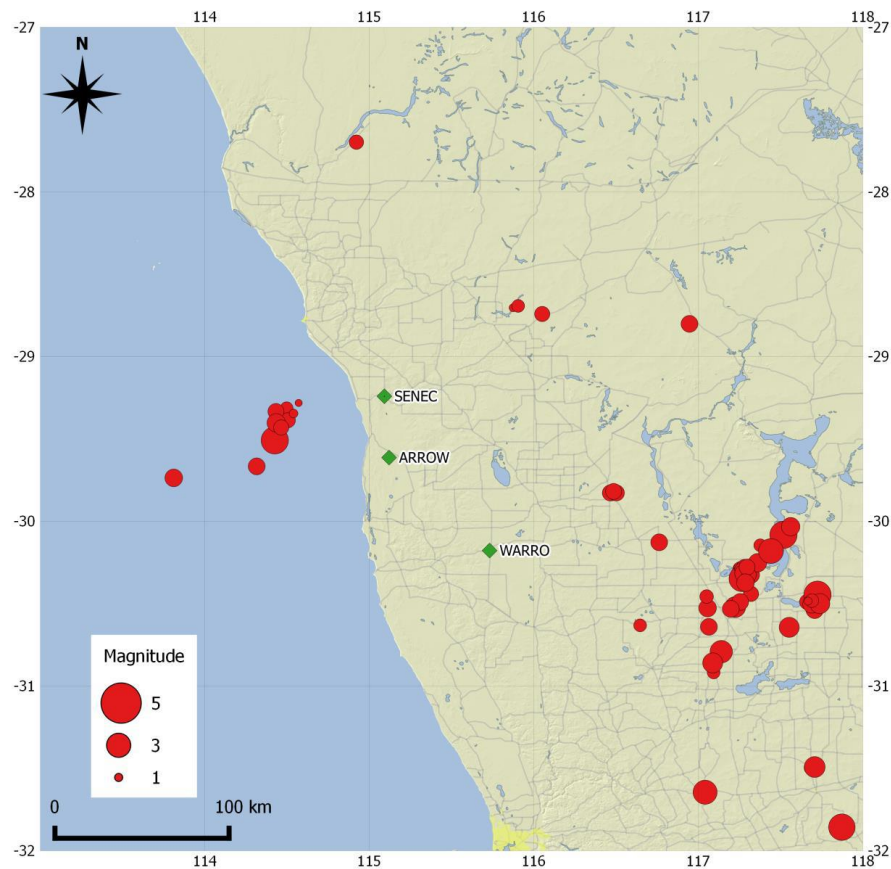


Figure 11 Seismic Monitoring Output for northern Perth Basin and surrounds, 2016

RESULTS & FORWARD PROGRAM

AS-2 was a successful exploration proof of concept well, with results exceeding the initial objectives and expectations of the technical group. The well proved that the unconventional formations were suitable for hydraulic fracture stimulation techniques and confirmed the unconventional resource along with high grading two specific zones for further shale gas exploration. Along with the shale gas discovery was a shale oil discovery – an unexpected development.

The collection and integration of the drilling, stimulation and production data provided clarity to the technical team on productive zones, demonstrating that these tight formations could be stimulated.

A 100km² 3D seismic survey was acquired in 2015 over the most prospective areas of EP413, with commercial studies subsequently completed to understand project economics. An independent resource estimate was completed, indicating a prospective gross recoverable resource of 2.6 TCF and a contingent gross recoverable resource of 316 BCF (Refer Figure 9).

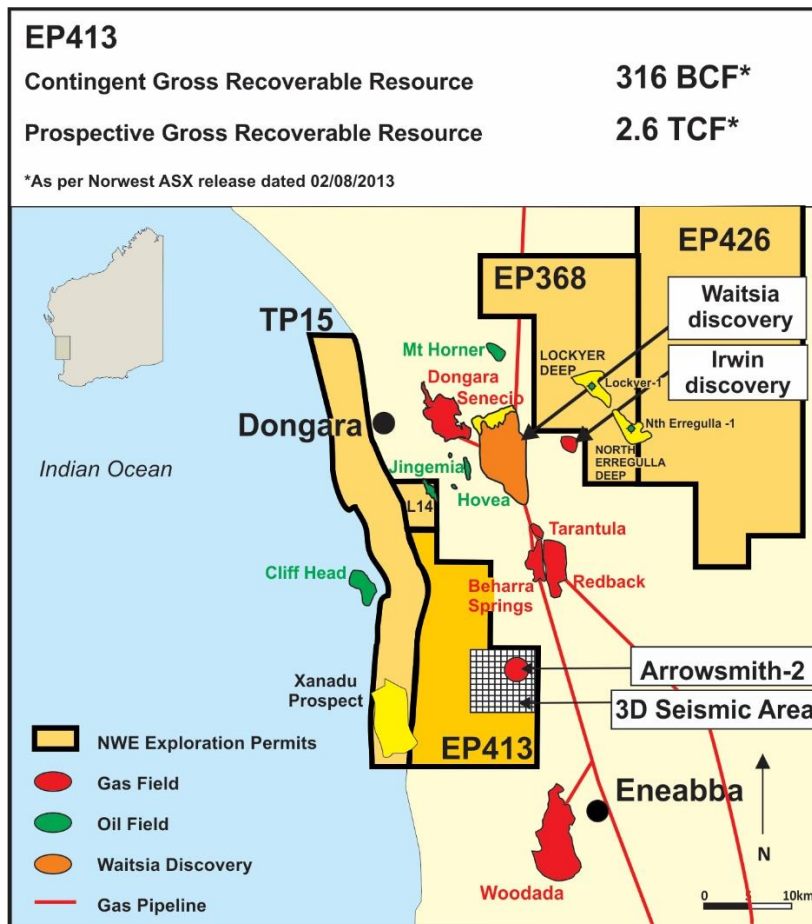


Figure 8 EP413 Location Map highlighting Independent Resource Estimates

The next step for the EP413 Joint Venture is to commit to the decision to drill a horizontal well, to tap into the extensive unconventional gas resources that are located within the permit boundaries.

This decision is ON HOLD until the findings of this inquiry are complete.

BIBLIOGRAPHY

CoreLab. 2018. "Imaging Services - SpectraScan." <http://www.corelab.com/protechnics/spectra-scan>.

Hortle, Allison, Praveen Kumar Rachakonda, Suman George, Matt Myers, and Cameron White. 2017. "Baseline characterisation and monitoring protocols for development of shale and tight gas resources, northern Perth Basin." *APPEA Journal* 57 (1):64-78.

ProTechnics. 2018. "SpectraStim." <http://www.corelab.com/protechnics/cms/docs/brochure/SPECTRASTIM.pdf>.