SEPTEMBER 2011

PETROLEUM IN WESTERN AUSTRALIA

WESTERN AUSTRALIA'S DIGEST OF PETROLEUM EXPLORATION, DEVELOPMENT AND PRODUCTION

Contents

Landscape near Karratha
(Photo courtesy of Woodside Energy Ltd)

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Cover Photo: Fracture stimulation equipment at Warro 4 in the northern Perth Basin
(Photo courtesy of Nirmal Mathew)

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Government of **Western Australia**
Department of **Mines and Petroleum**

WESTERN AUSTRALIA

Opportunities to Explore
BIDS INVITED FOR ACREAGE

Courtesy of Buru Energy Ltd

PETROLEUM ACREAGE

Northern Carnarvon Basin

There are two release areas in the highly prospective offshore Northern Carnarvon Basin. A combined release area is 1,742 km^2 in size. The other area is 1,441 km^2 in size. Targets may include Cretaceous, Jurassic and Triassic sandstones.

Canning Basin

There is one onshore release area on the Broome Platform of size 4,776 km^2.

Hydrocarbon shows are widespread in the Ordovician on the Broome Platform. The Ordovician of the Broome Platform has a salt seal in the Mallowa Salt and a notable source rock in the Goldwyer Formation. There are potential sub-salt and post-salt targets. The Goldwyer Formation is a potential shale gas target.

Perth Basin

There are six release areas in the onshore northern Perth Basin. Area size ranges from 75 km^2 to 2,633 km^2. The northern Perth Basin has numerous seismic lines, wells, and has had oil and gas production from Permian and Jurassic reservoirs. Two gas pipelines run through or are adjacent to the release areas. A sealed highway runs south to the State capital Perth and the Kwinana oil refinery.

Bids close 8 March 2012.

GEOTHERMAL ACREAGE

Acreage is available for the whole of the State not covered by permits or applications. Application is by a Geothermal Prospecting Authority (GSPA) with Acreage Option (AO).

Companies are invited to apply for areas each with size up to 160 5'x5' graticular blocks.

Companies interested in geothermal acreage are allowed to bid for multiple areas and are expected to drill at least one well to a depth of 400 m during the first two years of obtaining a geothermal title.

Geothermal acreage information is available from DMP on the web at: www.dmp.wa.gov.au/acreage_release

FURTHER INFORMATION

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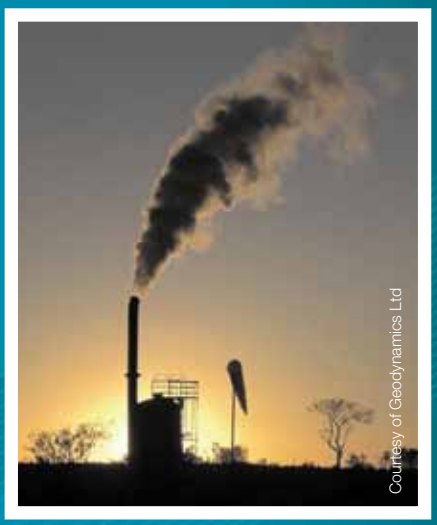


Courtesy of Geodynamics Ltd

Acreage release packages contain relevant information about the release areas, land access and how to make a valid application for an Exploration Permit.

Acreage release CD packages are available from DMP and a web version is also available: www.dmp.wa.gov.au/acreage_release

www.dmp.wa.gov.au

Hon. Norman Moore MLC
Minister for Mines and Petroleum

Minister's Message

The petroleum sector is Western Australia's second largest sector after iron ore. Last year it accounted for more than $22 billion or 25 per cent of total sales. In 2010, approximately $2.5 billion was spent on petroleum exploration in Western Australia, the second highest figure on record.

The State is Australia's largest producer of oil and gas. Last year, WA was responsible 89 per cent of the nation's crude oil and condensate production and 71 per cent of Australia's natural gas production. This is a trend that is set to continue.

There is more than $140 billion worth of projects in the pipeline in Western Australia. These will generate thousands of jobs in the next decade.

We have eight liquified natural gas (LNG) projects that are coming close to starting; six projects, including Gorgon and Pluto, which are moving ahead; and we can see another six to eight on-line, with final decisions to be made in the next year.

To put this into perspective, at the end of last year, we had 4,020 giga cubic metres (142 trillion cubic feet) of gas resources, which is, at our current rate of consumption, enough to provide energy for 125 years.

Once we increase production, which will happen in the next six to seven years, we have calculated we may have 30 to 35 years of gas resources behind us. However, this doesn't include yet-to-be discovered resources.

There is also the potential for significant onshore discoveries. If shale and tight gas production is demonstrated, we would see a further expansion of the industry. Shale reservoirs have so far been identified in the Perth and Canning basins.

An independent report released in April by the US Energy Information Administration lists Australia as one of the top ten countries with technically recoverable shale gas resources, equalling 11,213 Gm^3 (396 Tcf).

WA's shale gas resources total 8,155 Gm^3 (288 Tcf), which is two times the current amount of natural gas the Department of Mines and Petroleum currently has on file. Shale gas is in its infancy stage in WA, but it looks like this sector will have high potential.

However, it is vital that the department and industry address public concerns surrounding shale, tight and coal seam gas.

DMP is aware of concerns that the hydraulic fracturing process associated with shale, tight and coal seam gas (CSG) has potentially serious environmental impacts, including issues associated with water supplies.

However, there are a number of mitigating factors influencing the situation in Western Australia to make it very different to other parts of the world, particularly where CSG is the target, such as in Queensland and New South Wales.

Importantly, shale gas and tight gas resources in Western Australia are located at deep horizons, well separated from fresh water aquifers.

In Queensland for example, it is common for resources to be located relatively close to the surface at approximately 200–1,000 metres, where aquifers can also be located.

In Western Australia, our fresh water aquifers are typically located no deeper than 600 metres, with our unconventional gas resources located at depths beyond 2,000 metres.

This means that there is generally a separation between aquifers and unconventional gas resources of at least 1.4 kilometres.

DMP has extensive experience in regulation, having been ensuring the safe development of these resources and the use of these operational techniques, including hydraulic fracturing, for more than 40 years.

The approvals process used ensures that any company seeking to carry out petroleum drilling operations must submit a Drilling Application, Environmental Management Plan and Safety Management Plan detailing their intended actions. This includes details of chemicals to be used and how the environment, including ground water, will be protected.

DMP is also able to request further information from companies to ensure that all necessary precautions are being taken to protect the environment.

DMP liaises with other State Government agencies, such as the Environmental Protection Authority (EPA) and the Department of Water to ensure that a whole-of-Government approach is taken to protect the environment.

I am confident that the State's current regulatory processes will ensure water resources are adequately protected from any potential hydraulic fracturing activities. ■

Bill Tinapple
Executive Director
Petroleum Division

Executive Director's Message: Is Hydraulic Fracturing a Problem in WA?

Following adverse publicity from news coverage, documentaries and moratoriums imposed by some governments, there has been public concern in Western Australia over hydraulic fracturing and the potential to cause water pollution. Is it a serious problem in WA?

The application of technologies from overseas is providing the opportunity to tap new natural gas resources in Western Australia. The technologies are based on combining hydraulic fracturing with horizontal drilling in shale and tight formations to make these sources of gas commercially viable. Hydraulic fracturing creates flow paths in the impermeable rocks. As written in the previous edition of *Petroleum in Western Australia*, demonstration of commerciality could create the next phase of expansion in the State's gas and LNG industries.

At the end of 2010, WA was estimated to have over 4,000 Gm^3 (142 trillion cubic feet (Tcf)) of known gas resources. This is about two per cent of world gas reserves. These resources are mostly offshore WA in the Commonwealth Area. Industry is still discovering more gas than is produced, for example, for 2010, 226.5 Gm^3 (8 Tcf) was discovered while only just over 28.3 Gm^3 (1 Tcf) was produced.

However, despite new gas resources being discovered offshore, the real potential growth area for the State is onshore with shale gas and tight gas. A recent estimate (April 2011) by the US Energy Information Services estimated shale gas in the Perth Basin and Canning Basin to be 8,155 Gm^3 (288 Tcf). This estimate did not include other prospective areas or tight gas. Although there is some potential for coal seam gas (CSG) and some companies are exploring for it, CSG resources are still to be demonstrated. There is also potential for underground coal gasification (UCG), however, this is a different resource and covered under a different regulatory regime.

Most problems with hydraulic fracturing around the world and particularly in Australia have occurred with CSG. CSG is mostly shallow and near to or even inclusive of fresh ground water sources. On the other hand, WA targets for shale gas and tight gas are much deeper, between 2,500 m and 5,000 m.

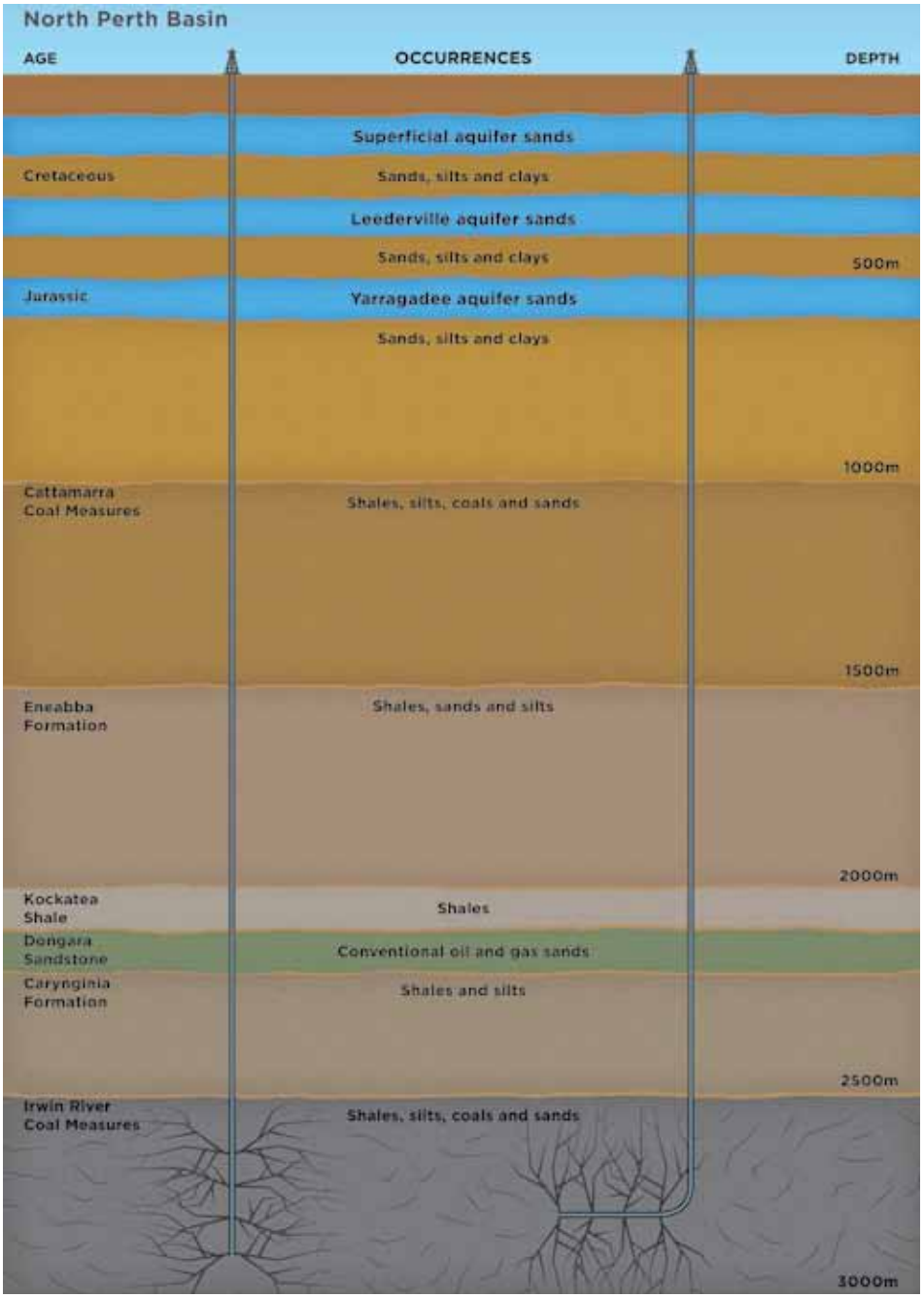


Figure 1 | **Schematic of the depth of hydraulic fracturing in relation to the northern Perth Basin geology**

The height of fractures caused by hydraulic fracturing is limited to about 300 m (see Figure 1).

The buffer zone of rock and shale prevents fracturing fluids from reaching ground water zones.

One pathway for fracturing fluids to potentially reach ground water zones is through wells. Proper well design and construction provides protection and prevents leakage to the surrounding rock formations.

The other pathway for fracturing fluids to potentially reach ground water zones is from the surface. Although about 60 per cent of fluids are locked in the deep formations, about 40 per cent flows back to the surface and has to be recovered and safely disposed of. Unlike de-watering that is required for CSG, shale gas and tight gas do not have significant produced formation water. Proper design of structures for containment of any flow-back fluids will prevent impacts to soil and ground water.

Companies are required to submit well drilling programs as well as environment management programs for assessment and approval.

DMP not only monitors drilling (including hydraulic fracturing) at this preliminary stage but monitors activities throughout drilling by reviewing daily drilling reports, meetings and site visits, as required.

Use of toxic chemicals is of concern. Fracturing fluids consist of 90% water, 9.5% sand (or other materials to prop open fractures) and 0.5% chemical additives (to create flow properties for the fluids). Industry and governments have been pushing to avoid the use of toxic chemicals. Most chemical additives in use are chemicals used in everyday households (see Figure 2). DMP is initiating the publishing of chemical additives proposed for fracturing fluids on its website for public access.

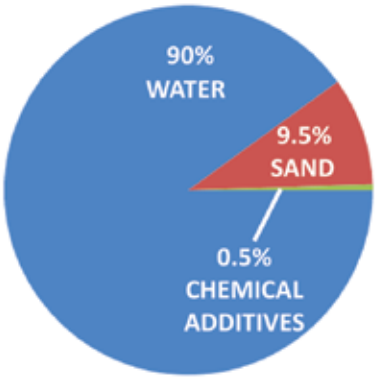
The use of hydraulic fracturing and the techniques involved are not new. The technique was used on Barrow Island in WA about 50 years ago to try to improve oil flow from wells.

The technique has been used in approximately one million wells in the United States over 60 years. Has it been safe? The US EPA and Ground Water Protection Council found in a 2004 assessment that there was no link between hydraulic fracturing and ground water impacts for CSG. The US EPA has recently initiated another assessment. In WA there have been no indications of ground water impacts.

DMP, however, is working to ensure that the regulatory regime in the State, and the way it is applied, are appropriate. We have had an independent review, which found that the regime and the way it is applied are good but that some improvements should be made to regulations. DMP is currently implementing these. Further, DMP is working with other State agencies to ensure the overall approach is effective.

I am hopeful that shale gas and tight gas will provide the next big resource expansion for the State and confident that this can happen in a socially and environmentally acceptable way. ■

Typical Shale Fracturing Mixture Makeup



Typical Chemical Additives Used in Frac Water

Compound	Purpose	Common application
Acids	Helps dissolve minerals and initate fissure in rock (pre-fracture)	Swimming pool cleaner
Sodium Chloride	Allows a delayed breakdown of the gel polymer chains	Table salt
Polyacrylamide	Minimizes the friction between fluid and pipe	Water treatment, soil conditioner
Ethylene Glycol	Prevents scale deposits in the pipe	Automotive anti-freeze, deicing agent, household cleaners
Borate Salts	Maintains fluid viscosity as temperature increases	Laundry detergent, hand soap, cosmetics
Sodium/Potassium Carbonate	Maintains effectiveness of other components, such as crosslinkers	Washing soda, detergent, soap, water softener, glass, ceramics
Glutaraldehyde	Eliminates bacteria in the water	Disinfectant, sterilization of medical and dental equipment
Guar Gum	Thickens the water to suspend the sand	Thickener in cosmetics, baked goods, ice cream, toothpaste, sauces
Citric Acid	Prevents precipitation of metal oxides	Food additive; food and beverages; lemon juice
Isopropenol	Used to increase the viscosity of the fracture fluid	Glass cleaner, antiperspirant, hair coloring

Source: DOE, GWPC: Modern Gas Shale Development in the United States: A Primer (2009)

Figure 2 | **The chemical additives that may make up the 0.5% of fracturing fluids used in hydraulic fracturing**

Petroleum Exploration, Production and Development Activity in Western Australia — Highlights from January to June 2011

Karina Jonasson
Petroleum Resource Geologist
Resources Branch

Drillers at work on the *Jack Bates*
(Photo courtesy of Kai Photography and Hess Exploration)

This article highlights petroleum exploration, production and development activities for the second half of the 2010–11 fiscal year. Statistical summary tables for this period can be found in the back of this magazine. A summary of activities carried out in the 2010 calendar year can be found in the April 2010 edition of the *Petroleum in Western Australia* magazine.

Wells drilled in 2010–11 consisted of 37 new field wildcats, 16 extension, and 14 development wells, for a total of 67 wells, which is two fewer than last fiscal year (Fig. 1). Of these, 15 wells were drilled onshore. While development activity is being maintained at the same level as last year, the amount of exploration drilling has been decreasing over the last few years. A total of 10,797 line km from 2D seismic and airborne gravity surveys and 23,942 km^2 from 3D seismic surveys (one of which was shot onshore) were carried out this fiscal year in Western Australia.

Drilling was again concentrated in the offshore Carnarvon Basin where Chevron, Apache, Woodside and Santos were the main operators with successful exploration activities in the first half of 2011. Empire Oil and Gas was the only successful onshore operator, with the discovery of gas and condensate at Red Gully 1 in the Perth Basin (Figs 2–4).

Offshore in the Carnarvon Basin, Apache's Zola 1ST1 was a natural gas discovery, Santos drilled Finucane South 1A resulting in an oil discovery, and Chevron's Orthrus 2 proved a deeper discovery in the Orthrus field. Apache also had success with Balnaves Deep 1, encountering oil and gas. Woodside's Martin 1 well intersected gas while its appraisal well at Laverda North 1 encountered oil.

One field started up production in the first half of 2011 — Apache's Halyard gas and condensate field came on line in June. Both the Ravensworth and Redback fields started production in the second half of 2010.

In February, Chevron announced drilling success at Orthrus 2 which was drilled to a total depth of 4,297 m in WA-24-R. The well encountered 74 m of net gas pay, of which 31 m of net gas pay was encountered in a deeper, previously unexplored target interval in the Orthrus field.

Zola 1ST1 was spudded on 1 December 2010 in WA-290-P and abandoned on 27 April 2011. The well tested the gas potential of several top and intra Triassic Mungaroo Formation sands (the primary reservoir at Gorgon) and discovered approximately 125 m of net gas pay in several sandstones from 4,099.5 to 4,602.5 m depth, where thickness and reservoir quality were reportedly better than expected. The Zola structure is a very large Triassic tilted fault block on trend with the giant Gorgon gasfield and had been one of the largest undrilled structural features in the Carnarvon Basin. Apache has stated that data gathered to date in Zola 1 and Zola 1ST1 has confirmed a significant gas discovery in the Mungaroo Formation. The well results indicate that volumetrically the greater Zola structure could be at the upper end of pre drill estimates of 28.3–56.6 Gm^3 (1–2 Tcf).

Located close to existing and developing gas infrastructure, Zola could have multiple potential development options. Any development at Zola could also include the overlying Antiope gas discovery from 1999-2000 (estimated at ~3.4 Gm^3 (120 Bcf)).

Balnaves Deep 1 was drilled in WA-356-P in March 2011 to appraise the Balnaves field following three successful appraisal wells by Apache in October. In May the company reported 110.3 m of net pay in a deeper Mungaroo gas pool in Balnaves Deep 1. The discovery will likely be tied in with the development of Apache's Julimar-Brunello complex as additional gas for the Wheatstone project.

Woodside's gas discovery at Martin 1 in March, with a 100 m gross gas column, will likely contribute to the Pluto LNG project along with other recent discoveries in WA-404-P, such as Martell 1, Noblige 1, Larsen 1, Larsen Deep 1 and Remy 1.

In June an exciting oil discovery was made with the drilling of the Finucane

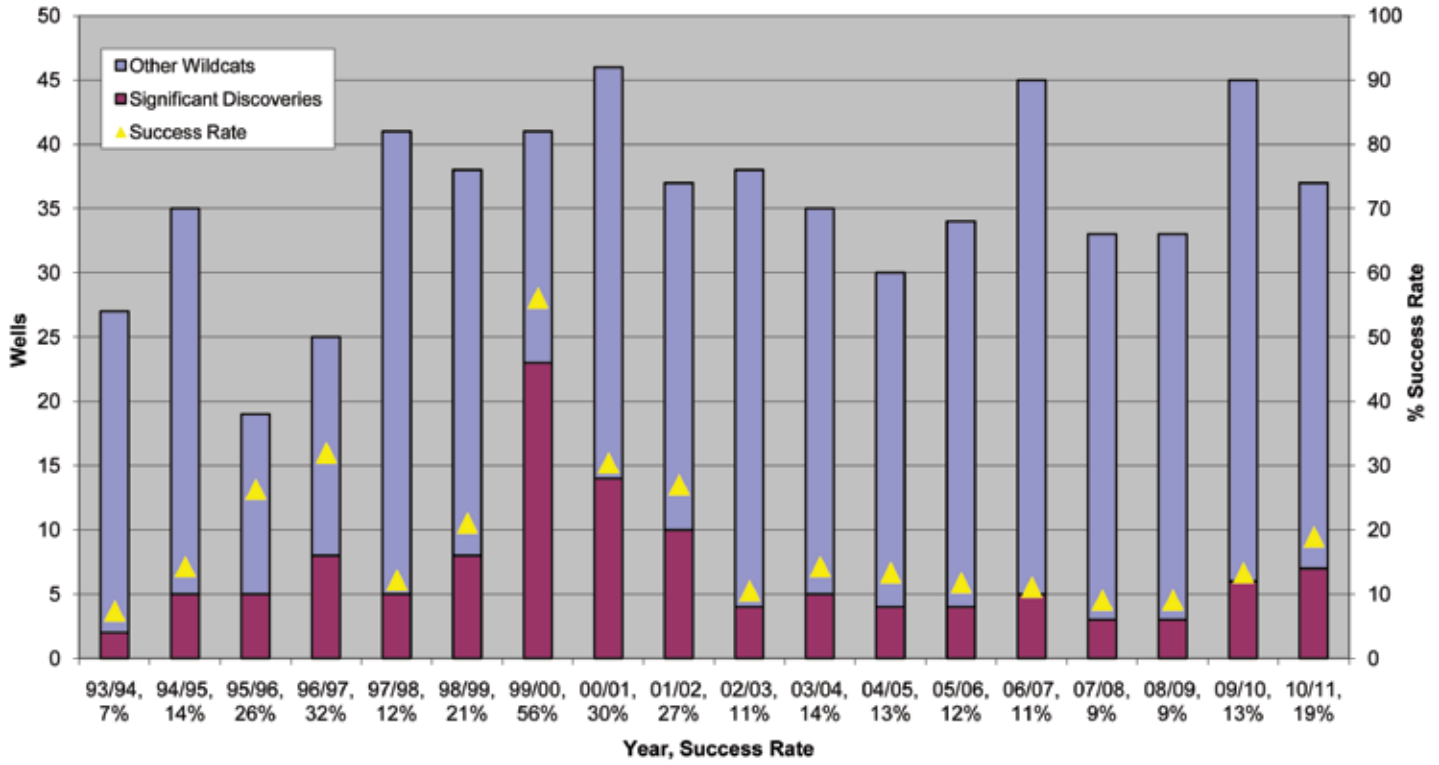


Figure 1 | **New field wildcats and significant discoveries in Western Australia (93/94–10/11)**

South 1A well in WA-191-P by Santos. It is located in 140 m water depth 2 km south-southwest of the Finucane 1 well drilled in 1987 which encountered oil shows at the top of the Angel Formation despite being drilled off structure. Finucane South 1A encountered an 18.5 m net oil column in Late Jurassic reservoir in the Angel Formation. The well was drilled to a total depth of 3,190 m. Santos will be evaluating whether the discovery can be developed through the nearby Mutineer Exeter facility 15 km to the west, along with the adjacent Fletcher field.

Woodside's Laverda North 2 appraisal well in WA-36-R intersected an 18 m gross oil column in new oil-bearing sands, greatly increasing the estimates of recoverable oil in the Laverda area. Laverda North 2 was drilled in May 2011 to test an extension to the Laverda oilfield, which was discovered in 2000. The Greater Laverda area could potentially hold more than 16 GL (100 MMbbl) of recoverable oil, which could result in a stand-alone development in production as early as 2015.

Onshore, Red Gully 1 was a successful gas and condensate well. Unconventional gas exploration continues to gather momentum. While shale gas exploration is still in its infancy in Australia, Australian shales have been compared favourably to those in the US in recent reports. Several onshore operators will begin testing their wells using techniques developed in the US, particularly in the Perth Basin where there is existing infrastructure and a market for the gas.

EXPLORATION ACTIVITY BY BASIN

Bonaparte Basin

Two wells, Laperouse 1 and Durville 1 in WA-403-P were drilled by Total. A 2D seismic survey was shot offshore in WA-446-P.

Browse Basin

Woodside's NFW Omar 1 in WA-397-P and Shell's extension well at Concerto were the only two wells drilled in the Browse in 2010–11. Two 2D and three 3D surveys were completed in the basin.

Canning Basin

Buru continues its exploration program in the basin with three wildcat wells and two 2D surveys one of which covered Yulleroo South prospect. The Yulleroo 3D seismic survey acquisition is scheduled to commence in July 2011. The Valhalla 2 exploration well was spudded 6 June 2011 and was still drilling at the time of writing.

Carnarvon Basin

Twenty-four new field wildcats were drilled offshore. There were also 14 extension and 17 development wells. Most of the discoveries made in the Carnarvon Basin were gas pools as previously discussed. Santos's Finucane South 1A was an oil discovery in WA-191-P. Hess started appraisal drilling at some of its many discoveries in WA-390-P. A total of 20,813 km^3 of 3D seismic was acquired from 17 marine surveys. Onshore, New Standard completed two geochemical surveys.

Perth Basin

Norwest Energy and partner Bharat Petroleum spudded an offshore oil exploration well (targeting TP/15) from an onshore location in L2. Red Hill South 1 spudded on 1 March 2011 using Hunt Energy's Rig 2. The target reservoir was the late Permian Dongara Sandstone, at a depth of 1,580 m. Hydrocarbon shows were encountered at 1,710–1,716 m and at 1,766–1,780 m, however the hydrocarbon saturations are too low to be commercial. A gas discovery was made by Empire Oil and Gas at Red Gully 1 which was drilled from the same well site as Gingin West 1 in 2010. Empire recorded stabilised flow rates of 0.33 Mm^3/d (11.7 MMcf/d) of gas and 133 kL (837 bbl) of condensate per day from Red Gully 1.

The Arrowsmith 2 exploration well in the onshore Perth Basin, which spudded at the end of May, has been suspended until the well can be fracture stimulated to investigate the tight gas shale units in the Carynginia Formation.

Green Rock Energy Limited and BHP Billiton Worsley Alumina Pty Ltd carried out temperature soil and soil-gas sampling and gravity surveys for a geothermal project covering GEP 10, GEP 11 and GEP 12 in the Perth and Collie basins. Field acquisition occurred in 2010 and interpretation of data was carried out in 2011, and reported in June 2011.

PRODUCTION

In 2010, 67 fields were producing hydrocarbons from 42 licences in Western Australia (Bonaparte, Canning, Carnarvon and Perth basins). Average daily production in 2010 was 58,189.5 kL/d for liquids and 99,895.5 km^3/d gas. Production and reserves data to the end of the 2010 calendar year can be found in the tables section at the back of the magazine.

One new field came online in the first half of 2011: Apache's Halyard gas and condensate field, which was tied back to the Varanus Island processing facilities via East Spar. Halyard supplies domestic gas for Western Australia. Halyard will have an initial capacity of 1.4 Mm^3 (50 MMcf) of gas equivalent per day, and will double once the Spar 2 well is tied into the development. Apache is operator and holds a 55 per cent interest in the development. Santos holds the remaining 45 per cent.

Production Forecast

The Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) June 2011 report indicated that in 2010–11, Australian LNG exports are estimated to increase by eight per cent to 19.3 MMt due to higher demand from Japan, Korea and China. The exports would be augmented by start-up of projects currently under construction including Gorgon and two LNG projects in Queensland. In 2011–12, ABARES said there was potential for LNG exports to continue to increase by two per cent to 19.7 MMt underpinned by the scheduled start-up of the Pluto project in March 2012, with increased production supported by the Halyard and Reindeer fields in the Carnarvon Basin.

Australia's gas production is forecast to increase by 11 per cent to 5.4 Gm^3 (190.7 Bcf) during 2010–11, and by a further 17 per cent in 2011–12.

ABARES said Australia's oil and condensate production would decline by 1.5 per cent in 2010–11 to 25.2 GL (158.5 MMbbl) mainly due to weather disruptions and despite the ramp-up of Pyrenees and Van Gogh which has supported increased production since the second half of 2010. In 2011–12 production is forecast to increase by seven per cent to 26.9 GL (169 MMbbl), strengthened by new projects in the Carnarvon and Bonaparte basins.

DEVELOPMENT ACTIVITY OFFSHORE

Balnaves

The Balnaves field is an oil accumulation in the Mungaroo Formation in a separate reservoir beneath the large gas reservoirs of the Brunello gasfield. Balnaves 1 encountered 20 m of net oil pay in 2009. Apache has estimated 2.2–2.8 GL (14–18 MMbbl) of oil equivalent could be recoverable from the accumulation. Apache is reportedly working towards a final investment decision on the development of the Balnaves oilfield. The project is expected to cost $445 million to develop through a floating, production, storage and offloading vessel and first production from the field is expected in 2014 at 4,770 kL (30,000 bbl) of oil equivalent per day.

Browse LNG

Woodside is planning the Tridacna 3D survey over the southern portion of the Torosa gasfield which lies partly beneath Scott Reef. The survey is expected to take place during June to November and follows on from previous seismic surveys carried out in 2007 and 2008 as part of the ongoing program to appraise Torosa.

The proposed Browse development at James Price Point in Western Australia's Kimberley region includes the Torosa, Brecknock and Calliance discoveries, located offshore around 425 km north of Broome. The fields contain a combined contingent resource of about 396 Gm^3 (14 Tcf) of dry gas and 58.8 GL (370 MMbbl) of condensate.

Woodside started front-end engineering and design (FEED) work for the Browse project in February. In May the traditional owners of James Price Point reached a consent agreement with Woodside and the Western Australian government for the development of a LNG hub. A final investment decision for the development is targeted for mid-2012 while first gas is expected by 2017.

Coniston-Novara

Apache has given approval in February to go ahead with the development of the Coniston and Novara oilfields, located in WA-35-L and WA-255-P, via a tieback to the Van Gogh development. A preliminary field development plan has been submitted. The other partners in Coniston are Inpex (41.3 per cent) and Woodside (13 per cent). First oil production from Coniston is expected in 2013.

Dixon

The Commonwealth and State governments have thrown down the gauntlet to the North West Shelf Venture with the Joint Authority's decision not to renew the Dixon Retention Lease (WA-9-R) in the North West Shelf. The North West Shelf Venture has applied for a Production Licence and submitted a preliminary field development plan.

Gorgon

Award of contracts continues at the Gorgon project in a bid to start domestic gas production from Gorgon by the end of 2015, a year after the first liquefied natural cargo ships in 2014. Chevron says the project is on schedule and on budget. The *Atwood Osprey* started a drilling program in May in the Greater Gorgon area consisting of an exploration well and Gorgon development wells.

Ichthys

Federal environmental approval has been given to the Ichthys project. Ichthys is intended to deliver 8.4 million tonnes (MMt) of LNG and 1.6 MMt of liquefied petroleum gas per year as well as 15.9 ML (100,000 bbl) of condensate per day at peak. A final investment decision is expected later this year, with first gas planned for 2016.

NWS CWLH & NRB

The $1.8 billion North West Shelf oil redevelopment project was adversely affected by the bad weather experienced in Australia's North West in the first part of this year, and is now expected to start production in October. Woodside said completion of critical subsea work was affected while a mechanical fault was also experienced with a contractor's installation support vessel. It added that it did not expect any increase in the cost of the oil redevelopment project, which includes replacement of the *Cossack Pioneer* floating, production, storage and offloading facility at the Cossack Wanaea Lambert Hermes (CWLH) oilfields with the *Okha* FPSO.

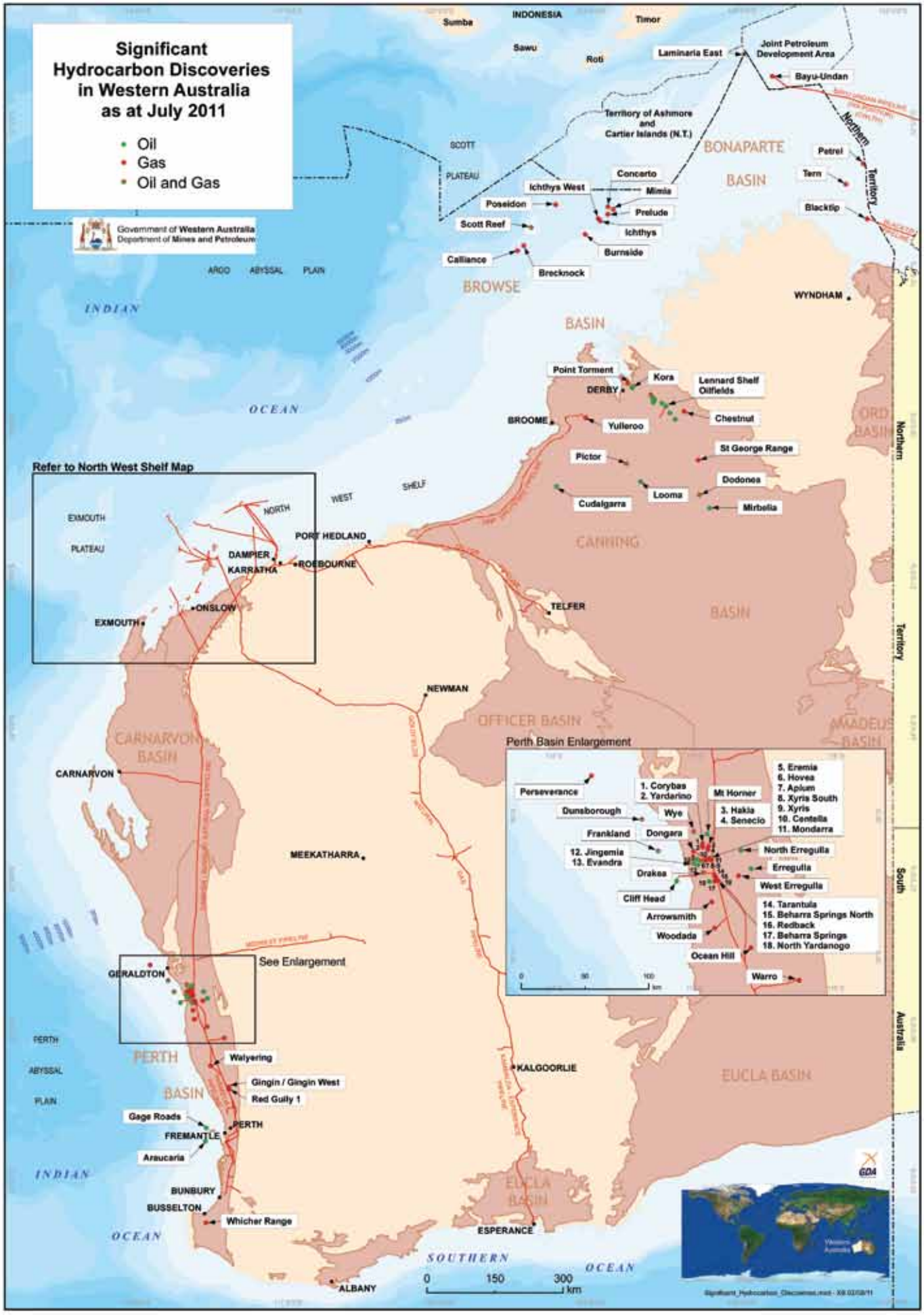


Figure 2 | **Significant hydrocarbon discoveries in Western Australia**

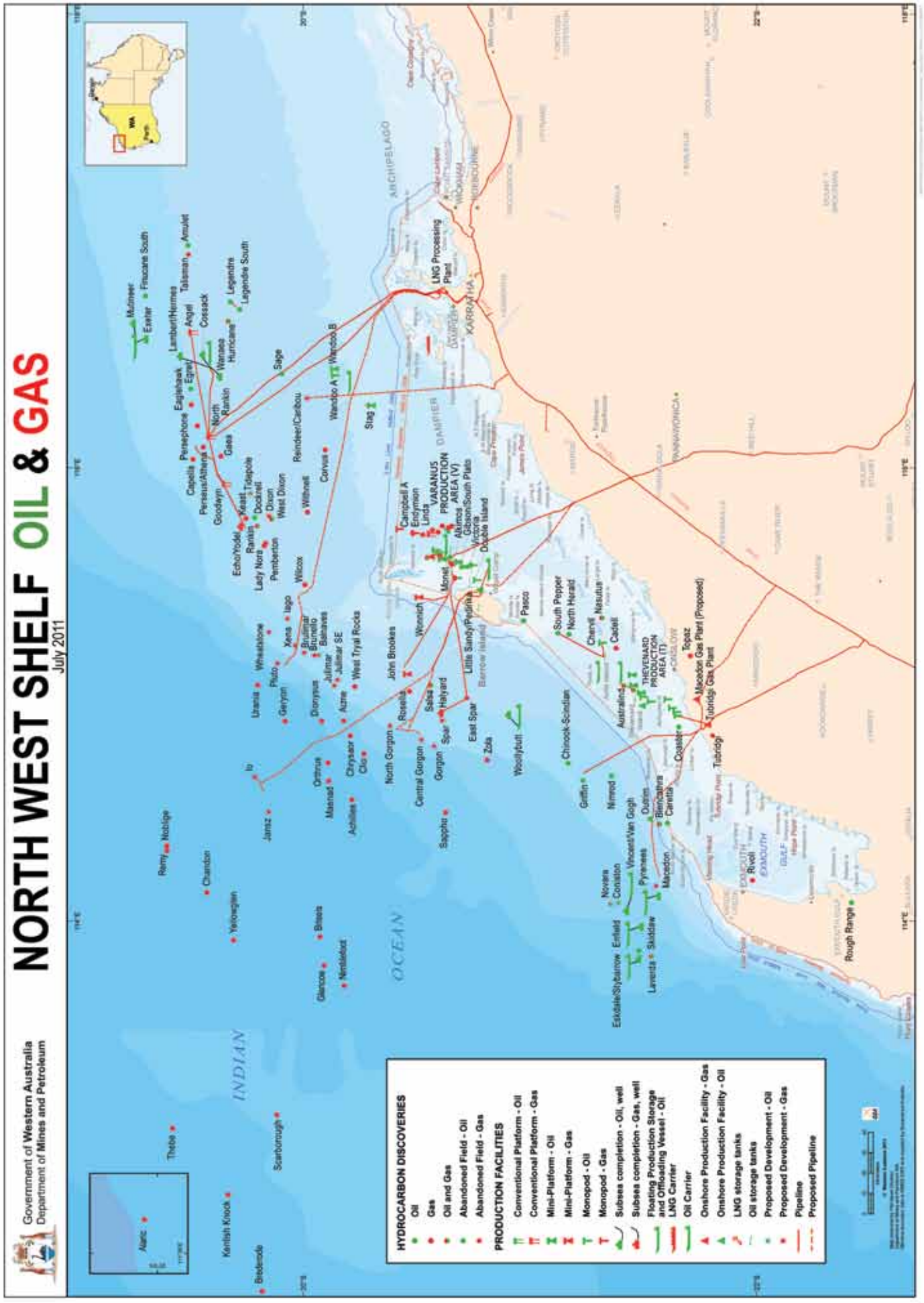


Figure 3 | **North West Shelf production facilities and significant hydrocrabon discoveries**

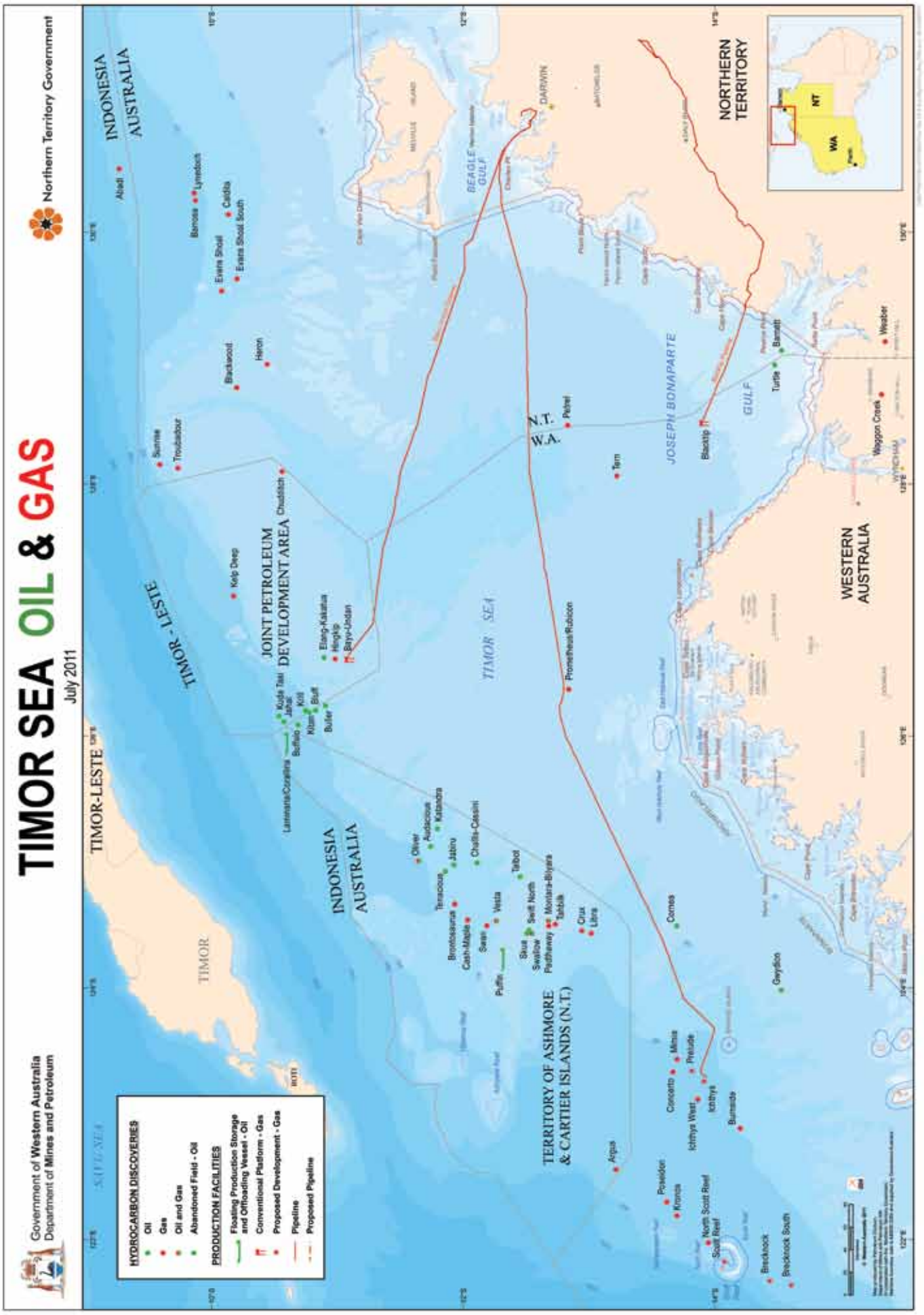


Figure 4 | **Timor Sea production facilities and significant hydrocarbon discoveries**

Macedon

Following approval in September 2010, contracts continue to be filled for BHP Billiton's Macedon project including one for pipeline construction to the Streicher Clough JV. The Macedon development involves four offshore production wells supplying a wet gas pipeline to an onshore gas treatment plant to be built at Ashburton North, 17 km southwest of Onslow. This will be connected to the Dampier to Bunbury Natural Gas Pipeline for sale into WA's domestic gas market. First gas is targeted for 2013. Macedon has estimated recoverable reserves of 11.3–21.2 Gm^3 (400–750 Bcf) of gas.

Pluto

Woodside announced its Pluto liquefied natural gas project would cost an extra $900 million and be another six months late, blowing out costs on an already extended project. The company blames slower than expected progress in commissioning of the onshore gas plant and seven weeks of delays caused by bad weather. Woodside now expects to ship its first cargo of LNG from the project in March 2012.

Prelude

In May 2011, Royal Dutch Shell made the decision to proceed with the Prelude FLNG Project and start construction of its pioneering FLNG facility, to be the largest floating structure ever built at 488 m long and 74 m wide. Once constructed the facility will be towed to location where it will be permanently moored by four groups of massive mooring chains in 250 m-deep water. Each mooring chain held to the sea floor by suction piles the size of small houses, and the FLNG facility has been designed to withstand a Category 5 cyclone. The vessel is expected to be ready in 2016 with first gas in the same year.

The Prelude FLNG facility is expected to be permanently moored about 200 km from the coast for its 25 year project life span, and will be capable of producing at least 3.6 million tonnes of LNG per year, as well as 400,000 tpa liquid petroleum gas (LPG) and 1.3 MMtpa condensate for export. The Prelude field lies in wholly Shell owned WA-371-P and contains estimated reserves of 71 to 85 Gm^3 (2.5 to 3.0 Tcf) gas and 1.9 GL (120 MMbbl) of condensate.

The Concerto field will also be developed via this facility. Shell has already agreed to sell LNG from Prelude to Japan's Osaka Gas.

Reindeer

The Devil Creek project, which will take gas from the Reindeer field located in the offshore WA-209-P block, is on schedule to deliver first gas by November 2011. The Devil Creek plant, located about 50 km from Karratha, is expected to supply up to 220 TJ of gas into the Dampier-Bunbury Natural Gas Pipeline and will also supply up to 8 kL (50 bbl) of condensate per day. The plant will be Western Australia's third domestic natural gas processing hub and the first new one in more than 15 years.

Scarborough

BHP Billiton and ExxonMobil are considering a range of development options for development of their Scarborough field, including an onshore plant, floating LNG and making a deal with an existing project. Woodside Petroleum's Pluto project is considered to be a front-runner.

Aerial view of the Pluto LNG plant at Karratha
(Photo courtesy of Woodside Energy)

Wheatstone

With the FEED stage complete and EPA approval granted for the Wheatstone project (June), FID is expected in the second half of 2011. Chevron is still waiting on State and Federal environmental approval. The Wheatstone project will take gas from Chevron's wholly owned Wheatstone field, located in WA-37-L and WA-38-L.

Apache is also seeking environmental approval for the development of its Julimar and Brunello gasfields, which will feed gas into Wheatstone. The project will take gas from Apache Energy and Kufpec Australia's Julimar and Brunello fields under a deal that gives the two companies a 13 per cent and 7 per cent equity stake in the Wheatstone facilities respectively. First LNG shipments are expected by 2016.

DEVELOPMENT ACTIVITY ONSHORE

Warro

The Warro 4 appraisal well spudded in April 2011 and was drilled to a total depth of 4,137 m and suspended with gas shows. Transerv, the operator of the project, has confirmed the field's potential after the drilling of the well. The Warro gasfield is estimated to hold up to 283 Gm^3 (10 Tcf) of gas in place. A 3D seismic program over the Warro Project area, was carried out in February–March 2011. A Haliburton fraccing crew will be mobilising to Perth to carry out operations on Warro 4 for Transerv before moving on to three other wells. Future plans include a pipeline in late 2012 and anticipated gas production by end of 2013 or start of 2014. Warro is located 200 km north of Perth and 31 km east of both the Dampier-Bunbury Natural Gas Pipeline and the Dongara-Perth Parmelia Pipeline.

Woodada Deep

AWE's shale gas drilling activity commenced in the onshore Perth Basin with the drilling of the Arrowsmith 2 well in EP 413, southeast of the Arrowsmith 1 well which flowed gas on test from the middle Carynginia shale interval. Plans are underway for fracture stimulation and testing of the Arrowsmith 2, Woodada Deep 1 (shale gas) and Senecio 2 (tight gas) in the second half of 2011. Up to 566 Gm^3 (20 Tcf) of gas in place has been estimated in the shales of the Carynginia Formation in this area of the Perth Basin. Senecio could add up to 2.83 Gm^3 (100 Bcf) gross recoverable gas.

The Arrowsmith 2 well is located approximately 25 km from the Woodada Deep 1 well which was deepened by AWE in April 2010 to core the Carynginia shale interval. A coring program included convention and sidewall cores cut in the Carynginia, IRCM and High Cliff Sandstone formations in Arrowsmith 2. ■

Fracture stimulation equipment at Warro 4
(Photo courtesy of Yaman Ali)

Awards of Petroleum Exploration Permits

Richard Bruce
Exploration Geologist
Resources Branch

Exploring offshore Western Australia
(Photo courtesy Apache Energy Ltd)

Commonwealth Award of Petroleum Exploration Permits

These new permits result from the first round of the 2010 Acreage Release that closed on 11 November 2010.

Commonwealth award information was sourced from Western Australia's online Petroleum and Geothermal Register and from the July 2011 Australian Petroleum News.

The total indicative value of work commitments for all of the following Commonwealth permits is $128,485,000.

In June 2011 permits WA-453-P and WA-454-P were granted.

WA-453-P (released as W10-16) in the Barrow Sub-basin of the Northern Carnarvon Basin has been awarded to *Apache Energy Limited*. The company proposed a guaranteed work program of 80 km^2 3D seismic processing and geotechnical studies to an estimated value of $685,000. The secondary work program consists of one exploration well and geotechnical studies to an estimated value of $25.4 million. There were no other bids for this area.

WA-454-P (released as W10-2) in the Northern Bonaparte Basin has been awarded to *MEO Australia Limited*. The company proposed a guaranteed work program of a 300 km 2D seismic survey, 750 km 2D seismic reprocessing, a 400 km^2 3D seismic survey and geotechnical studies to an estimated value of $4.55 million. The secondary work program consists of one exploration well and geotechnical studies to an estimated value of $20.5 million. There was one other bid for this area.

In July 2011 permits WA-455-P, WA-456-P, WA-457-P and WA-458-P were granted.

WA-455-P (released as W10-18) in the Barrow Sub-basin of the Northern Carnarvon Basin has been awarded to *Chevron Barcoo Pty Ltd*. The company proposed a guaranteed work program of 600 km of new 2D seismic surveying, one exploration well and geotechnical studies to an estimated value of $6.5 million. The secondary work program consists of an exploration well and geotechnical studies to an estimated value of $4.5 million. There were three other bids for this area.

WA-456-P (released as W10-19) in the Barrow Sub-basin of the Northern Carnarvon Basin has been awarded to *Chevron Barcoo Pty Ltd*. The company proposed a guaranteed work program of two exploration wells and geotechnical studies to an estimated value of $8.5 million. The secondary work program consists of an exploration well and geotechnical studies to an estimated value of $4.5 million. There were two other bids for this area.

WA-457-P (released as W10-14) in the Dampier Sub-basin of the Northern Carnarvon Basin has been awarded to *Flow Energy Limited*. The company proposed a guaranteed work program of 322 km^2 of new 3D seismic surveying, 403 km^2 3D seismic reprocessing, 200 km 2D seismic reprocessing and geotechnical studies to an estimated value of $4.3 million. The secondary work program consists of one exploration well and geotechnical studies to an estimated value of $22.8 million. There were two other bids for this area.

WA-458-P (released as W10-10) in the Dampier Sub-basin of the Northern Carnarvon Basin has been awarded to *Flow Energy Limited*. The company proposed a guaranteed work program of 242 km^2 of new 3D seismic surveying, 335 km^2 3D seismic reprocessing, 50 km 2D seismic reprocessing and geotechnical studies to an estimated value of $3.45 million. The secondary work program consists of one exploration well and geotechnical studies to an estimated value of $22.8 million. There were three other bids for this area.

State Award of Petroleum Exploration Permits

To the end of June 2011, petroleum Exploration Permits awarded in State areas were as follows:

In February 2011, **EP 476** (arising from SPA 4/06-7 AO) in the Canning Basin was awarded to *Buru Energy Limited*. The firm two-year period program consists of a 150 km 2D seismic survey and geotechnical studies to an estimated value of $1.2 million. The remaining program consists of one exploration well and geotechnical studies to an estimated value of $3.3 million.

In April 2011, **EP 477** (arising from splitting of EP 442) in the Canning Basin was awarded to *Buru Energy Limited*. The firm two-year period program consists of one exploration well and geotechnical studies to an estimated value of $3.05 million. The remaining program consists of geological and geophysical studies, and an exploration well to an estimated value of $3.075 million.

In April 2011, **EP 478** (arising from splitting of EP 442) in the Canning Basin was awarded to *Buru Energy Limited*. The firm two-year period program consists of geological and geophysical studies and one exploration well to an estimated value of $3.1 million. The remaining program consists of geological and geophysical studies to an estimated value of $150,000.

The total indicative value of work commitments for these State permits is $13,875,000. ▪

Drill pipe ready to go in the onshore Perth Basin
(Photo courtesy of Karina Jonasson)

State Areas Released for Petroleum Exploration September 2011

Richard Bruce
Exploration Geologist
Resources Branch

Recording seismic data in the onshore Perth Basin
(Photo courtesy of ARC Energy Ltd)

DMP continues to promote the petroleum potential of Western Australia's vast sedimentary basins using a specific area release system which includes onshore areas.

A CD package accompanies the acreage release and contains information about the prospectivity of release areas, available data listings, land access and how to make a valid application for an Exploration Permit.

In September 2011, DMP released a total of nine blocks (Fig. 1). This comprised one block in the onshore Canning Basin, two blocks in the offshore Northern Carnarvon Basin, and six blocks in the onshore Perth Basin.

Interest in the Canning Basin has increased in recent times particularly with ARC Energy and ARC's spinoff company Buru Energy taking up an extensive acreage holding, drilling wells and acquiring 2D and the basin's first 3D seismic. In addition, Mitsubishi Corporation has exercised its option to participate in Buru's 2011 exploration program in the Canning Basin.

The size of the Canning Basin block is 4,776 km^2. Release area L11-5 is situated on the Broome Platform. The Broome Platform has Ordovician sourced plays including migration into Permian reservoirs, and has some shale gas potential.

There are two release areas in the highly prospective offshore Northern Carnarvon Basin. A combined release area T11-3/L11-6 is 1,742 km^2 in size. The other area L11-7 is 1,441 km^2 in size. Targets may include Cretaceous, Jurassic and Triassic sandstones.

The six release areas (L11-8 to L11-12) in the onshore northern Perth Basin range in size from 75 km^2 to 2,633 km^2. The region has a thick Lower Triassic source and seal interval, as well as likely source intervals in the Lower Jurassic. The northern Perth Basin has numerous seismic lines, wells, and has had oil and gas production from Permian and Jurassic reservoirs. Two gas pipelines occur to the east of the release area. A sealed highway runs south to the State capital Perth and the Kwinana oil refinery.

Work program bids for the release areas close at 4pm on Thursday 8 March 2012.

Should you require any further information or assistance, please contact Richard Bruce (08 9222 3314) of DMP's Petroleum Division or Alan Millar (08 9222 3841) of the Geological Survey of Western Australia. All enquiries will be dealt with in strictest confidence. ■

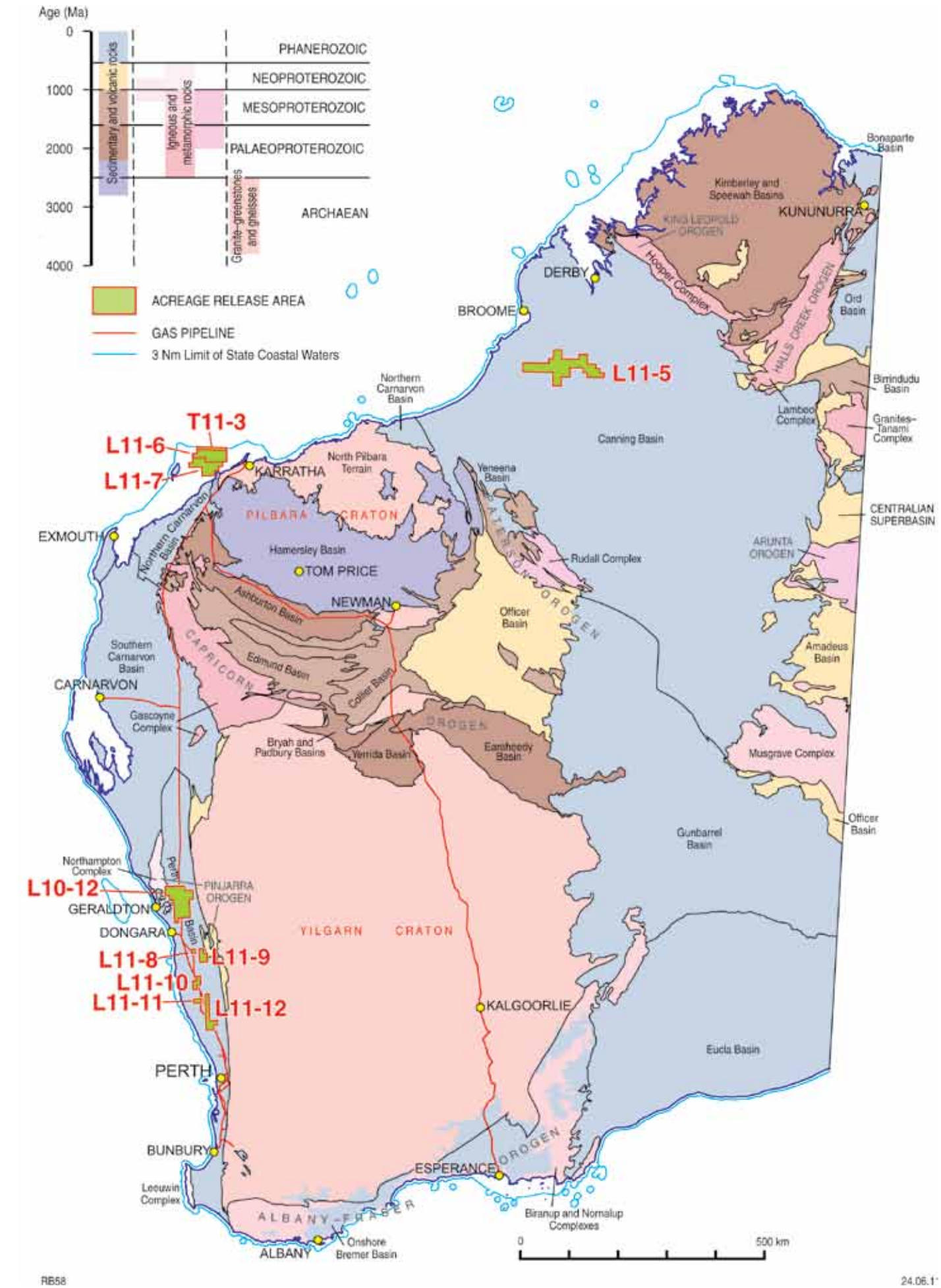


Figure 1 | **September 2011 State petroleum release areas**

Shallow Gas in the Onshore Carnarvon Basin of Western Australia

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Onshore Northern Carnarvon Basin near Nanutarra
(Photo courtesy of Arthur Mory)

INTRODUCTION

Shallow gas is a relative term but it can be defined as natural gas occurring at subsurface depths of less than 1,200 m. Shallow natural gas can be generally classified as either thermogenic gas or biogenic gas. Thermogenic gas is generated at depth within the basin and migrates up faults as free gas or as gas associated with oil. Biogenic gas can be further subdivided as either early generation or late generation biogenic gas.

Since shallow gas accumulations typically have little or no associated liquids, and are often perceived to be small, there has been little development of these reserves in the past. Some of the reasons for their lack of development are:

- modest inferred pool sizes, generally less than 28.32 MMm^3 (1 Bcf);
- the extra expense required for compression due to low reservoir pressure;
- the need for gravel pack completions due to loose, unconsolidated sands;
- historically low natural gas pricing.

As exploration companies often don't log the shallow section of hole corresponding to the surface casing, most accumulations are still intact and represent virgin reserves. In the US, there have been a number of successful completions of shallow Pliocene–Pleistocene gas in Southeast Louisiana at depths of less than 1,067m. Though these plays have been largely ignored in the past, in recent times there has been a renewed interest in them and now they are being targeted via recompletion of existing wells.

SHALLOW GAS IN WESTERN AUSTRALIA

In Western Australia (WA), shallow gas occurrences have been observed in the Mardie Greensand member of the Muderong Shale and Yarraloola Conglomerate, in the Peedamullah Shelf on the onshore Carnarvon Basin. The Carnarvon Basin is a Paleozoic to Cainozoic depocentre which encompasses over 1,000 km of the west and northwest coast of Western Australia. The basin covers about 115,000 km^2 onshore extending from just south of Kalbarri to Karratha along the western and northwestern coastline of WA. The onshore part is readily accessible from the North West Coastal Highway, and the Dampier to Bunbury Natural Gas Pipeline (DBNGP) passes down the eastern side.

All the hydrocarbon occurrences in the Peedamullah Shelf area have been discovered within the Early Cretaceous section at depths ranging from 65 to 550 metres, mainly within the low-permeability Mardie Greensand (Fig.1). The greensand is underlain by the highly permeable Yarraloola Conglomerate, which is an artesian aquifier and has probably acted as the main conduit for hydrocarbon migration out of the Barrow Sub-basin. There is no evidence of major structural control on the hydrocarbon shows which occur sporadically over a large area.

Whilst permeability barriers within the Mardie Greensand probably influence the present distribution of hydrocarbons, there is no evidence that the hydraulics of the Yarraloola Conglomerate have been important in the localisation of accumulations discovered to date. Water salinity studies suggest that influx of meteoric water from the Yarraloola Conglomerate outcrop has resulted in a hydrodynamic trap for hydrocarbons as they migrated updip from the Barrow Sub-basin. During the Late Tertiary a much larger accumulation may have existed within the Yarraloola Conglomerate and the Mardie Greensand. The northwesterly flow of water has now ceased and the hydrocarbons have dispersed, except for the accumulation trapped within the relatively impermeable Mardie Greensand.

SHALLOW GAS OCCURRENCES

There are at least 79 wells in the onshore Carnarvon Basin which encountered gas shows. Most of the shallow gas accumulations recognised are found around the Peedamullah Shelf area at depths between 65 and 550 m. The shallow gas occurrences (with good gas shows) are listed in Table 1 and their locations are shown in Figure 2.

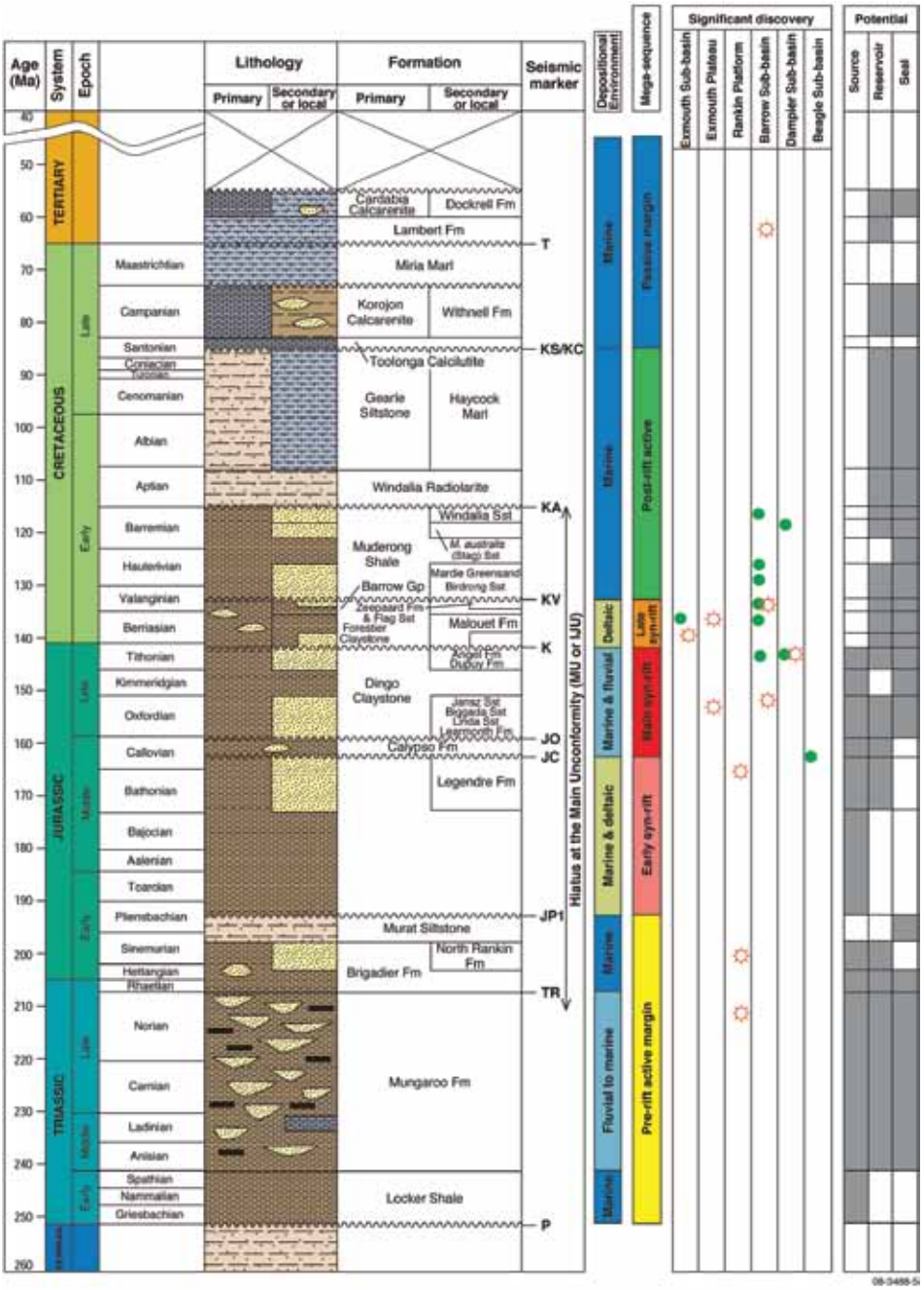

Figure 1 | **Regional stratigraphy of the Northern Carnarvon Basin (Young and Laurie, 1996)**

1. Mardie

Mardie 1 was drilled in 1967 by WAPET following encouraging signs of hydrocarbons in five deep seismic holes drilled earlier in the same area. The well encountered hydrocarbon shows in the shallow Mardie Greensand. Following this the Mardie 2 well was drilled in 1969 with an objective to penetrate the total thickness of the greensand but avoid intersecting the Yarraloola Conglomerate aquifer. The well was suspended due to negative results of core analyses undertaken (Reid, 1969).

In 1974, the Mardie 1A appraisal well was drilled to test the Mardie Greensand which had produced significant hydrocarbon shows in Mardie 1. The Mardie 1A well was drilled as a twin to the adjacent Mardie 1 well. In 1991, Mardie 1B was drilled as part of a two well program along with East Somelim 1 as a redrill of Mardie 1A. The well encountered significant oil and gas shows in the Upper Muderong Shale and Mardie Greensand. Mardie 3 was drilled in 1993 to test the hydrocarbon potential of the Intra-Muderong sands and the Mardie Greensand. Strong hydrocarbon shows were recorded in the upper part of the Mardie Greensand whereas there were no hydrocarbon shows recorded in the Yarraloola Conglomerate (Stirling Resources, 1994).

The oil and gas shows encountered in the Mardie wells are believed to be a stratigraphic accumulation and not directly related to a structural trap (Lennard Oil, 1991). From the results of Mardie 1, it was understood that the overlying shales of the Windalia and Gearle provide a sufficient impermeable

Table 1 – Shallow gas occurrences (with good gas shows)

Well Name(s)	Drilled by	Year Drilled	Depth (m)	Oil/Gas Shows	Current Permit
Mardie 1	WAPET	1967	222	Oil and gas	EP 446
Mardie 2	WAPET	1969	164.9	Oil and gas	EP 446
Mardie 1A	WAPET	1974	164	Oil	EP 446
Mardie 1B	Lennard Oil	1991	165.8	Oil and gas	EP 446
Mardie 3	Stirling Resources	1993	165	Oil and gas	EP 446
Mulyery 1	WAPET	1968	139.6	Gas	EP 446
Windoo 1	Hematite Petroleum	1972	218.85	Oil and gas	EP 446
Windoo 1A	WAPET	1974	174.3	Oil and gas	EP 446
Carnie 1	Avon Engineering	1982	163	Gas	EP 446
Sapphire 1	Carnarvon Petroleum	1993	558	Oil and gas	EP 444
Topaz 1	Pan Pacific Petroleun	1995	423	Oil and gas	EP 444
Topaz 2	Pan Pacific Petroleum	1996	446	Oil and gas	EP 444

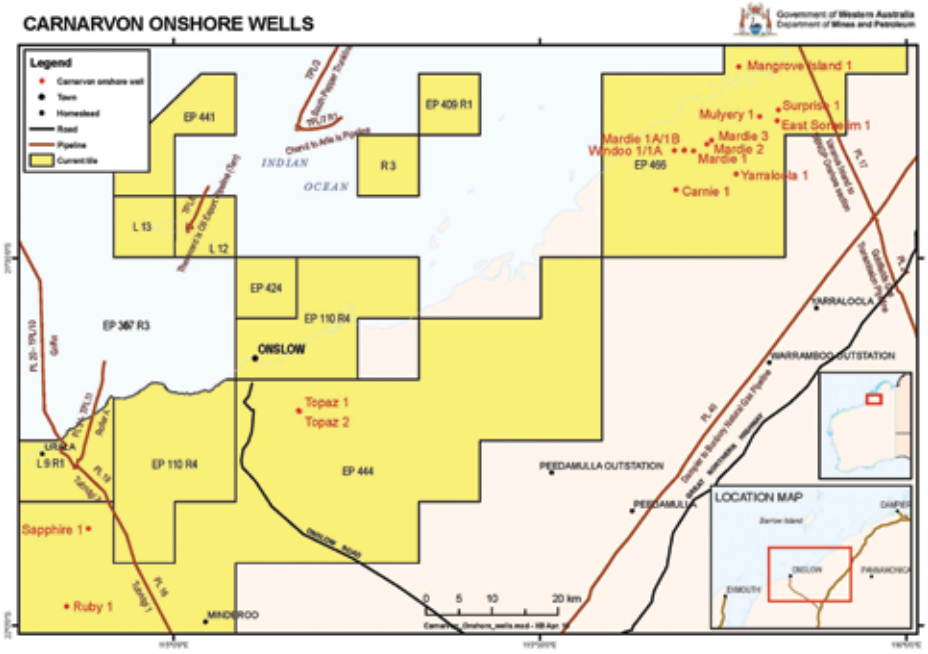

Figure 2 | **Shallow gas occurrences (with well names)**

cover for entrapment of hydrocarbons in structurally favourable locations (Bowering and Parry, 1968).

The results of Mardie 1 demonstrated the presence of 32 m of basal Cretaceous conglomerate (Yarraloola Conglomerate), an excellent potential reservoir rock. The well also indicated a large areal extent of the sand horizon in the Windalia Radiolarite and a slightly thicker greensand horizon. The greensand horizon in Mardie 1 exhibited excellent porosity and permeability values (see Reservoir Properties) which would seem to constitute a favourable reservoir rock (Bowering and Parry, 1968).

Hydrocarbon shows

In Mardie 1A, significant hydrocarbon shows were encountered at 155 m and the results of core analyses showed the presence of oil in the interval 160 m to 165 m (Reid, 1969). Also in Mardie 1B, strong hydrocarbon shows were encountered in the Mardie Greensand member (Lennard Oil, 1991). Mardie 2 demonstrated an unpredictable distribution of hydrocarbons owing to the reservoir continuity between the greensand member and the underlying Yarraloola Conglomerate. The presence of hydrocarbons was noted in the Windalia Radiolarite and Windalia Sand Member but unfortunately any possible locations would probably be offshore (Reid, 1969). Small amounts of gas were recorded throughout the Muderong Shale and the Mardie Greensand in the Mardie 3 well. Strong hydrocarbon shows were recorded in the upper part of the Mardie Greensand from 153 m to 159 m. No hydrocarbons shows were recorded in the Intra-Muderong sands or the Yarraloola Conglomerate (Stirling Resources, 1994).

In Mardie 1, cores of Mardie Greensand oozed viscous brown oil of 14.5° to 20° API gravity and exhibited brilliant yellow fluorescence. Whilst drilling in the Yarraloola Conglomerate, circulation was lost. The well blew a small volume of gas followed by artesian flow. Testing produced no oil and only a small flow of gas at 300–600 m^3/d (10–20 Mscf/d).

The Mardie Greensand was cored in Mardie 2, but contained only 0.1 m of oil saturation (fluorescence) at the top of the unit. Gas shows were encountered in the shallower Windalia Sand Member (Thomas, 1978).

In Mardie 1A cores of the Mardie Greensand were found to be oil saturated, profusely bleeding a greenish-brown oil, and exhibiting extensive strong fluorescence. Exhaustive pump testing of the well produced no liquid hydrocarbons but some gas initially at 500 m^3/d (17 Mscf/d) declining to 200 m^3/d (7.6 Mscf/d) after six days (Thomas, 1978).

Small amounts of gas were detected throughout the Gearle Siltstone, Muderong Shale and Mardie Greensand in the Mardie 1B well. The greensand member had strong oil shows in Mardie 1B and strong gas readings of 100% methane were recorded whilst coring this interval. Also, there were significant oil fluorescence shows in the Muderong Shale and gas readings consisting of 100% methane were recorded.

In the Mardie 3 well, the maximum amount of ditch gas recorded whilst drilling was 25 units (C1) at 107 m in the Muderong Shale and 4.5 units (C1) at 159 m in the Mardie Greensand. The maximum amount of connection gas recorded was 250 units. The gas encountered consisted primarily of methane with trace amounts of ethane. Two perforated intervals were tested in the Intra-Muderong Sands but there were no hydrocarbons associated with the resulting flow. Strong hydrocarbon shows were observed in the upper part of the Mardie Greensand from 153 to 159 m. Total gas readings recorded whilst drilling the interval ranged from 3 to 4.5 units and consisted of methane. A drillstem test (DST) of the interval 143 to 159 m recovered no formation fluids. Also, there were no hydrocarbon shows in the Yarraloola Conglomerate (Stirling Resources, 1994).

Reservoir properties

Core analysis of the Mardie Greensand in the Mardie 1 well indicated porosities of 31.6% to 52.1% and permeabilities of 9 to 208 mD. In Mardie 1A, the results indicated porosities of 23.0% to 46.5% and permeabilities of 0.5 mD to 263 mD (Crank and O'Shaughnessy, 1974). There was no favourable reservoir development throughout the prospective Muderong Shale, Mardie Greensand and Yarraloola Conglomerate section at the Mardie 3 location. Investigation of cutting samples and analysis of wireline log shows that no good quality sands were developed in these lithological units. Porosity in these zones was poor to fair at best, with high water saturations (Stirling Resources, 1994). The gas accumulation occurs mainly in the Mardie Greensand member immediately overlying the Yarraloola Conglomerate.

2. Mulyery

Mulyery 1 was drilled in the Robe River Embayment to investigate the hydrocarbon potential of the Mardie Greensand member of the Muderong Shale, in particular whether a balanced production of gas or oil could be maintained from this formation.

The well penetrated 12.19 m of Quarternary conglomerate and gravel, and Tertiary limestone, greensand and conglomerate, before drilling 105.46 m of Cretaceous shale, sandstone and conglomerate. The Mardie Greensand is present between 123.75 m to 128.02 m, and contains a significant accumulation of gas, but only traces of oil.

Sustained gas production was obtained from the Mardie Greensand in the Robe River Embayment. It was not known whether the accompanying water flow is derived from the greensand or the basal Cretaceous conglomerate.

Hydrocarbon shows

A 36 hour flow test of the perforated interval 123.75 m to 128.02 m produced water at the rate of 31.8 kL/d (200 bbl/d) and gas at the rate of 1,130 m^3/d (40,000 ft^3/d). Because of the high pressure in the greensand (about 250 psi), the formation was given a Bradenhead squeeze at 200 psi, and the well was abandoned (Jones, 1968).

Reservoir properties

The Mardie Greensand consists of patches of clean pale grey sandstone within the Muderong Shale. Core samples fluoresced a patchy pale yellow white colour. Measured porosities ranged from 17% to 46% and permeabilities ranged from 28 to 1,218 mD. Mulyery 1 has indicated an increased areal extent of the Mardie Greensand in the Robe River Embayment, and has established its potential as a hydrocarbon reservoir. It penetrated a gas cap in the Mardie Greensand in a structurally high position. The structural dip of the Mardie Greensand is northwest at less than 1°.

3. Windoo

Windoo 1 was drilled in the onshore Robe River area to a total depth of 218.85 m and was plugged and abandoned. Windoo 1A is a re-drill of Windoo 1 which recorded good gas shows in the Mardie Greensand (Crank and O'Shaughnessy, 1974). Windoo 1A was drilled to a depth of 164.29 m and also encountered hydrocarbons in the Mardie Greensand. The well was exhaustively pump tested after drilling.

The stratigraphy of the Windoo area consists of a veneer of Lower Cretaceous and Cainozoic sediments which have overlapped a complexly faulted Paleozoic and Proterozoic platform. The Paleozoic section is everywhere overlain by the permeable fluviatile Lower Cretaceous Yarraloola Conglomerate. Conformably overlying the Yarraloola Conglomerate is a marine unit, the Muderong Shale, which has a very glauconitic basal section known as the Mardie Greensand. The top of the Mardie Greensand in Windoo 1A was 0.6 m lower that the Windoo 1 well.

Hydrocarbon shows

Windoo 1 flowed formation water to surface whilst pulling out and running in the hole, after lost circulation problems caused the well to kick (Hematite Petroleum Pty Ltd, 1972). The formation water was likely derived from the Yarraloola interval whereas the gas was considered to come from the Mardie Greensand interval (164.59 to 173.74 m). No estimates of the gas flow were made but the gas flow was very small. The estimate of shut in pressure at the formation was around 265 psi and the gas flowing from the relatively tight Mardie Greensand was approximately 90% methane (CH4). In Windoo 1A, the first hydrocarbons were detected at 94.49 m where 10 units of gas were recorded. From here to the total depth gas readings of up to 25 units were encountered and the well kicked several times (Crank and O'Shaughnessy, 1974).

Reservoir properties

In Windoo 1A, only 0.91 m of the core was analysed and the results showed porosities ranging from 39.3% to 42.6% and permeabilities ranging from 70 to 418 mD (Crank and O'Shaughnessy, 1974).

4. Carnie

Carnie 1 was located near the coast in the northern onshore Carnarvon Basin. The well was drilled to test the hydrocarbon potential of the Mardie Greensand.

The Carnie 1 well was spudded in the recent alluvial flood plain deposits consisting of clays, silts and sands resting on the Trealla Limestone (at 6 m). Immediately below the Trealla Limestone, an arenaceous claystone at the top of the Muderong Shale was encountered followed by a less arenaceous claystones to the top of the Mardie Greensand, a glauconitic fine-grained sandstone. The well terminated at a depth of 163 m.

Seismic mapping of the area was rudimentary due to incomplete seismic coverage. However, the shallow well control was relatively good and structural influences could be seen from the Scholl Island Fault which runs through the embayment (Furr and Allchurch, 1982). North–south faulting may explain the variable thickness of the Mardie Greensand which also appears to be influenced by the Mardie high. The hydrocarbon accumulation is understood to be in the Mardie Greensand which rests on the Yarraloola Conglomerate.

Hydrocarbon shows

Testing of the Carnie well (DST 1) produced dry gas without water at maximum initial flow rates of approximately 850 m^3/d (30 Mcf/d), through a 3.175 mm (1/8 inch) choke, decreasing rapidly with time. The results indicated a very limited gas reservoir with maximum shut-in pressure of 220 psi. A major sand unit in the upper part of the Muderong Shale had good gas shows. The main target, the Mardie Greensand, also had good gas shows and a core cut in this formation showed good fluorescence and oil was visible on its surface (Furr and Allchurch, 1982).

Reservoir properties

In Carnie 1, the visual porosity in the core from the Mardie Greensand appeared poor as the matrix was clay. Results from the core analysis, carried out on cores cut in the Mardie Greensand, showed porosity values between 33.7% to 40.5% and permeability values ranging from 72 to 813 mD (Furr and Allchurch, 1982).

Carnie 1 confirmed that the Robe River Embayment shallows inland without significant changes in lithology. A 4% KCl mud gave sufficient inhibition to drill through the Muderong Shale section. Native clays became a part of the mud system, and it became necessary to dilute the mud to control the solids. The interval 151 to 156 m was drilled using a 10.1 to 10.2 lbs/gal mud and this was increased to 10.5 to 10.6 lbs/gal after small gas kicks occurred. The drilling parameters and completion techniques used in wells drilled in previous years within this area were thought to have heavily damaged the greensand, which was the main reason for reduced ability to produce hydrocarbons in earlier wells.

The Carnie 1 well was drilled using drilling parameters which would result in minimal damage to the formation whilst taking care not to drill into the Yarraloola Conglomerate artesian aquifer.

5. Sapphire

Sapphire 1 was drilled in the onshore Carnarvon Basin to test a Triassic Mungaroo Formation sandstone objective within a truncation trap beneath the Base Cretaceous Unconformity (BCU). Minor hydrocarbon shows were encountered above and below the unconformity in poor reservoir sands within the Mardie Greensand interval of the Muderong Shale and within the Locker Shale. A DST was run over this interval and a full string of formation water (approximately 2 kL) was recovered (Carnarvon Petroleum, 1993).

The Sapphire structure is situated to the southeast of the Tubridgi gasfield. The shape of the Top Locker Shale surface at the BCU in Sapphire 1 was determined by a syncline developed in the Paleozoic which persists southeasterly into the Ashburton Sub-basin. This syncline is understood to have generated a seal trap by establishing the Locker Shale as a lateral seal and the Muderong Shale as a top seal to the Mungaroo Formation reservoir sandstones (Carnarvon Petroleum, 1993).

The Sapphire prospect is located updip of the Tubridgi gasfield and it has been suggested that the hydrocarbons in Sapphire were sourced by oil that migrated out of the Tubridgi gasfield. A remnant oil leg in the Tubridgi field suggests that the Tubridgi anticline, which was filled to spill point with gas before production from the field, could have originally contained oil that was then displaced by later gas migration. This displaced oil would have migrated up-dip towards the Sapphire structure (Carnarvon Petroleum, 1993).

A thick sand unit developed at the base of the Mungaroo Formation was the predicted reservoir objective at Sapphire 1. However, the well encountered oil fluorescence in both the Mardie Greensand and Locker Shale units (Carnarvon Petroleum, 1993). The DST over this interval was unsuccessful.

Hydrocarbon shows

Gas readings measured in the well were generally low, peaking at 2% at 265 m and generally tailed off to 0.2% at TD. The predominant gas was methane with only slight traces of heavier gases present. Minor oil shows were encountered over the interval 390 to 409 m, recognised by fluorescence within the cutting samples. The interval 385 to 409 m was tested with an open-hole DST and 2 kL (13.2 bbl) of water was recovered without any hydrocarbon indications (Carnarvon Petroleum, 1993).

Reservoir properties

The recovery of 2 kL of formation water from the Mardie Greensand-Locker Shale interval tested between 385 and 409 m indicated the presence of some permeable layers throughout this zone. The cutting samples and sidewall cores showed a glauconitic sandstone section in the Mardie and some thin interbedded fine-grained sandstone in the Locker Shale. Log interpretation indicated permeability within the Locker Shale with a number of intervals that showed shallow invasion by mud filtrate. Porosities in this interval averaged at around 10% (Carnarvon Petroleum, 1993).

6. Topaz

Topaz 1 was drilled in the onshore Carnarvon Basin to a total depth of 421 m. The well was designed to evaluate a northeast trending horst in the Lower Cretaceous Birdrong Sandstone. This primary reservoir target was intersected at 337 m and minor oil shows were observed between 335 to 341 m. An open-hole DST flowed gas to the surface but the log evaluation results indicated limited gas pay (Pan Pacific Petroleum, 1996). Topaz 2 is located on a large salt flat, approximately 20 km southeast of Onslow and approximately 160 m to the southeast of Topaz 1. The well was designed to fully evaluate the Paleozoic structure as this interval was not adequately tested in Topaz 1. A DST flowed water to the surface with a scum of oil and no gas was reported. Log evaluations indicated only minor hydrocarbons from 340.5 m to 341.5 m (Mills, 1997).

The Topaz prospect was identified as a horst structure at Birdrong level extending to 7.1 km^2 with 30 m of vertical relief. The Muderong Shale was suggested to be the main seal to the structure (Mills, 1997). The postulated source kitchen for Topaz lies to the northwest where Jurassic shales are thought to be the origin of the hydrocarbons for the offshore fields. The most likely conduit for migration of hydrocarbons into Topaz is up the Flinders Fault system and then at the Base Cretaceous level up the regional dip (Mills, 1997).

Hydrocarbon shows

In Topaz 1, minor oil shows were encountered between 335 m to 341 m. The Birdrong Sandstone showed good reservoir quality but had limited gas pay (Pan Pacific Petroleum, 1996). The Birdrong Sandstone was intersected at 340.5 m in Topaz 2. In Topaz 2, fair oil shows were encountered in loose quartz sandstone from 343 to 345 m and minor hydrocarbons were observed from 340.5 to 341.5 m (Mills, 1997).

Cutting gas levels were relatively low through Topaz 1 with a maximum of 4.3% and 3.7% at 215 m (near Top Muderong) and 340 m (Birdrong Sandstone) respectively. It was decided to run an open-hole DST based on strong drilling break at 338 to 340 m, good inferred porosity and associated shows (Pan Pacific Petroleum, 1996). Two open-hole off-bottom DSTs were conducted with DST 2 (interval 341 to 332 m) flowing gas at a stable rate of 19.8 m^3/d (0.7 Mcf/d) through a 6.35 mm (1/4") choke.

Cutting gas levels throughout Topaz 2 were relatively low and restricted to methane only. Total gas peaks were recorded at 236 m in a thin basal sandstone within the Windalia Radiolarite, at 260 m in silty claystones of the Muderong Shale and at 343 m in the uppermost Birdrong Sandstone. Fair oil shows were also recorded in the upper section of the Birdrong Sandstone (Mills, 1997). In Topaz 2, DST 1 was conducted over the uppermost section of the Birdrong Sandstone and this zone flowed water to the surface at 11.44 kL/d (72 bbl/d) with a slight oil scum. There was no gas to the surface. Log analysis showed that minor hydrocarbons were present within a thin sandstone section (340.5 to 341.5 m) in the Birdrong Sandstone.

Reservoir properties

In Topaz 1 oil was extracted from a core sample in the Birdrong Sandstone that showed the effects of extensive biodegradation. This is seen in Topaz 2 as well, indicated by the oil scum recovered on the DST. Ethane isotope analysis conducted on Topaz 1 DST gas samples suggests that the gas is either very immature or biogenic in origin (Pan Pacific Petroleum, 1996).

A biogenic source for the gas is consistent with the biodegraded nature of the oil recovered in Topaz 2.

WAY FORWARD

Shallow gas plays in Western Australia have been largely ignored in the past due to historical lack of gas demand, increased costs of compression and completion (sand screens), poor seismic imaging, and lack of logs to evaluate. Such reserves are perceived to be modest in comparison to deeper reservoirs, but the shallow depths of these pools require lower capital costs for exploration drilling and development.

Gravel Pack Completions

One of the most significant costs in shallow gas development is the need for gravel pack completions to prevent the production of loose, unconsolidated sand that, if unprotected, will cause premature cessation of production.

Seismic Data

The availability of good quality seismic data is important in terms of well planning and design. A cased-hole reservoir saturation tool (RST) of pulsed neutron logs (PNL) can be run in wells that were not previously logged in the shallow section. Cased-hole logs, particularly RST logs, have had wide application throughout the world for many years and they have the ability to effectively detect hydrocarbons in shallow sections. Careful detailed seismic and log analysis along with the study of analogous wells around the world (particularly US) is necessary for companies to enjoy success in shallow gas development.

Well Design and Economics

In terms of well design and economics, shallow gas wells can be drilled and completed at a very low expense in comparison to conventional gas wells. For example, a 580 m well is expected to take 6 days to drill, log and run casing plus a further 5 days to complete and an assumed 2 days for mobilisation and demobilisation. Shallow gas wells are vertical, normally pressured wellbores and the completion will usually involve running a 177.8 mm (7") production string. The capital expenses for a shallow gas well are relatively lower, however, there will be additional costs incurred for compression and gravel pack completions. Initial and abandonment costs would be the same as for a deeper reservoir.

Wellsite Compression

The deliverability of shallow gas wells can be improved by the installation of wellsite compression. The reservoir pressure in many of these shallow gas fields is very low compared to the gas purchaser's line pressure. Therefore, these wells will have limited flow rate or are incapable of flowing due to the high salesline pressure. The use of wellsite compression can improve the productivity and the ultimate recovery of the gas resource. The factors taken into consideration when selecting a compressor include: the sizing parameters of the compressors, reservoir characteristics (i.e. pressure), and the economics of purchasing versus leasing a compressor. The build up of fine sand, caused by the use of gravel pack completions, can also have an adverse effect by increasing the differential pressure and adds to the importance of to using wellsite compression. It is recommended to have a looping system for the compressors (used in various wells), connected in series, that can potentially bring down the costs incurred during development.

While shallow gas resources may be small in size, they represent a promising prospect for onshore operators. Shallow gas can potentially contribute to localised power generation or be used for feed gas for gas lift purposes. It is, therefore, an important resource to be considered for possible future development in WA.

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Heat Generation in the Darling Range Granites: Implications for Geothermal Exploration

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Close up of the recording instruments. The RS 125 spectrometer (orange) with detecting head, containing the detecting crystal, placed on the rock surface, and beside this is a total count Geiger counter (black meter). A compass (to detect fracture orientation), scale and recording book are also shown
(Photos courtesy of Mike Middleton)

Geothermal energy is one of the few renewable energy sources that promises to provide a substantial supplement to base-load electrical power or other substitutes, such as air conditioning or space heating. It is currently used for space heating (i.e. swimming pools) in a number of applications in Perth, and two major projects are now underway to apply geothermal energy to power air conditioning instead of using electricity or gas. These projects draw geothermal energy from hot water in sedimentary rocks buried between 1,000 and 3,000 metres beneath Perth. These are considered as ***low temperature*** economic (commercial) geothermal resource projects, because the temperatures expected are between 60 °C to 100 °C. However, there are numerous other places to find geothermal energy. This article reports another way to exploit low temperature geothermal resources.

It is commonly recognised that granitic basement rocks with a high content of the radiogenic elements Uranium (U), Thorium (Th) and Potassium (K), also referred to as "hot granites", provide a dominant component to the heat flow in Hot Dry Rock (HDR) geothermal regimes. In HDR regimes, these hot granites reside beneath a thermal blanket comprised of between three to five kilometres of sedimentary rocks. This is the main paradigm driving geothermal exploration in the Cooper Basin and elsewhere in South Australia.

In contrast to normal HDR regimes, this article reports the results of a study of heat generation and corresponding temperatures at depth in outcropping granite batholiths in the Darling Range to the east of the Perth metropolitan area. These areas do not have blankets of sediments to act as thermal blankets. However, some important results pertaining to geothermal energy have emerged.

Heat generation in the Darling Range granites may have relevance for the exploration for geothermal energy "hot spots" either in the Perth Basin immediately to the west of the Darling Range, or within the Darling Range itself.

Western Australia has several regions where hot granites are known to occur in outcrop. The locations of high radioactivity rocks, including hot granites, are also well defined by the Geoscience Australia (GA) ternary radiogenic map of Australia (Stolz, 2010). The GA data can be used to create a surface heat generation map (Fig. 1). This is prepared by using appropriate factors (Kappelmeyer and Haenel, 1974, pg. 28) to convert U, Th and K concentrations into an approximation of heat generation in units of microwatts per cubic metre (μWm^{-3}). These factors are 0.26 for Uranium concentration expressed as parts per million (ppm), 0.07 for Thorium concentration expressed as ppm, and 0.10 for Potassium concentration expressed as percent by volume.

It appears that, in this conversion to elemental concentration from airborne radiometric survey data, the calibration used by GA appears to place a ceiling on heat generation values at approximately 5 μWm^{-3}. Accordingly, values greater than this do not appear on the map. It is also important to bear in mind that outcrops with higher heat generation may be localised, and so do not appear on such a regional map. Nevertheless, this map provides valuable information on the distribution of areas of high surface heat generation.

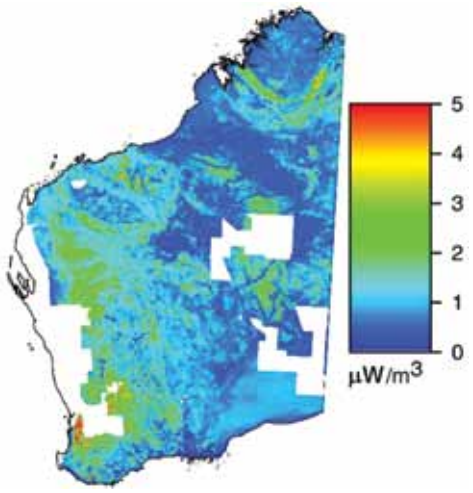

Figure 1 | **Surface heat generation map derived from the Geoscience Australia National Radiometric Database. U, Th and K concentration data have been adjusted by factors (Kappelmeyer and Haenel, 1974, pg. 28) to approximate heat generation (in μWm^{-3}) at the surface.**

The map in Figure 1 shows a zone of high heat generation in the Darling Range immediately to the east of Perth. Various scattered zones of high heat generation also occur in the vicinity of Kellerberrin in the Wheatbelt region of the Yilgarn Craton, and some localities in the Pilbara and Kimberley regions. The blank parts of the map indicate regions where radiometric data have not been collated (although now collected) into the GA database at the time preparation of this article.

Previous work (Jaeger, 1970; Sass *et al*., 1976; Hot Dry Rocks Pty Ltd, 2008) has been published on heat generation in granites in the Yilgarn Craton in various locations of the western part of the Craton. The heat generation of outcropping hot granites in the Yilgarn Craton has been measured in the range of 1 to 20 μWm^{-3}. Some of these values are substantially greater than the data displayed for Figure 1, and are similar to published values for the Cooper Basin HDR granites (ca. 10 μWm^{-3}). A list of heat generation values for granites and gneissic rocks to the east of the Perth Basin has been compiled by the company Hot Dry Rocks Pty Ltd in a report prepared for the Geological Survey Division of DMP (http://www.dmp.wa.gov.au/documents/Reports/G31888A2.pdf).

No heat generation information for the granites in the Darling Range has been previously published to the author's knowledge. Further, little work has been published on the temperatures observed within outcropping hot granites in Australia. Jaeger (1970) published geothermal data, including temperature versus depth, for various boreholes drilled to approximately 320 m depth in granites in the Yilgarn Craton. This work highlighted a location (Doodlakine: 31° 34' S, 117° 49' E) that exhibited high radiogenic heat production over the complete borehole depth (average heat generation was measured to be 8.9 μWm^{-3}) with an average geothermal gradient in the borehole of ~17 °C/km. In contrast to the Doodlakine site, localities with lower heat generation (ca. 2 μWm^{-3}) appear to support geothermal gradients in the order of 8 to 10 °C/km (Sass *et al*., 1976). The frequency of high heat generation sites close to the Perth Basin is poorly known, and the map in Figure 1 unfortunately cannot provide information on heat generation greater than 5 μWm^{-3}.

In an attempt to improve our knowledge of the distribution of hot granites near the Perth region, measurements of U, Th and K in the Darling Range granites were carried out using the "assay" feature of an RS125 spectrometer (locations shown in Figure 2). At each of these locations, numerous repeat measurements were taken for each site to obtain an understanding of statistical variation, due to the random nature of radioactive decay for U, Th and K isotopes. Also, at three locations a series of sub-sites at the location were measured in order to evaluate the spatial variation of U, Th and K over the outcrop area.

The elemental abundances observed at these sites were converted to heat generation in units of μWm^{-3} using the factors mentioned above. These new data exhibit a good linear relationship between U concentration and heat generation (designated as Ao). Figure 3 shows this relationship, which indicates that the observed mean heat generation at the locations (and sub-sites at various locations) ranged between 3 μWm^{-3} and 10 μWm^{-3} throughout the Darling Range region. These data indicate that the Darling Range is an area containing particularly hot granites, and may support relatively high temperatures at drillable depths even within the granites themselves.

Figure 2 | **Locations of measurements of U, Th and K for Darling Range granites. The approximate location of the Darling Fault is shown as the red line; the Yilgarn Craton is to the east of this fault and the Perth Basin is to the west. The Darling Range is the elevated region of the Yilgarn Craton immediately east of the Darling Fault. Google Earth is acknowledged as the source of the base map**.

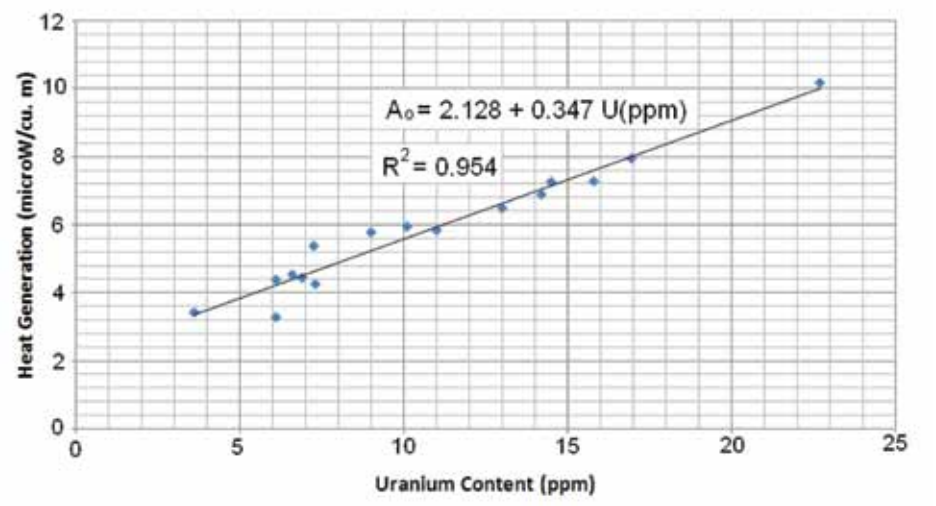

Figure 3 | **Plot of heat generation (Ao in units of μWm^{-3}) versus Uranium concentration (U in ppm) for various outcropping granites in the Darling Range region (see Figure 2 for locations). A very good linear relationship is observed with a coefficient of determination of 0.954. The figure shows that heat generation varies between 4 and 10 μWm^{-3}.**

In terms of extrapolating these heat generation data to depth, the Doodlakine data of Jaeger (1970) suggest that surface heat generation may extend to considerable depths, and this may also be the case for the Darling Range granites.

The thickness of granitic/granitoid intrusions in the Yilgarn Craton is largely unknown at present. However, a deep seismic reflection profile over part of the western Yilgarn Craton, north of Perth (Middleton *et al*., 1995; Wilde *et al*., 1996), detected possible intrusive bodies with thicknesses between 1,000 m to 7,000 m. A thickness of 4,500 m for hot granites in the western Yilgarn Craton has been proposed by Jaeger (1970) and Sass *et a*l. (1976), although this is based on a very limited dataset. A thickness of 6,000 m is assumed for this study, which is consistent with the deep seismic reflection data.

A simple model (Carslaw and Jaeger, 1959, p. 79) is used to determine the temperature at depth in a granitic body with uniform heat generation. The main unknown parameters in this modelling exercise are heat generation within the outcropping (surface) layer of hot granite (Ao) and its thickness (L). The other parameters, such as thermal conductivity (K), basal heat flow (Qb) and surface temperature (Ts) are relatively well known (Schön, 1996; Jaeger, 1970), and commonly observed values have been assumed (see Table 1).

Four cases with different heat generation, which ranges from the lowest (4 μWm^{-3}) to the highest (10 μWm^{-3}) observed in the Darling Range, are considered in order to investigate temperatures at depth within the granite. Figure 4 shows temperature versus depth for each of the four cases with corresponding parameters shown in Table 1.

Case 1 can occur within the Darling Range, as the parameters assumed have certainly been observed in study reported herein. The Doodlakine data near Kellerberrin, reported in detail by Jaeger (1970), is approximately equivalent to case 2.

Case 3 probably represents many typical temperature profiles expected to be encountered in Darling Range granite batholiths.

Table 1. Parameters assumed for five cases, and calculated surface heat flow (Qs). The parameters are described in Figure 3

PARAMETER	CASE			
	1	2	3	4
Ao (μWm^{-3})	10	8	6	4
K ($Wm^{-1}K^{-1}$)	3	3	3	3
L (km)	6	6	6	6
Qb (mWm^{-2})	26.3	26.3	26.3	26.3
Ts (°C)	21	21	21	21

Case 4 most likely represents the minimum case for the Darling Range, where heat generation in the granite layer is approximately 4 μWm^{-3}, despite heat generation of between 1 μWm^{-3} and 2 μWm^{-3} being typical for much of the Yilgarn Craton to the east of the Darling Range (see Figure 1).

If the same granitic rocks extend beneath the Perth Basin to the west of the Darling Fault, then the thick sedimentary cover of the Perth Basin will provide an excellent thermal blanket over the granites, and a situation similar to the Cooper Basin of central Australia may be expected to exist.

From this study, it can be recognised that temperatures between 3,000 m and 4,000 m in the Darling Range may fall in the range of 90 °C to 115 °C. This temperature range is sufficient to permit electricity generation with organic rankine cycle (ORC) or variable phase cycle (VPC) turbines (Welch and Boyle, 2009), or heating ventilation and air conditioning applications (Regenauer-Lieb, 2011).

In conclusion, the study indicates that exploring granites in the Darling Range for geothermal energy has a depth limit of 3,000 to 4,000 metres, and this is due to the economic constraints of drilling.

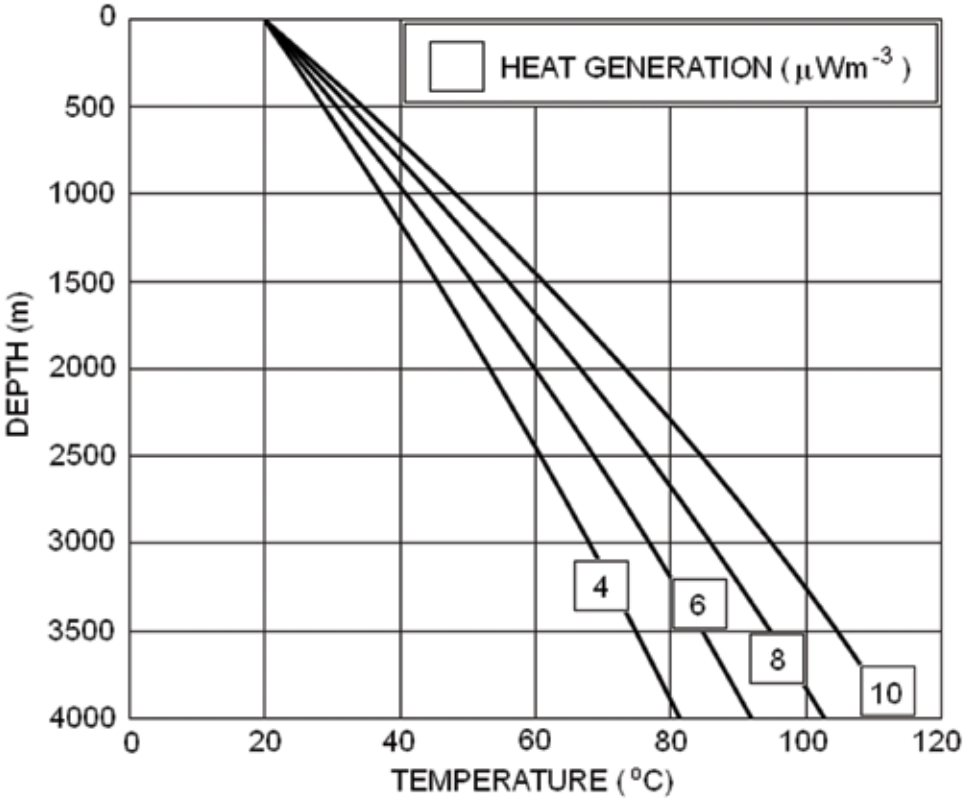

Figure 4 | **Temperature versus depth for the four cases proposed in Table 1. The curve for each case is identified by the heat generation value in the square. Recognise that heat generation of 10 μWm^{-3} is Case 1 and 4 μWm^{-3} is Case 4 in Table 1.**

Exploring granites also has a temperature limit, due to the physical properties (i.e. radiogenic element content, depth extent and thermal conductivity). However, the temperature limits of this new play appear to be between 90 °C to 115 °C, which are not incompatible with the low temperature geothermal developments currently proposed, or now working, in the Perth metropolitan area. If drilling in crystalline rocks, like granites, were less than 50 per cent of the cost of drilling in sedimentary rocks, this play may become more attractive.

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The RS 125 spectrometer (orange) and Geiger counter (black meter) on a roadside granite outcrop near Kalamunda. This site yielded a mean heat generation value of 10.18 μWm^{-3}, which is one of the highest values observed in the Darling Range

The RS 125 spectrometer (orange) and Geiger counter (black meter) on a granite outcrop near Glen Forrest. Measurements were taken on granite outcrops from fresh to various stages of weathering, and generally very little variation in the radioactive elements was observed with respect to weathering

A measurement site near Glen Forrest, where measurements were made on the outcrops in the foreground and others to a distance of about 100 m seen in the photo. The observed heat generation varied from 5.96 to 7.96 μWm^{-3} across the granite outcrops in various states of weathering

Company Focus: Green Rock Energy Limited

Adrian Larking
Director of Operations

Geothermal well testing at Dr Jörg Baumgärtner's Insheim geothermal power project in Germany
(Photo courtesy of Green Rock Energy)

Green Rock Energy Limited (Green Rock) is a Perth based company which began its life as a company listed on the Australian Securities Exchange (Code GRK) in 2005. Its primary aim is to explore for and develop geothermal energy for commercial purposes. Geothermal energy has the advantages of delivering energy around the clock, being essentially emission free and not requiring backup power or storage unlike intermittent renewable such as wind and solar energy.

The Company is one of the pioneers of geothermal energy exploration in Australia and has assembled a portfolio of geothermal projects in Western Australia, South Australia and Hungary with the main focus being on locating geothermal reserves where resources can be commercialised quickly. Recently Green Rock branched into petroleum exploration in the Fitzroy Trough which holds substantial potential for both conventional and unconventional hydrocarbon resources in the Laurel and Anderson formations. The petroleum industry is not new to the Company as its Chairman Jeff Schneider and Managing Director Richard Beresford have held executive roles with major companies such Woodside and British Gas, and the author with Western Mining Petroleum.

In two States, Western Australia and South Australia, Green Rock helped open the door to the commercial exploitation of geothermal energy by being the first listed company to encourage the State Governments to enable exploration and production of geothermal energy for commercial uses. In response the Government of the time in each State amended their respective onshore Petroleum Act to include the legal rights to explore for and produce geothermal energy. In Western Australia this happened in 2008. The Petroleum Acts were chosen as the legislative vehicle to regulate geothermal energy. This choice enabled essentially the same administrative provisions from oil and gas legislation and regulation to be duplicated or adapted for the utilisation of geothermal energy.

Even earlier, in the late 1990s, Green Rock's founders Simon Ashton and the author requested the SA Government to introduce geothermal legislation. As a consequence Green Rock later acquired geothermal exploration licences surrounding the world scale Olympic Dam mine in South Australia where it identified an extensive heat flow anomaly and large in-place geothermal resource sourced substantially from thermally anomalous radiogenic granite batholiths. The Company diamond drilled a slim exploration well to around 2,000 metres deep in the hot granite and successfully opened fractures in the granite by using hydraulic fracturing. Further work on these licences will depend to some extent on future plans for the mine which has a large power requirement.

In recent years Green Rock has moved its focus to recovering geothermal fluids from natural sedimentary aquifers in the Perth Basin, Hungary and South Australia.

In July 2009 Green Rock, along with The University of Western Australia (UWA), was granted the first Geothermal Exploration Permit (Permit) in Western Australia, GEP 1. Since then the Company has acquired Permits in the Perth Basin in WA totalling around 2,094 km^2 near Dongara together with another 594 km^2 near the Urella Fault near the eastern limb of the northern Perth Basin and 684 km^2 in the Perth Metropolitan area. Another 857 km^2 is held in and around the Collie Basin in a joint venture with BHP Billiton Worsley Alumina.

Key geological ingredients for geothermal energy resource potential include a heat source, heat trap in the form of thermally insulating rocks such as low thermal conductivity shales or coals and underlying naturally permeable reservoir rocks or fractures. Unlike petroleum, geothermal heat in the sub-surface is not structurally or stratigraphically confined in the subsurface but natural geothermal water must be found in extensive pores, cavities or fractures. Natural geothermal energy in the form of hot water is known as conventional geothermal energy. The key challenge for conventional geothermal energy will be to find where these hot spots have sufficient volume and water flow capacity.

Recovery of naturally hot geothermal water trapped underground in permeable sedimentary sequences is not the same as recovery of heat from "hot rocks". In contrast heat is recovered from "hot rocks" or "hot dry rocks" by pumping cool water down an injection well and up a production well through fractures engineered in the hot rocks by hydraulic fracturing (Fig. 1). Over 10,000 MW of electricity is produced worldwide from conventional geothermal energy. Most of this is produced from fractures in volcanic environments where rain water has seeped underground and becomes heated as it nears hot magma at depth (Fig. 1). There is also the potential for recovery of geothermal energy on a large scale from sedimentary environments without the need for any new technology. Because of its substantially lower energy content than petroleum, much higher production flow rates are needed for geothermal energy to be commercially viable. Very high flow rates of geothermal fluid have been achieved from highly permeable aquifers, faults or fractures by using geothermal well designs, completions and drilling practices which can differ substantially from practices used in the petroleum industry where water production is not wanted.

Geothermal energy is currently recovered on a commercial scale from hot sedimentary aquifers in the Paris Basin in France and in Hungary for direct heating projects. In Tuscany and in Bavaria and the Rhine Graben in Germany geothermal energy is used for both power production and district heating. In Bavaria geothermal production flow rates around

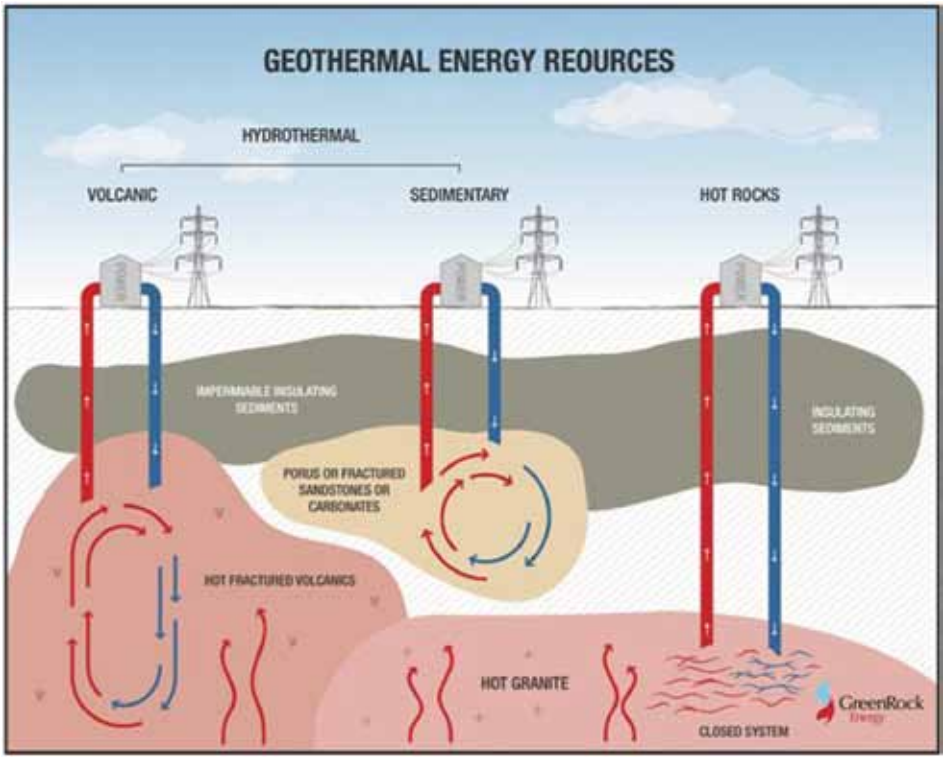

Figure 1 | **Various types of geothermal energy resources**

200 litres/second (i.e. over 100,000 bwd) are being achieved by Siemens. In the northern Rhine Graben at Landau where Green Rock's director Dr Jörg Baumgärtner commissioned Germany's first commercial geothermal power plant in 2007, geothermal water production is flowing at around 80 litres/second (43,000 bwd). Indeed it is aspects of the Perth Basin's similarity to the northern Rhine Graben where a successful geothermal industry has emerged that has enthused Dr Baumgärtner and Green Rock about the geothermal potential of the northern Perth Basin.

The Perth Basin is a 1,000 km long rift aligned in a north-south direction, which formed by extension of the crust culminating when India split from the west coast of Australia. In the northern Perth Basin the rift is filled with around 8 km of predominantly Permian to Cretaceous aged sediments. In the northern Perth Basin the Company aims to recover geothermal energy from water trapped in hot permeable sediments which can be produced at a sustainable commercial flow rate from natural primary and fracture permeability.

The Ormat power plant at Mokai, New Zealand — the type of geothermal power plant Green Rock Energy hope to install in the northern Perth Basin
(Photo courtesy of Green Rock Energy)

Most of the geological and thermal information about the sedimentary sequences in the Perth Basin comes from petroleum wells and from much shallower water bores. While the information is generally sparse throughout the basin, the best data is from the northern Perth Basin where there is the greatest concentration of petroleum wells and seismic coverage, especially near the 13 oil and gas field discoveries (Fig. 2).

In the northern Perth Basin, temperature gradients exceeding 5°C/100 m and heat flows exceeding 100 mW/m^2 in places have been measured from wells and deep bores near the petroleum fields. Over 250 petroleum wells have been drilled in the Perth Basin and conductive heat flows have been assessed and modelled for 183 of these wells by the Australian geothermal consultancy firm Hot Dry Rocks Pty Ltd. Results showed the northern Perth Basin is the hottest part of the Perth Basin. Modelled surface heat flows in the Perth Basin ranged from 30–140 mW/m^2, with a median value of 95 mW/m^2 for all wells in the northern Perth Basin, and a median value of around 76 mW/m^2 for the basin as a whole (Fig. 3). The Australian median surface heat flow is 64.5 mW/m^2 from the Australian heat flow database.

Green Rock has acquired geothermal Permits in the northern Perth Basin where geothermal heat flows are the highest in the basin and where petroleum wells have intersected geothermal water with temperatures above 150°C at depths less than 4,000 metres (Fig. 4). These temperatures are considered to be sufficient for commercial generation of electricity provided that sufficient geothermal water flow rates can be produced from the sediments.

The principle objective is to select the optimum drill location in the northern Perth Basin in the second half of 2012 depending on the availability of a suitable rig. Temperature mapping of the northern Perth Basin Permits has been completed and the Company's exploration is now focussing on mapping natural permeability within the locations identified with the highest sub-surface heat flow. Existing 3D and 2D seismic is being re-interpreted and well logs and drilling information analysed for this purpose.

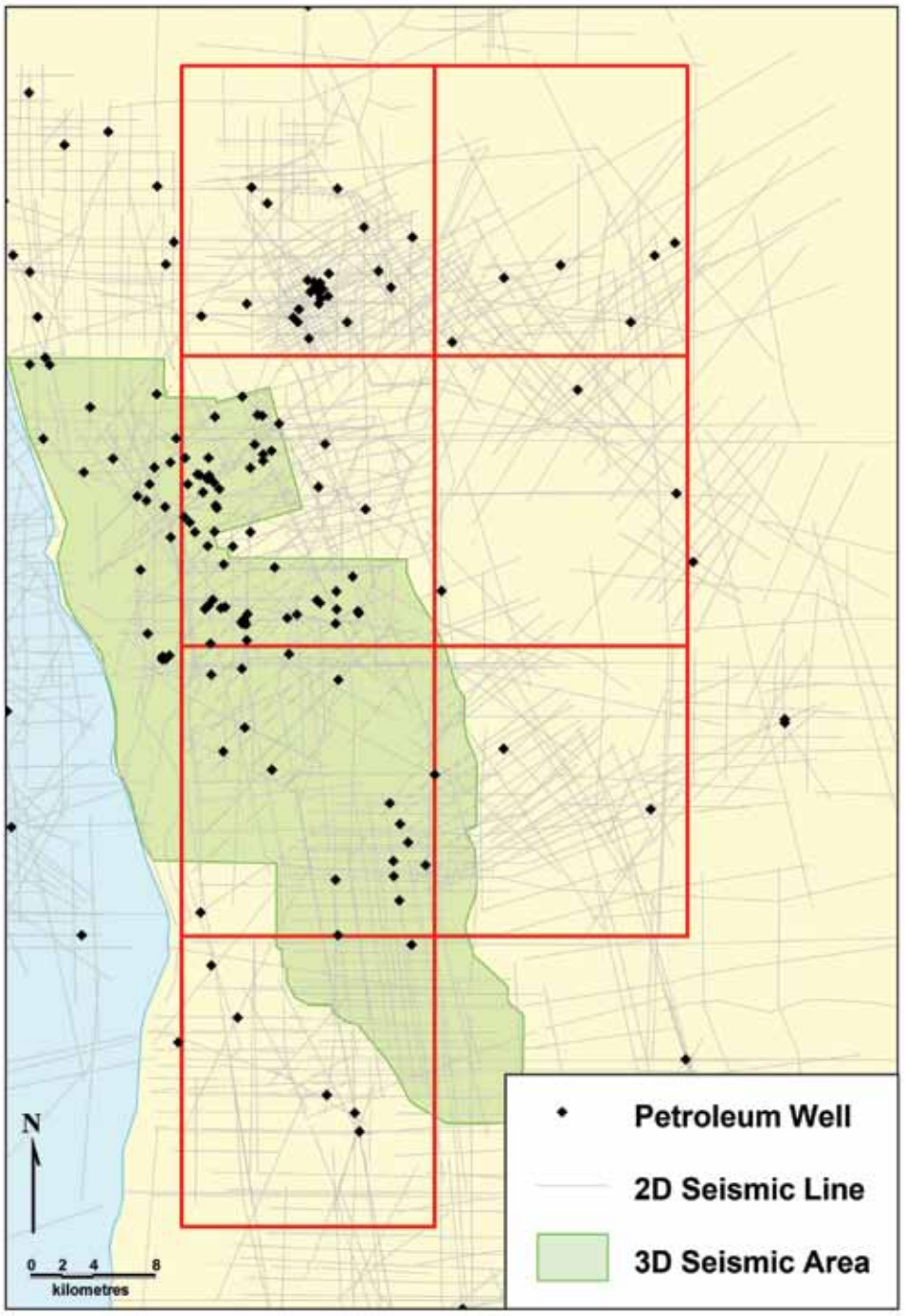

Figure 2 | **Green Rock Energy's Geothermal Exploration Permits overlain by wells and seismic**

An advantage of the northern Perth Basin is that the Permits are located near transmission lines connected to the high voltage grid which will supply a rapidly expanding power market in the mid-west region. Unlike in member countries of the European Union such as Germany and Hungary, electricity generated from geothermal energy in Australia does not benefit from any feed in tariff arrangement and retail electricity prices in Australia are substantially lower than in Hungary and Gemany. However in Australia generators of renewable energy including geothermal energy are entitled under Federal legislation to sell Renewable Energy Certificates (REC) in addition to selling the electricity they generate. In the absence of feed in tariffs, electricity is sold in Western Australia to utilities via power purchase agreements. Green Rock has recently signed a binding MOU with leading renewable energy company Pacific Hydro to cooperate on the development of power projects in the northern Perth Basin. Pacific Hydro brings expertise and experience of installation of power plants and surface facilities and connection to the SWIS power grid in WA and the NEM grid in SE Australia.

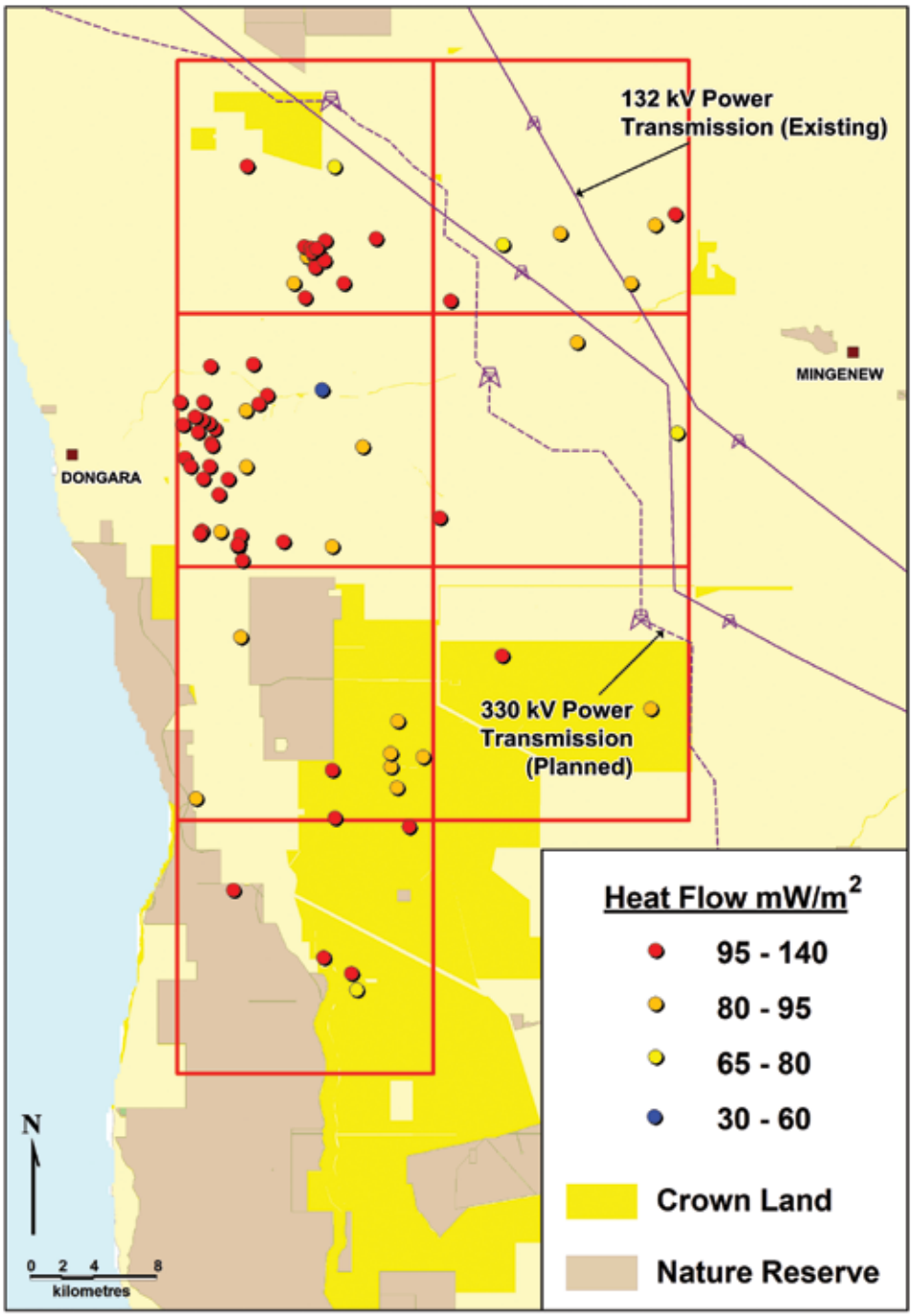

Figure 3 | **Heat flow in Green Rock Energy's Permits in the northern Perth Basin**

In the Perth Metropolitan area Green Rock's Geothermal Exploration Permits extend from Cottesloe in the south to north near Yanchep. In this area geothermal energy is being recovered from permeable aquifers in GEP 1 down to a depth of around 1,000 metres to heat swimming pools. Temperatures from permeable aquifers from depths down to 3,000 metres are expected to be insufficient for commercial scale generation of electricity but adequate for direct heat uses such as purification and desalination of water by distillation and for air-conditioning of buildings. The challenge for direct heat projects is to find commercial markets with sufficiently large base load energy demand to justify drilling the production and re-injection wells to the depth where the reservoir temperatures are sufficient for the required end use. Large scale air-conditioning of commercial and industrial buildings such as in high density developments has potential scale. For this purpose Green Rock Energy is consulting with the developers of new developments planned for a population of 30,000 at Stirling in GEP 1 and for a suburb for 60,000 people at Alkimos in GEP 2 which hope to utilise renewable energy.

Green Rock is investing in Hungary because it has a generally high geothermal temperature gradient due to its relatively thin crust. In Hungary Green Rock owns 50 per cent of Central European Geothermal Energy (CEGE), a joint venture company it formed with Hungary's largest company Hungarian Oil and Gas Company (MOL) which owns the other 50 per cent. CEGE plans to develop geothermal energy in Hungary for power generation and direct heat uses.

In February this year CEGE purchased one of the 5,000 petroleum wells MOL has drilled in Hungary. This was after CEGE and BESTEC Gmbh, the German geothermal power developer and operator managed by Green Rock director Dr Jörg Baumgärtner, evaluated data from the well and concluded that the geothermal reservoir tapped by the well in fractured Triassic carbonates should be capable of generating megawatts of electricity. The well is close to existing power infrastructure. CEGE's target is to commence power production in the next two years, subject to obtaining the geothermal concession for the area under legislation being introduced by the Hungarian Government.

This year Green Rock branched into hydrocarbon exploration in the Canning Basin when it executed a farm-in agreement with the New Standard Energy Group (NSE) to earn an interest in permit EP 417 operated by NSE in the Fitzroy Trough (Fig. 5). Green Rock will partially fund the deepening and testing of the existing Lawford 1 well planned for the third quarter 2011. The well provides prospectivity for conventional gas in a large capacity structure and for tight gas and shale gas. Green Rock and NSE have also executed an Area of Mutual Interest (AMI) Agreement to provide further opportunities in the Canning Basin, with Green Rock having a 40 per cent working interest in any new permits. The parties will focus on areas that are prospective for unconventional hydrocarbons within the agreed AMI. In this respect NSE has recently been granted the Seven Lakes Special Prospecting Authority adjacent to EP 417.

Exploration in the Canning Basin is set to increase significantly in 2011 and 2012, particularly focusing on conventional, tight and shale gas. This is evidenced by major activity planned by Buru and its joint venture partner Mitsubishi and the recent announcement by NSE of its farmout to Conoco Phillips. ■

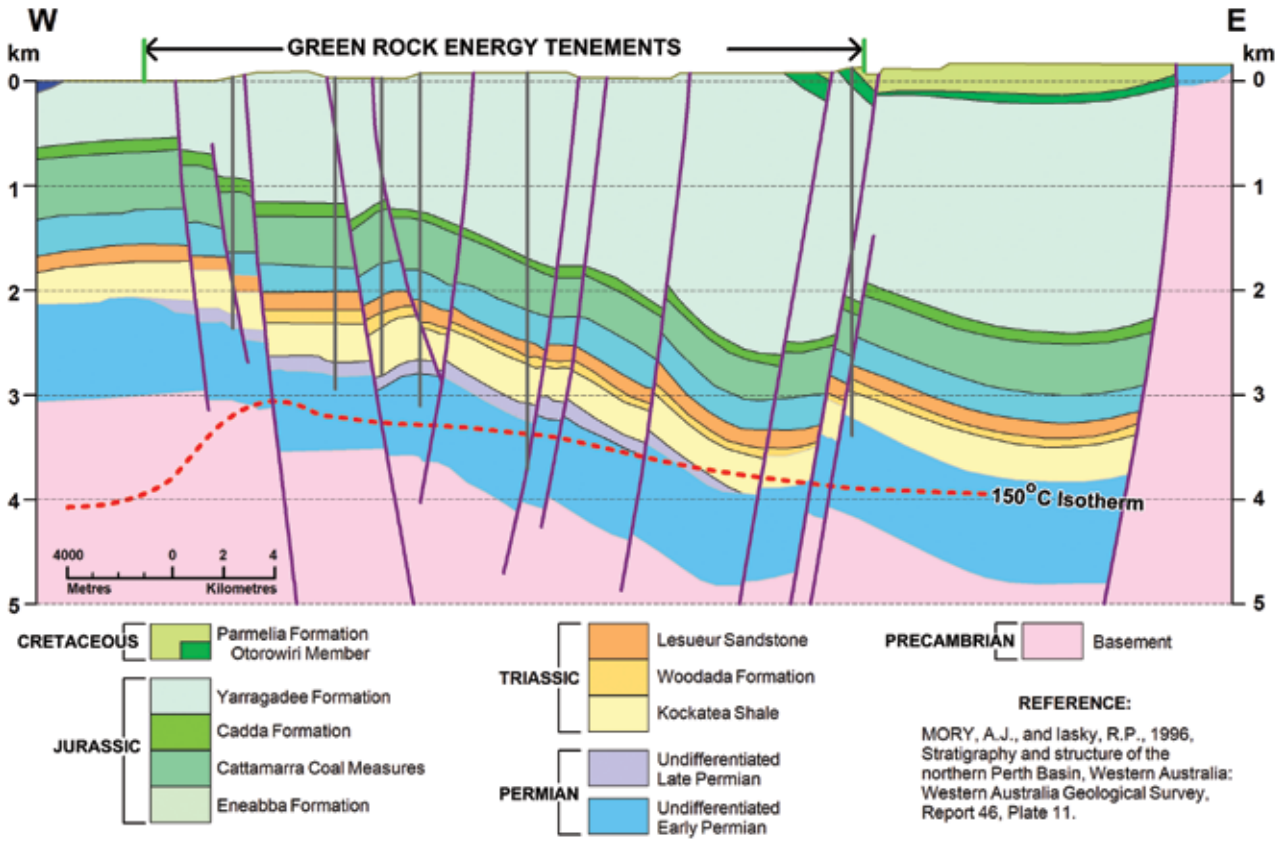

Figure 4 | **Geological cross section of the northern Perth Basin showing area covered by Green Rock's GEPs**

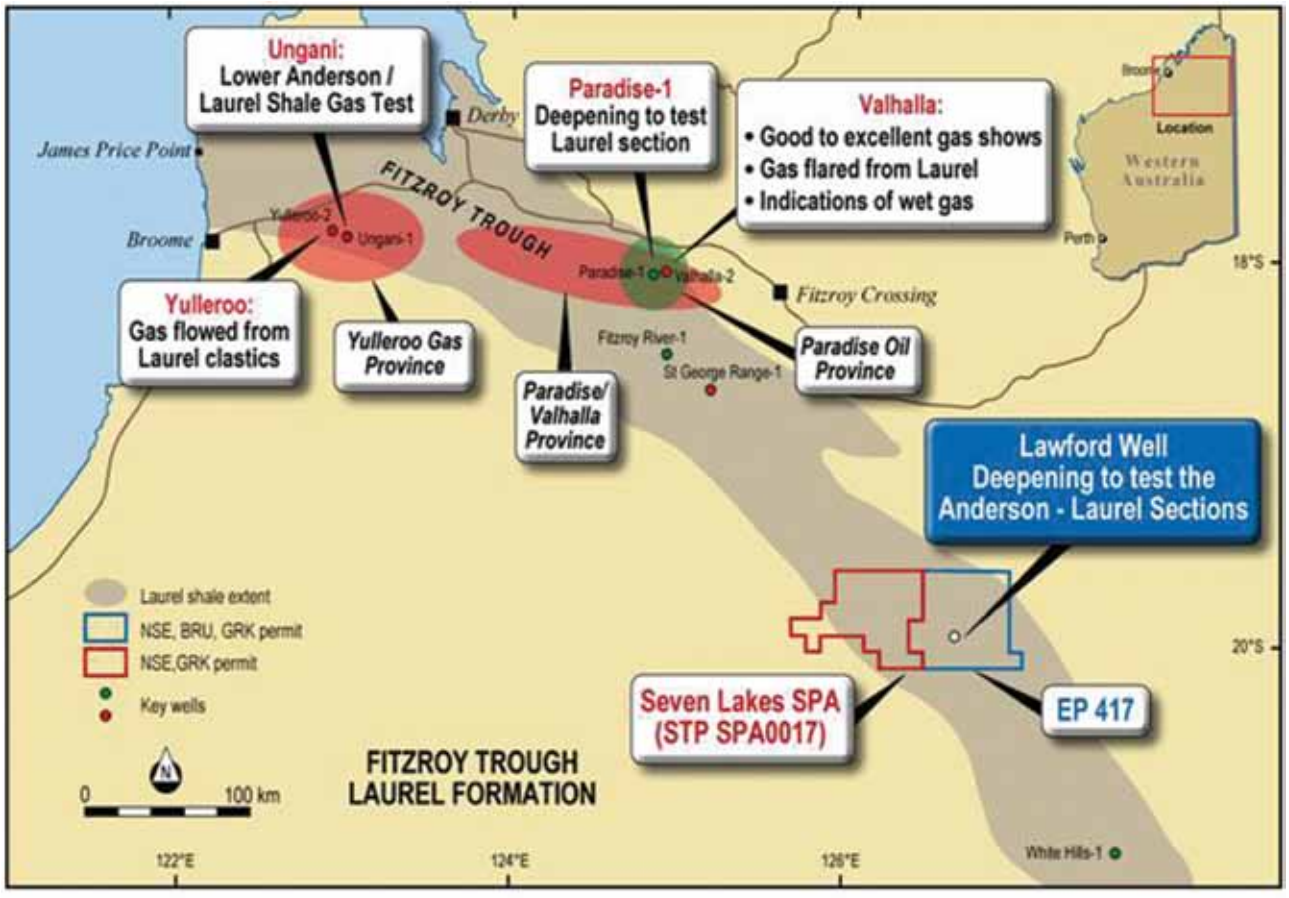

Figure 5 | **Prospectivity of Fitzroy Trough where Green Rock Energy have farmed in to EP 417**
(Courtesy of New Standard Energy)

Collie Hub Carbon Capture and Storage Project

Jianhua Liu
Petroleum Engineer Special Projects
Resources Branch

On 11 June 2011, the Minister for Resources, Energy and Tourism, Mr Martin Ferguson announced the Carbon Capture and Storage (CCS) Flagship funding of $52 million to the Western Australian Collie South West Hub project to progress under a staged and gated approach. What is the Collie Hub CCS project? Where did it come from and what is the way forward?

The CCS Flagship program, built on the National Low Emission Coal Initiative, will include industrial scale demonstrations that will contribute to meeting 1,000 MV of low emissions fossil fuel power generation in Australia. The South West Collie Hub project is investigating potentially suitable storage sites near the industry centres of Kwinana and Collie, a large source region of carbon dioxide (CO_2). The project aims to store up to 3.3 mega tonnes of CO_2 per annum, captured from surrounding industry including coal-fired power plants.

The southwest of Western Australia, from Kwinana through to Collie (Fig. 1), is one of Australia's major industrial areas, generating billions of dollars of domestic and export revenue. According to an estimation by the National Carbon Storage Taskforce in 2009, however, this area also contributes about 25 million tonnes per annum of carbon dioxide (CO_2). In order to reduce CO_2 emission, industries in this area have taken initiatives to investigate the potential of carbon dioxide capture and geological storage in this region. The Collie Hub CCS project represents a government–industry partnership between the Department of Mines and Petroleum (DMP) and six major industry partners in the area — Griffin Energy, Verve Energy, BHP Billiton Worsley Alumina, Westfarmers Premier Coal, Perdaman Chemicals and Fertilisers, and Alcoa Australia.

Initial investigation of the potential for CO_2 geological storage dates back more than a decade as part of the GEODISC Program by the then Australian Petroleum Cooperative Research Centre. In this program, sources of emission and potential geological storage sites, including the southern Perth Basin, were identified for further investigation. In 2007, the Department of Industry and Resources and the Coal Futures Group funded a more detailed study in this area. This study was carried out by the CRC for Greenhouse Gas Technologies (CO2CRC). The preliminary investigation by the CO2CRC identified the southern Perth Basin as having potential for CCS. The study found that the fresh water Yarragadee Formation was absent above the Lesueur Sandstone Formation in the Harvey Ridge region and recommended that further study should be undertaken to investigate its CO_2 geological storage potential (Fig. 2). In 2010, the DMP and industry partners commissioned Carbon Storage Solutions, a division of international oilfield services provider Schlumberger, to test the validity of suitable locations to store carbon dioxide in the southern Perth Basin by examining available seismic data and existing well cores. Both static modelling and dynamic modelling have been conducted. The independent studies have recognised the potential of the Lesueur Formation as a significant unconventional storage site.

Figure 1 | **Mapping showing the South West of Western Australia and the proposed Collie Hub CCS region (Van Gent and Stalker, 2010)**

The Collie Hub project proposed detailed research and development plans, and enabling case and business case as a part of securing the CCS Flagship funding (Fig. 3). The funding will enable the Collie Hub project to move to the next phase of decision making which includes the progression of pre-competitive data acquisition and analysis of the potential storage area. The enabling case includes expansion of red mud sequestration of CO_2 from Kwinana to Pinjarra and Wagerup where CO_2 will be used to neutralise highly alkali residue after alumina is extracted from bauxite, and proving the suitability of the Lesueur Formation for unconventional geological storage of CO_2. The Kwinana Pipeline between Kwinana and the Lesueur CO_2 injection area will be established at this phase as well. If it is proven, this enabling case will be able to store up to 3.3 mega tonnes per annum of CO_2 with potential for expansion to the business case.

Public outreach is an important part of the project. Since the announcement of the Collie Hub CCS Flagship project, the Lesueur Community Consultative Group has been established by the Hon. Mr Norman Moore, Minister for Mines and Petroleum, Western Australia.

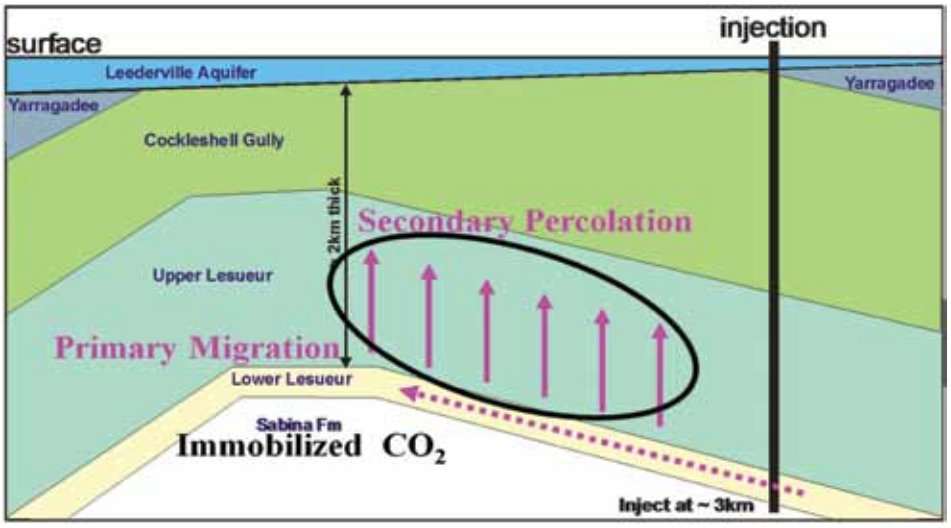

Figure 2 | **Schematic diagram of the unconventional CCS storage mechanisms proposed for the Lesueur Sandstone Formation (Varma *et al.*, 2007)**

Seismic surveying has been carried out in this area and data acquired are being interpreted. In addition, a stratigraphic well will be drilled in the second half of this year to better understand the geology of this region. At the moment, planning for the drilling of a stratigraphic well and associated well logs and testing is well underway. There is no doubt that findings from the seismic survey and well will shed light on the future of the Collie Hub CCS project.

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Van Gent, D. and Stalker, L., 2010, Collie South West CO_2 Hub—A future CCS flagship? SPE News, issue 140

Varma, S., Dance, T., Underschultz, J., Langford, R.P., and Dodds, K., 2007, Regional Study on Potential CO_2 Geosequestration in the Collie Basin and the Perth Basin of Western Australia. Prepared for the Department of Industry and Resources and the Coal Futures Group, May 2007. CO2CRC Report No: RPT07-0529 ■

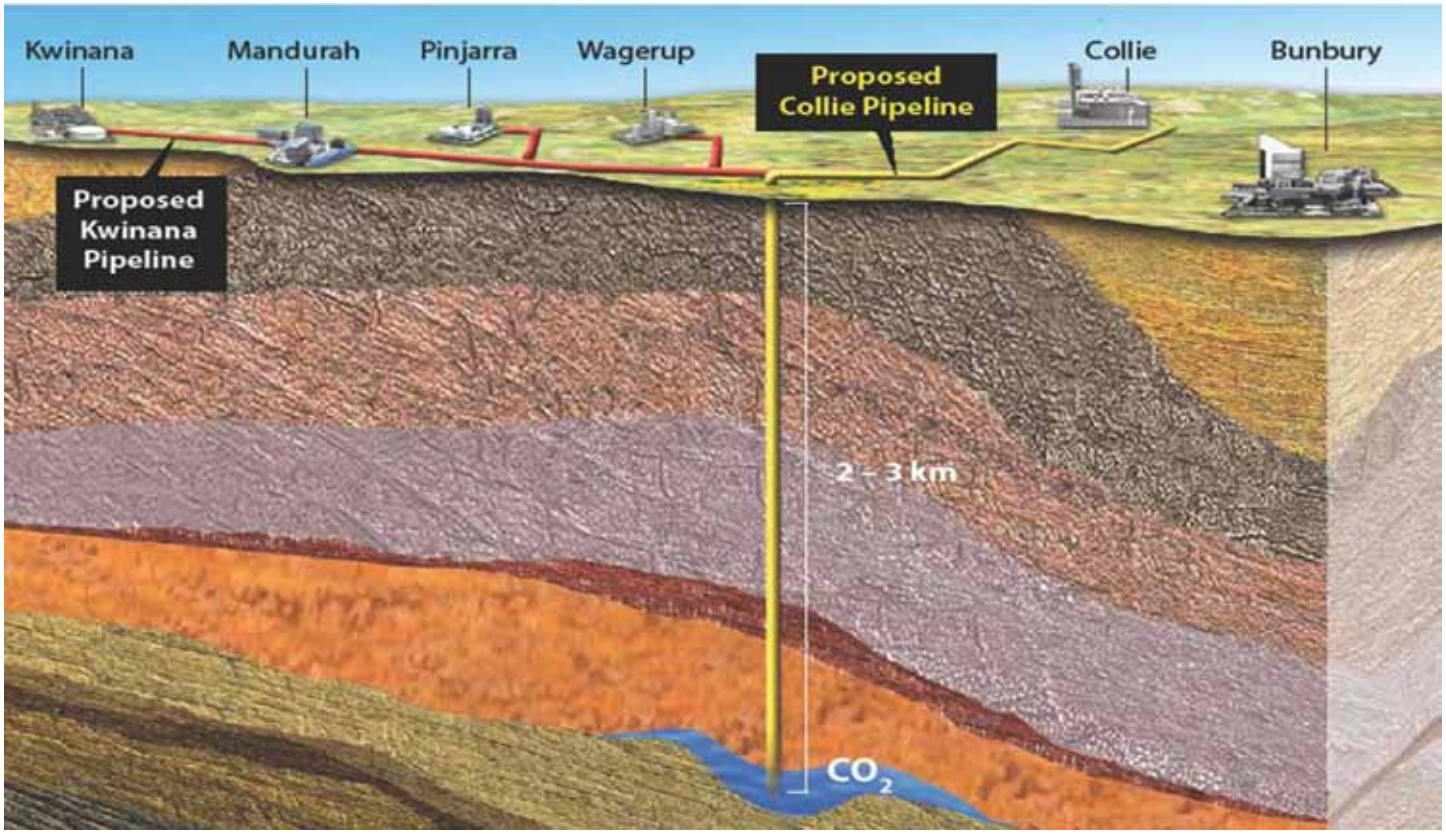

Figure 3 | **The proposed South West Collie Hub CCS Project (source: www.dmp.wa.gov.au)**

Table 1. 2010 Production by Field and Cumulative Production as at 31 December 2010

Field	Operator	2010 Production by Field			Cumulative Production			Permit
		Oil	Condensate	Gas	Oil	Condensate	Gas	
		kL	kL	10^3 m^3	kL	kL	10^3 m^3	
Albert	Apache	4,415	13	1,196	61,749	41	6,367	TL/6
Angel	Woodside	0	2,329,421	7,899,932	0	4,771,924	15,984,521	WA-3-L
Apium	AWE	0	63	4,349	0	355	30,603	L1
Artreus	Apache	9	0	37	32,836	14	3,850	TL/6
Bambra	Apache	67,974	30,030	323,677	309,109	114,650	846,715	TL/1
Barrow Island	Chevron	311,510	0	35,934	50,296,651	0	5,315,949	L1H
Beharra Springs N	Origin	0	341	41,804	0	24,211	2,279,971	L11
Beharra Springs S	Origin	0	11	1,112	0	2,012	206,230	L11
Blacktip	Eni	0	10,564	582,861	0	11,096	644,188	WA-33-L
Blina	Buru Energy	690	0	0	296,817	0	0	L6
Boundary	Buru Energy	292	0	0	20,743	0	0	L6
Cliff Head	ROC Oil	234,030	0	1,530	1,664,098	0	7,396	WA-31-L
Corybas	AWE	0	180	7,129	0	180	7,129	L2
Cossack	Woodside	263,643	0	7,042	12,848,307	0	384,977	WA-9-L
Cowle	Chevron	2,772	0	1,861	531,266	0	89,628	TL/4
Crest	Chevron	299	0	695	275,054	108	62,686	L12, L13
Crosby	BHP Billiton	1,908,621	0	72,190	1,908,621	0	72,190	WA-42-L
Dongara	AWE	1,217	4	19,079	193,094	49,681	12,889,122	L1, L2
Double Island	Apache	16,167	49	6,751	692,177	2,825	51,803	TL/9
Echo/Yodel	Woodside	0	176,313	200,844	0	10,747,852	13,567,553	WA-23/24-L
Enfield	Woodside	1,520,104	0	110,249	9,123,159	0	762,309	WA-28-L
Eremia	AWE	2,717	0	1,427	242,506	0	13,035	L1
Eskdale	BHP Billiton	87,614	0	86,268	398,900	0	268,310	WA-32-L
Exeter	Santos	27,873	0	149	2,513,130	0	4,997	WA-27-L
Gipsy	Apache	18	0	8	363,641	2,502	79,189	TL/1
Goodwyn	Woodside	0	1,487,995	7,533,371	0	44,299,453	128,855,757	WA-5-L
Gudrun	Apache	15	0	5	118,735	75	7,745	TL/1
Harriet	Apache	18,483	181	7,664	8,200,239	60,217	1,492,451	TL/1
Hermes	Woodside	1,261,095	0	89,767	12,681,481	0	844,868	WA-16-L
Hovea	AWE	19,264	0	4,263	1,157,714	251	100,471	L1
Jingemia	Origin	23,611	0	2,064	715,013	0	33,810	L14
John Brookes	Apache	0	167,451	2,838,976	0	745,329	11,955,870	WA-29-L
Laminaria East	Woodside	16,382	0	1,680	1,549,415	70,625	26,534	WA-18-L
Lee	Apache	0	14,907	122,315	0	107,492	707,522	TL/1
Legendre North	Apache	122,449	0	86,914	6,781,400	0	1,749,003	WA-20-L
Legendre South	Apache	35,531	0	224,003	884,778	0	1,222,452	WA-20-L
Little Sandy	Apache	4,083	12	1,593	92,230	455	13,301	TL/6
Lloyd	Buru Energy	160	0	0	30,284	0	0	L8
Macedon	BHP Billiton	0	0	16,761	0	0	16,761	WA-42-L
Mohave	Apache	13,457	123	8,472	155,052	231	26,830	TL/6
Mount Horner	AWE	1,663	0	0	298,094	0	0	L7
Mutineer	Santos	252,218	0	1,451	6,044,518	0	12,955	WA-26-L
North Alkimos	Apache	1,189	5	1,631	11,244	94	21,823	TL/6
North Rankin	Woodside	0	235,922	2,275,191	0	24,697,633	193,530,684	WA-1-L
Pedirka	Apache	12,378	50	6,563	326,938	1,254	37,201	TL/6
Perseus	Woodside	0	2,379,384	12,055,759	0	22,170,967	108,497,522	WA-1-L

Table 1. 2010 Production by Field and Cumulative Production as at 31 December 2010

Field	Operator	2010 Production by Field			Cumulative Production			Permit
		Oil	Condensate	Gas	Oil	Condensate	Gas	
		kL	kL	10^3 m^3	kL	kL	10^3 m^3	
Ravensworth	BHP Billiton	624,565	0	124,143	624,565	0	124,143	WA-42-L
Redback	Origin	0	15	11,175	0	15	11,175	L11
Roller	Chevron	39,616	0	12,818	7,117,562	0	755,893	TL/7
Rose	Apache	0	5,525	40,348	0	204,880	997,470	TL/1
Saladin	Chevron	66,007	0	22,638	15,468,324	0	1,741,051	TL/4
Searipple	Woodside	0	477,111	482,667	0	1,233,077	1,223,687	WA-1-L
Simpson	Apache	9,079	2,503	3,793	844,091	9,028	84,398	TL/1
Skate	Chevron	0	0	21,786	266,950	8,873	177,967	TL/7
South Plato	Apache	4,889	10	841	702,432	893	51,476	TL/6
Stag	Apache	342,022	0	4,267	8,560,191	0	398,721	WA-15-L
Stickle	BHP Billiton	1,543,454	0	104,632	1,543,454	0	104,632	WA-42-L
Stybarrow	BHP Billiton	586,147	0	35,459	6,408,459	1	388,182	WA-32-L
Sundown	Buru Energy	1,728	0	0	72,267	0	0	L8
Tarantula	Origin	0	69	7,386	0	3,927	315,450	L11
Van Gogh	Apache	1,878,286	0	157,015	1,878,286	0	157,015	WA-35-L
Victoria	Apache	2,844	8	594	52,422	375	8,435	TL/6
Vincent	Woodside	1,357,915	0	148,790	2,952,760	0	735,690	WA-28-L
Wanaea	Woodside	482,432	0	113,460	39,185,910	0	8,410,610	WA-11-L
Wandoo	Vermillion	426,541	0	38,535	12,623,493	0	1,006,511	WA-14-L
West Cycad	Apache	15,640	121	6,946	208,820	346	30,636	TL/9
West Terrace	Buru Energy	612	0	0	39,128	0	0	L8
Wonnich	Apache	0	36,374	419,020	0	438,937	4,345,206	TL/8
Woodada	AWE	0	0	583	0	10,603	1,496,908	L4, L5
Woollybutt	Eni	270,234	0	7,311	5,303,878	0	149,929	WA-25-L
Xyris	AWE	0	62	3,942	0	3,567	262,826	L1
Yammaderry	Chevron	395	0	9,001	857,756	0	107,726	TL/4
Yardarino	AWE	0	0	151	1,567	771	143,934	L2
Cumulative production for developed fields currently not producing					39,257,815	3,267,426	21,301,789	
Total		**13,884,349**	**7,354,817**	**36,461,868**	**264,789,123**	**113,064,246**	**547,263,738**	

Table 2a. Petroleum Reserves Estimates by Basin as at 31 December 2010 (metric units)						
Basin	Oil		Sales Gas		Condensate	
	GL		Gm^3		GL	
Category 1	P50	P90	P50	P90	P50	P90
Bonaparte	0.000	0.000	22.791	10.452	0.401	0.184
Northern Carnarvon	67.907	34.727	1,115.299	867.415	78.213	57.629
Perth	1.224	0.689	0.275	0.126	0.006	0.006
Total	**69.13**	**35.42**	**1,138.37**	**877.99**	**78.62**	**57.82**
Category 2	P50	P90	P50	P90	P50	P90
Bonaparte	0.000	0.000	60.698	34.118	1.650	0.957
Browse	0.000	0.000	447.750	267.289	57.540	34.620
Northern Carnarvon	4.129	2.217	766.544	437.410	39.316	20.114
Total	**4.13**	**2.22**	**1,274.99**	**738.82**	**98.51**	**55.69**
Category 3	P50	P90	P50	P90	P50	P90
Browse	0.000	0.000	406.659	301.754	99.125	73.423
Northern Carnarvon	3.790	2.350	261.716	184.435	20.913	13.615
Total	**3.79**	**2.35**	**668.38**	**486.19**	**120.04**	**87.04**
Category 4	P50	P90	P50	P90	P50	P90
Bonaparte	0.000	0.000	14.425	0.446	0.074	0.022
Browse	0.000	0.000	34.902	16.247	3.388	1.261
Carnarvon	41.388	22.909	436.638	272.571	17.268	10.324
Perth	0.000	0.000	5.500	5.500	0.000	0.000
Total	**41.39**	**22.91**	**491.47**	**294.76**	**20.73**	**11.61**
GRAND TOTAL	**118.44**	**62.89**	**3,573.20**	**2,397.76**	**317.89**	**212.16**

Table 2b. Petroleum Reserves Estimates by Basin as at 31 December 2010 (field units)						
Basin	Oil		Sales Gas		Condensate	
	MMbbl		Tcf		MMbbl	
Category 1	P50	P90	P50	P90	P50	P90
Bonaparte	0.000	0.000	0.804	0.369	2.525	1.163
Northern Carnarvon	427.127	218.431	39.386	30.632	491.944	362.481
Perth	7.700	4.339	0.004	0.009	0.042	0.040
Total	**434.83**	**222.77**	**40.19**	**31.01**	**494.51**	**363.68**
Category 2	P50	P90	P50	P90	P50	P90
Bonaparte	0.000	0.000	2.143	1.204	10.378	6.025
Browse	0.000	0.000	15.812	9.439	361.915	217.753
Northern Carnarvon	25.974	13.947	27.070	15.447	247.295	126.518
Total	**25.97**	**13.95**	**45.03**	**26.09**	**619.59**	**350.30**
Category 3	P50	P90	P50	P90	P50	P90
Browse	0.000	0.000	14.361	10.656	623.479	461.817
Northern Carnarvon	23.838	14.781	9.242	6.513	131.539	85.637
Total	**23.84**	**14.78**	**23.60**	**17.17**	**755.02**	**547.45**
Category 4	P50	P90	P50	P90	P50	P90
Bonaparte	0.000	0.000	0.015	0.509	0.469	0.143
Browse	0.000	0.000	1.232	0.573	21.310	7.936
Carnarvon	260.327	144.097	15.419	9.625	108.616	64.936
Perth	0.000	0.000	0.194	0.194	0.000	0.000
Total	**260.33**	**144.10**	**16.86**	**10.901**	**130.40**	**73.02**
GRAND TOTAL	**744.97**	**395.60**	**125.68**	**85.17**	**1,999.51**	**1,334.45**

NOTES

Canning Basin reserves are too small to measure.

Category 1 comprises current reserves of those fields which are producing hydrocarbons or have been declared commercial (FFDP approved and FID).

Category 2 comprises estimates of recoverable reserves which are held under Retention Leases and have not yet been declared commercially viable.

Category 3 comprises estimates of contingent resources which are held in other licences and have been declared commercially viable but may or may not have a FFDP and have not yet reached FID.

Category 4 comprises estimates of contingent resources which are held in other licences and have not yet been declared commercially viable and are not held under a Retention Lease.

Table 3. Seismic Surveys in Western Australia 2010–11 Fiscal Year — Statistical Summary

		2D (line km)	3D (km²)
Bonaparte Basin	Onshore		
	Offshore	209	
Browse Basin	Onshore		
	Offshore	9,739	3,037
Canning Basin	Onshore	761	
	Offshore		
Carnarvon Basin	Onshore		
	Offshore		20,813(a)
Perth Basin	Onshore	88	92
	Offshore		
Subtotal	Onshore	849	92
	Offshore	9,948	23,850
Total		**10,797**	**23,942**

The above table lists the quantity of 2D seismic and airborne gravity (line km) and 3D seismic (km²) acquired during the fiscal year. For surveys that commenced before 1 July 2010, only acquisition after this date is included.
(a) Includes km² from Eendracht and Schiele 3D M.S.S. commenced prior to July 2010.
The attached listing of surveys operating in the fiscal year includes all data gathered prior to 30 June 2010.

Table 4. Petroleum Wells in Western Australia 2010–11 Fiscal Year — Statistical Summary

		NFW		EXT		DEV		Subtotal		Total	
		Wells	Metres	Wells	Metres	Wells	Metres	Wells	Metres	Wells	Metres
Bonaparte Basin	Onshore									**2**	**8,504**
	Offshore	2	8,504					2	8,504		
Browse Basin	Onshore									**1**	**7,155**
	Offshore	1	4,824		2,331(a)			1	7,155		
Canning Basin	Onshore	5	8,940					5	8,940	**5**	**8,940**
	Offshore										
Carnarvon Basin	Onshore									**49**	**182,024**
	Offshore	24	97,593(b)	14	31,230	11	53,201(c)	49	182,024		
Perth Basin	Onshore	5	10,403	2	8,243	3	8,393	10	27,039	**10**	**27,039**
	Offshore										
Subtotal	Onshore	10	19,343	2	8,243	3	8,393	15	35,979	**67**	**233,662**
	Offshore	27	110,921	14	33,561	11	53,201	52	197,683		
Total		**37**	**130,264**	**16**	**41,804**	**14**	**61,594**	**67**	**233,662**		

The above table lists the number of wells spudded and metres drilled (subsurface) during the 2010–11 fiscal year.
For wells spudded before 1 July 2010, only metres drilled during the fiscal year are included in the above table.
(a) Concerto 1 spudded April 2010.
(b) Includes six wells spudded prior to 1 July 2010.
(c) Includes ENE 02 RD1 spudded May 2010 and 3 sidetracks to existing Wandoo development wells.

Table 5. Seismic Surveys in Western Australia Operating 2010–11 Fiscal Year

Survey Name	Class	On Off	Title	Operator	Commenced	Completed	2D/ Line km @ 30/06/2011	3D km² @ 30/06/2011
Bonaparte Basin								
WA-446-P 2D M.S.S.	2D	Off	WA-446-P	Finder No 1	25/10/2010	29/10/2010	209	
Browse Basin								
Golden Orb MultiClient 2D M.S.S.	2D	Off	12SL/09-0	PGS	28/06/2010	18/07/2010	2,507	
Vampire Non-Exclusive 2D M.S.S.	2D	Off	1SL/10-1	Searcher	1/11/2010	1/02/2011	7,232	
Bassett 3D M.S.S.	3D	Off	WA-408-P	Total	23/09/2010	20/10/2010		856
Byron 3D M.S.S.	3D	Off	WA-396-P, WA-397-P	Woodside	25/04/2011	7/05/2011		562
Ichthys 3D M.S.S.	3D	Off	WA-285-P R2, WA-37-R	Inpex	21/10/2010	23/12/2010		1,619
Canning Basin								
Pijalinga 2D S.S.	2D	On	EP 427, EP 442	Buru	2/10/2010	10/11/2010	415	
Yulleroo South 2D S.S.	2D	On	EP 391 R2, EP 428	Buru	27/08/2010	28/09/2010	346	
Goldwyer Aerial Gravity Survey	GRAVITY	On	EP 443, EP 450, EP 451, EP 456	New Standard	24/10/2010	10/12/2010	13,733	
Carnarvon Basin								
Phoenix MC3D M.S.S.	3D	Off	11SL/09-0	Fugro	9/12/2010	16/02/2011		1,212
Cambozola 3D M.S.S.	3D	Off	WA-290-P R1	Apache	22/05/2011	27/06/2011		964
Chamois 3D M.S.S.	3D	Off	WA-261-P R2	Apache	16/03/2011	9/04/2011		257
Eendracht 3D M.S.S.	3D	Off	6SL/08-9	Fugro	8/06/2009	27/10/2010		14,768
Endeavour MC3D Multiclient M.S.S.	3D	Off	3SL/10-1	WesternGeco	6/12/2010	11/03/2011		1,851
Enfield M5 4D M.S.S.	3D	Off	WA-28-L	Woodside	28/12/2010	12/01/2011		305
Gazelle 3D M.S.S.	3D	Off	WA-399-P	Apache	28/02/2011	11/03/2011		135
Kultarr 3D M.S.S.	3D	Off	WA-334-P R1	Apache	11/04/2011	19/04/2011		229
Movida 3D M.S.S.	3D	Off	WA-389-P	Woodside	10/03/2011	2/04/2011		1,613
Orcus 3D M.S.S.	3D	Off	WA-450-P	Apache	9/02/2011	20/05/2011		266
Pomodoro 3D M.S.S.	3D	Off	WA-426-P	Apache	16/01/2011	9/02/2011		317
Salsa 3D M.S.S.	3D	Off	WA-384-P	Shell	28/12/2010	5/02/2011		300
Schiele 3D M.S.S.	3D	Off	WA-362-P, WA-363-P	OMV Australia	21/04/2010	6/07/2010		3,943
Sovereign 3D M.S.S.	3D	Off	WA-383-P	Chevron	6/04/2011	21/04/2011		1,014
Stybarrow 4D Monitor M.S.S.	3D	Off	WA-32-L	BHPB	2/05/2011	19/05/2011		82
Vincent M1 4D M.S.S.	3D	Off	WA-28-L	Woodside	20/12/2010	27/12/2010		123
Zeebries MC3D M.S.S.	3D	Off	5SL10-1	Fugro	3/12/2010	3/05/2011		3,816
Ragnar Hub 2D C.S.E.M. Survey	CSEM	Off	WA-428-P, WA-430-P, WA-433-P	Woodside	10/12/2010	23/12/2010	126	
Kennedy Range Survey	GEOCHEM	On	6/08-9	New Standard	1/05/2009	7/01/2011		
Wandagee East Geochemistry	GEOCHEM	On	9/09-0	New Standard	8/04/2010	7/01/2011		
Eucla Basin								
Balladonia ESR Survey	ESR	On	4/09-0	Southern Sky	7/06/2010	30/06/2010	1,940	
Perth Basin								
Garibaldi 2D S.S.	2D	On	EP 430, EP 454	Empire Oil	1/04/2011	12/04/2011	88	
Warro 3D S.S.	3D	On	EP 321 R3, EP 407 R1	Latent	16/03/2011	28/03/2011		92
Collie Rock Chip & Soil Sampling Survey	GEOL	On	GEP 10, GEP 11, GEP 12	Green Rock	5/07/2010	12/07/2010		

Class - Classification
2D - 2D Reflection, 3D - 3D Reflection, GRAVITY - Airborne Gravity, ESR - Electron Spin Resonance,
CSEM - Controlled Source Electromagnetic Survey, GEOL - Geological Sampling Survey

Table 6. Petroleum Wells in Western Australia Operating 2010–11 Fiscal Year

Well Name	Class	On Off	Title	Operator	Latitude		
Bonaparte Basin							
Durville 1	NFW	OFF	WA-403-P	Total	11	31	14.390
Laperouse 1	NFW	OFF	WA-403-P	Total	11	46	42.800
Browse Basin							
Concerto 2 ST1	EXT	OFF	WA-371-P	Shell	13	40	53.108
Omar 1	NFW	OFF	WA-397-P	Woodside	15	3	56.969
Canning Basin							
Backreef 1	NFW	ON	L 6 R1	Oil Basin Ltd	17	36	32.990
Leander 1 ST1	NFW	ON	L 8 R1	Buru	17	30	56.400
Nangu 1	NFW	ON	EP 471	Buru	19	10	30.200
Valhalla 2	NFW	ON	EP 371 R1	Buru	18	4	4.130
Carnarvon Basin							
ENE 02 RD1	DEV	OFF	WA-28-L	Woodside	21	28	53.958
ENE 03 ST1	DEV	OFF	WA-28-L	Woodside	21	28	52.842
Macedon 10	DEV	OFF	WA-42-L	BHPB	21	34	2.560
Macedon 7	DEV	OFF	WA-42-L	BHPB	21	33	50.800
Macedon 8A	DEV	OFF	WA-42-L	BHPB	21	34	17.467
Macedon 9	DEV	OFF	WA-42-L	BHPB	21	34	33.220
PLA 01 ST1	DEV	OFF	WA-34-L	BHPB	19	54	49.270
Stag 36H ST2	DEV	OFF	WA-15-L	Apache	20	17	43.860
Stag 37H BHC1	DEV	OFF	WA-15-L	Apache	20	17	23.91
Stybarrow 12H	DEV	OFF	WA-32-L	BHPB	21	28	11.323
VNB-5H L2 ST1	DEV	OFF	WA-28-L	Woodside	21	26	1.32
VNB-6H L3	DEV	OFF	WA-28-L	Woodside	21	26	2.138
Wandoo A6 H3	DEV	OFF	WA-14-L	Vermillion	20	8	14.608
Wandoo B12 ST3	DEV	OFF	WA-14-L	Vermillion	20	7	41.150
Wandoo B8 ST1	DEV	OFF	WA-14-L	Vermillion	20	7	41.150
Balnaves 3	EXT	OFF	WA-356-P	Apache	20	3	40.239
Balnaves 4	EXT	OFF	WA-356-P	Apache	20	3	40.239
Bravo 2	EXT	OFF	WA-390-P	Hess	20	2	3.524
Chandon 3	EXT	OFF	WA-268-P R2	Chevron	19	35	52.590
Chester 2	EXT	OFF	WA-390-P	Hess	20	28	48.220
Chrysaor 2	EXT	OFF	WA-15-R R1	Chevron	20	8	27.280
Laverda North 1	EXT	OFF	WA-36-R	Woodside	21	30	44.720
Laverda North 2	EXT	OFF	WA-36-R	Woodside	21	30	44.720
Mentorc 2	EXT	OFF	WA-390-P	Hess	20	29	0.344
Orthrus 2	EXT	OFF	WA-24-R R1	Chevron	20	6	22.300
Spar 2	EXT	OFF	WA-4-R R2	Apache	20	36	31.981
Stag 34	EXT	OFF	WA-15-L	Apache	20	17	3.286
Stag 35	EXT	OFF	WA-15-L	Apache	20	17	3.286
West Tryal Rocks 4A	EXT	OFF	WA-5-R R3	Chevron	20	14	9.630
Acme 1	NFW	OFF	WA-205-P R3	Chevron	20	12	27.097
Alaric 1	NFW	OFF	WA-434-P	Woodside	19	56	31.924
Artemis 1	NFW	OFF	WA-360-P	MEO	19	32	39.800
Carnarvon Basin cont.							
Balnaves Deep 1	NFW	OFF	WA-356-P	Apache	20	4	58.213
Barberry 1	NFW	OFF	TL/2 R1	Apache	21	18	13.519
Black Pearl 1	NFW	OFF	WA-42-L	BHPB	21	34	7.347

Longitude			Gnd Elev/ Water Depth	RT/ KB	Spud Date	TD Date	Rig Release Date
127	6	59.180	108	24.7	7/01/2011	2/03/2011	12/03/2011
127	18	22.400	122	24.7	14/03/2011	14/05/2011	25/05/2011
123	21	31.310	268	24.7	4/04/2010	1/08/2010	17/08/2010
121	17	32.155	378.82	26.2	19/03/2011	18/05/2011	29/05/2011
124	33	44.950	63.2	67.55	11/10/2010	27/10/2010	2/11/2010
124	14	19.5	38.5	43.6	8/07/2010	4/09/2010	8/09/2010
122	3	50.800	73	77	28/11/2010	5/12/2010	7/12/2010
124	46	4.200	110	115.8	6/06/2011		
113	59	17.693	521.3	22.9	6/05/2010	17/07/2010	5/08/2010
113	59	17.851	522.3	22.9	6/08/2010	15/09/2010	5/10/2010
114	10	8.640	179.7	22	14/08/2010	27/08/2010	14/12/2010
114	13	24.6	161.2	22	21/11/2010	1/12/2010	14/12/2010
114	11	46.992	168.7	22.2	17/10/2010	3/11/2010	14/12/2010
114	9	31.460	179	22	19/09/2010	23/09/2010	14/12/2010
115	7	54.530	829.1	22.3	4/10/2010	15/10/2010	14/11/2010
116	15	31.41	48.9	61.3	16/12/2010	21/01/2011	29/01/2011
116	16	30.99	48.9	61.3	31/10/2010	7/12/2010	29/01/2011
113	50	47.358	800.7	22.3	31/07/2010	17/08/2010	22/09/2010
114	2	0.215	392.9	22.9	2/03/2011	1/06/2011	
114	1	57.677	392	22.9	28/02/2011	3/05/2011	
116	25	22.431	54	39.44	10/10/2010	12/10/2010	18/10/2010
116	26	4.040	53.9	42.26	31/08/2010	3/09/2010	18/10/2010
116	26	4.040	54.2	42.26	23/09/2010	27/09/2010	18/10/2010
115	11	7.031	162	25	27/07/2010	27/08/2010	30/09/2010
115	11	7.031	162	25	15/09/2010	26/09/2010	30/09/2010
113	37	33.129	1,088.2	29	22/04/2011	2/05/2011	17/05/2011
114	9	22.560	1,207.7	22.3	2/03/2011	20/03/2011	1/04/2011
113	54	20.100	1,125.8	21.9	5/06/2011		
114	53	11.960	919.7	22.3	3/04/2011	29/04/2011	16/05/2011
113	51	46.827	808.5	32	9/12/2010	7/04/2011	23/04/2011
113	51	46.830	808.5	32	14/04/2011	15/04/2011	23/04/2011
113	44	22.350	1,134	29	12/03/2011	10/04/2011	19/04/2011
114	4	4.000	1,194	22	16/08/2010	1/12/2010	26/02/2011
114	54	22.098	112	25	2/10/2010	1/11/2010	29/11/2010
116	15	24.767	49.1	36.54	31/07/2010	6/08/2010	17/08/2010
116	15	24.767	49.1	36.54	9/08/2010	12/08/2010	17/08/2010
115	1	43.640	139.2	22.3	18/05/2011	22/06/2011	
114	49	8.941	877	22.3	18/06/2010	13/07/2010	26/07/2010
111	38	57.262	1,992.5	31.5	23/07/2010	17/08/2010	3/09/2010
115	31	50.900	425	25	25/11/2010	12/12/2010	26/12/2010
115	10	34.192	135.3	21.5	18/03/2011	16/04/2011	27/04/2011
115	11	40.157	16	38.5	12/07/2010	23/07/2010	28/07/2010
114	8	31.120	184	22.2	26/07/2010	3/08/2010	9/08/2010

Table 6. Petroleum Wells in Western Australia Operating 2010–11 Fiscal Year

Well Name	Class	On Off	Title	Operator	Latitude		
Camus 1	NFW	OFF	WA-404-P	Woodside	19	6	54.850
Chester 1 ST1	NFW	OFF	WA-390-P	Hess	20	28	44.22
Cimatti 1	NFW	OFF	WA-28-L	Woodside	21	26	43.596
Cimatti 2	NFW	OFF	WA-28-L	Woodside	21	26	43.596
Crusader 1	NFW	OFF	WA-35-L	Apache	21	23	49.475
Emersons 1	NFW	OFF	WA-356-P	Apache	20	4	25.282
Finucane South 1A	NFW	OFF	WA-191-P R5	Santos	19	18	17.220
Fullswing 1	NFW	OFF	WA-412-P	Japan Energy	19	23	15.385
Furness 1	NFW	OFF	WA-255-P R2	BHPB	21	24	17.838
Galahad 1	NFW	OFF	WA-363-P	Eni	17	46	1.190
Gawain 1	NFW	OFF	WA-362-P	Eni	18	10	22.160
La Rocca 1	NFW	OFF	WA-388-P	Apache	19	14	38.247
Larsen Deep 1	NFW	OFF	WA-404-P	Woodside	19	24	12.759
Laurel 1	NFW	OFF	TP/7 R3	Apache	21	12	50.701
Makybe Diva 1	NFW	OFF	WA-390-P	Hess	20	15	57.172
Martin 1	NFW	OFF	WA-404-P	Woodside	19	25	32.923
Moyet 1	NFW	OFF	WA-404-P	Woodside	19	14	57.317
Opel 1	NFW	OFF	WA-36-R	Woodside	21	30	50.741
Remy 1A CH1	NFW	OFF	WA-404-P	Woodside	19	23	58.224
The Grafter 1	NFW	OFF	WA-390-P	Hess	20	15	57.172
Tiberius 1	NFW	OFF	WA-434-P	Woodside	20	9	13.215
Xeres 1A	NFW	OFF	WA-34-L	Woodside	19	54	55.393
Zagreus 1	NFW	OFF	WA-40-L	Chevron	20	8	7.210
Zola 1 ST1	NFW	OFF	WA-290-P R1	Apache	20	48	40.833
Perth Basin							
Mondarra 6	DEV	ON	L 1 R1	APA	29	18	43.700
Mondarra 7	DEV	ON	L 1 R1	APA	29	18	43.720
Mondarra 8	DEV	ON	L 1 R1	APA	29	18	43.720
Warro 4	EXT	ON	EP 407 R1	Latent	30	10	18.500
Wolf 1	EXT	ON	EP 320 R3	Origin	29	29	1.690
Arrowsmith 2	NFW	ON	EP 413 R2	Norwest Energy	29	36	47.711
Dibblers 1	NFW	ON	EP 437	CalEnergy	29	6	33.900
Dunnart 1	NFW	ON	EP 437	CalEnergy	29	9	24.100
Red Gully 1	NFW	ON	EP 389 R1	Empire Oil	31	10	49.768
Redhill South 1	NFW	ON	TP/15 R1	Norwest Energy	29	17	47.570

Classification
DEV Development Well
EXT Extension Well
NFW New Field Wildcat
WIW Water Injector Well

Longitude			Gnd Elev/ Water Depth	RT/ KB	Spud Date	TD Date	Rig Release Date
114	16	23.120	1,348	31.5	27/03/2010	25/09/2010	4/10/2010
113	55	39.320	1,121	29	20/06/2010	27/08/2010	7/09/2010
113	58	15.444	547.4	22.9	1/11/2010	13/11/2010	30/11/2010
113	58	15.444	547.4	22.9	18/11/2010	21/11/2010	30/11/2010
114	1	21.327	428.1	21.5	11/02/2011	10/03/2011	16/03/2011
115	17	49.984	76.8	41.5	22/05/2011		
116	45	30.110	133.4	25	3/05/2011	23/05/2011	30/05/2011
116	18	12.796	133.8	22.2	19/12/2010	24/01/2011	7/02/2011
113	55	58.598	606.7	22.2	1/07/2010	13/07/2010	22/07/2010
115	44	57.240	1,576.5	25	25/04/2011	15/05/2011	26/05/2011
115	0	25.100	1,962.8	25	12/02/2011	12/04/2011	22/04/2011
115	41	10.667	407	21.5	30/04/2011	25/05/2011	6/06/2011
114	14	59.409	1,242.6	26.2	19/03/2010	18/08/2010	13/09/2010
115	7	22.036	22	38.4	12/06/2010	2/07/2010	10/07/2010
113	41	20.691	1,117.33	29	28/09/2010	6/10/2010	16/10/2010
114	22	34.051	1,342.8	32	14/12/2010	13/03/2011	24/03/2011
114	12	37.832	1,296.2	31.5	6/09/2010	27/11/2010	3/12/2010
113	50	32.524	841	31.5	6/12/2010		
114	18	42.811	1,293.3	26.2	6/10/2010	18/11/2010	23/12/2010
113	41	20.691	1,117.33	29	9/09/2010	24/09/2010	16/10/2010
111	35	41.467	1,657.8	31.5	16/06/2010	13/07/2010	21/07/2010
115	15	3.912	190.3	32	27/04/2011	20/05/2011	18/06/2011
114	6	58.760	1,189.3	28.7	27/05/2011	26/06/2011	
114	42	43.687	284.7	25	1/12/2010	9/04/2011	27/04/2011
115	7	8.370	79.19	86.96	13/09/2010	6/10/2010	14/10/2010
115	7	10.040	79.16	86.93	22/10/2010	12/11/2010	23/12/2010
115	7	10.040	79.16	86.3	18/11/2010	7/12/2010	23/12/2010
115	43	59.400	278.5	286.3	11/04/2011	5/05/2011	11/05/2011
115	9	45.460	60	67.77	18/07/2010	18/08/2010	2/09/2010
115	7	14.439	42	49.77	30/05/2011	18/06/2011	
114	54	21.800	14.8	18.3	21/01/2011	3/02/2011	8/02/2011
114	56	15.600	41.8	45.3	5/12/2010	11/01/2011	16/01/2011
115	49	34.763	176.58	184.35	6/01/2011	11/02/2011	2/03/2011
114	55	33.840	2.38	6.68	28/02/2011	19/03/2011	22/03/2011

Table 7. List of Petroleum and Geothermal Titles and Holders in Western Australia as at 1 July 2011

OFFSHORE PETROLEUM AND GREENHOUSE GAS STORAGE ACT 2006
Exploration Permit

Title	Registered Holders (* denotes Nominee)
WA-1-P R7	Apache Northwest Pty Ltd
	Santos Limited
WA-18-P R6	Bonaparte Gas & Oil Pty Limited
	Santos Limited
	* GDF SUEZ Bonaparte Pty Ltd
WA-28-P R7	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	CNOOC NWS Private Limited
	Chevron Australia Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Woodside Energy Ltd
WA-155-P R5	Apache Permits Pty Ltd
	BHP Billiton Petroleum (Australia) Pty Ltd
	Inpex Alpha Ltd
WA-191-P R5	Kufpec Australia Pty Ltd
	Nippon Oil Exploration (Dampier) Pty Ltd
	Santos Limited
	Tap (Shelfal) Pty Ltd
WA-192-P R5	Apache Northwest Pty Ltd
WA-202-P R4	Apache Northwest Pty Ltd
WA-205-P R3	Chevron (TAPL) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	* Chevron Australia Pty Ltd
WA-208-P R3	AGL Upstream Gas (MOS) Pty Limited
	Apache Northwest Pty Ltd
	Beach Energy Limited
	Eni Australia Limited
	Santos Limited
	Santos Offshore Pty Ltd
WA-209-P R3	Santos Offshore Pty Ltd
	* Apache Northwest Pty Ltd
WA-214-P R3	Santos (BOL) Pty Ltd
	* Apache Northwest Pty Ltd
WA-246-P R2	Kufpec Australia Pty Ltd
	Pan Pacific Petroleum (South Aust) Pty Ltd
	Santos Offshore Pty Ltd
	Tap (Harriet) Pty Ltd
	* Apache Northwest Pty Ltd
WA-253-P R2	Chevron (TAPL) Pty Ltd
	* Chevron Australia Pty Ltd
WA-254-P R2	Apache Northwest Pty Ltd
	First Australian Resources Limited
	Pan Pacific Petroleum NL
	Senex Energy Limited
	Sun Resources NL
WA-255-P R2	Woodside Energy Ltd
	* BHP Billiton Petroleum (Australia) Pty Ltd
WA-261-P R2	Apache Northwest Pty Ltd
	Bow Energy Ltd
	Strike Energy Limited
	Tap (Shelfal) Pty Ltd
WA-264-P R1	Beach Petroleum Limited
	Kufpec Australia Pty Ltd
	* Santos Offshore Pty Ltd
WA-268-P R2	Chevron (TAPL) Pty Ltd
	Chevron Australia Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Shell Development (Australia) Proprietary Limited
WA-269-P R2	Japan Australia LNG (MIMI) Pty Ltd
	Woodside Energy Ltd
WA-271-P R2	Mitsui E&P Australia Pty Limited
	* Woodside Energy Ltd
WA-274-P R1	Chevron Australia (WA-274-P) Pty Ltd
	Inpex Browse Ltd
	* Coveyork Pty Limited
WA-275-P R2	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	Chevron Australia Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Woodside Energy Ltd
WA-279-P R1	Eni Australia B.V.
WA-281-P R1	Beach Energy Limited
	Chevron Australia (WA-281-P) Pty Ltd
	Inpex Browse Ltd
	* Santos Offshore Pty Ltd
WA-285-P R2	Inpex Browse Ltd
	Total E & P Australia
WA-290-P R1	Nippon Oil Exploration (Dampier) Pty Ltd
	OMV Australia Pty Ltd
	Santos Offshore Pty Ltd
	Tap (Shelfal) Pty Ltd
	* Apache Northwest Pty Ltd
WA-302-P R1	BHP Billiton Petroleum (North West Shelf) Pty Ltd
WA-313-P R1	Eni Australia B.V.
WA-314-P	ConocoPhillips (Browse Basin) Pty Ltd
	Karoon Gas Browse Basin Pty Ltd
WA-315-P	ConocoPhillips (Browse Basin) Pty Ltd
	Karoon Gas Browse Basin Pty Ltd
WA-320-P	Tap (Shelfal) Pty Ltd
	* OMV Australia Pty Ltd
WA-323-P R1	Octanex N.L.
	Santos Offshore Pty Ltd
	Strata Resources Pty Ltd
WA-329-P	United Oil & Gas Pty Ltd
WA-330-P R1	Octanex N.L.
	Santos Offshore Pty Ltd
	Strata Resources Pty Ltd
WA-334-P R1	Tap (Harriet) Pty Ltd
	* Apache Northwest Pty Ltd
WA-335-P	BHP Billiton Petroleum (North West Shelf) Pty Ltd

Table 7. List of Petroleum and Geothermal Titles and Holders in Western Australia as at 1 July 2011

	Kufpec Australia Pty Ltd
	* Apache Northwest Pty Ltd
WA-341-P R1	Inpex Browse Ltd
	Total E & P Australia
WA-342-P R1	Coldron Pty Ltd
	Cornea Energy Pty Ltd
	Cornea Oil & Gas Pty Ltd
	Cornea Petroleum Pty Ltd
	Cornea Resources Pty Ltd
WA-343-P	Inpex Browse Ltd
	Total E & P Australia
WA-344-P R1	Inpex Browse Ltd
	Total E & P Australia
WA-346-P R1	BHP Billiton Petroleum (North West Shelf) Pty Ltd
WA-347-P R1	Kansai Electric Power Australia Pty Ltd
	Tokyo Gas Pluto Pty Ltd
	Woodside Burrup Pty Ltd
WA-348-P R1	Kansai Electric Power Australia Pty Ltd
	Tokyo Gas Pluto Pty Ltd
	* Woodside Burrup Pty Ltd
WA-350-P R1	Kansai Electric Power Australia Pty Ltd
	Tokyo Gas Pluto Pty Ltd
	Woodside Burrup Pty Ltd
WA-351-P R1	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	Tap (Shelfal) Pty Ltd
WA-355-P	Apache Northwest Pty Ltd
WA-356-P	Apache Julimar Pty Ltd
	Kufpec Australia (Julimar) Pty Ltd
WA-357-P	Inpex Alpha Ltd
	* Apache Northwest Pty Ltd
WA-358-P	OMV Australia Pty Ltd
WA-359-P	Exoil Limited
	* Cue Exploration Pty Ltd
WA-360-P	Cue Exploration Pty Ltd
	North West Shelf Exploration Pty Ltd
	Petrobras International Braspetro BV - PIB BV
	Rankin Trend Pty Ltd
WA-361-P R1	Cue Exploration Pty Ltd
	Mineralogy Pty Ltd
	North West Shelf Exploration Pty Ltd
WA-362-P	Eni Australia Limited
	Exmouth Exploration Pty Ltd
	Octanex N.L.
	Strata Resources N.L.
	* OMV Australia Pty Ltd
WA-363-P	Eni Australia Limited
	Exmouth Exploration Pty Ltd
	Octanex N.L.
	Strata Resources N.L.
	* OMV Australia Pty Ltd
WA-364-P	Chevron Australia (WA-364-P) Pty Ltd
	Shell Development (Australia) Proprietary Limited
WA-365-P	Chevron Australia (WA-365-P) Pty Ltd
	Shell Development (Australia) Proprietary Limited
WA-366-P	Chevron Australia (WA-366-P) Pty Ltd
	Shell Development (Australia) Proprietary Limited
WA-367-P	Chevron Australia (WA-367-P) Pty Ltd
	Shell Development (Australia) Proprietary Limited
WA-371-P	Shell Development (Australia) Proprietary Limited
WA-374-P	Mobil Australia Resources Company Pty Limited
	Shell Development (Australia) Proprietary Limited
	* Chevron Australia (WA-374-P) Pty Ltd
WA-375-P	Goldsborough Energy Pty Ltd
	Torrens Oil & Gas Pty Ltd
WA-376-P	Goldsborough Energy Pty Ltd
	Torrens Oil & Gas Pty Ltd
WA-377-P	Nexus Energy WA377P Pty Ltd
WA-378-P	Mitsui E&P Australia Pty Limited
	PTTEP Australasia (Ashmore Cartier) Pty Ltd
	Toyota Tsusho Gas E&P Browse Pty Ltd
	Woodside Energy Ltd
WA-379-P	Arcadia Petroleum Limited
	Cathay Petroleum International Limited
WA-380-P	Arcadia Petroleum Limited
	Cathay Petroleum International Limited
WA-381-P	Emphazise Pty Ltd
	Lempika Pty Ltd
	Westralian Petroleum Pty Ltd
WA-382-P	Emphazise Pty Ltd
	Lempika Pty Ltd
	Westralian Petroleum Pty Ltd
WA-383-P	Shell Development (Australia) Proprietary Limited
	* Chevron Australia (WA-383-P) Pty Ltd
WA-384-P	Shell Development (Australia) Proprietary Limited
WA-385-P	Shell Development (Australia) Proprietary Limited
WA-386-P	Eni Australia Limited
	Exmouth Exploration Pty Ltd
	* OMV Australia Pty Ltd
WA-387-P	Eni Australia Limited
	Exmouth Exploration Pty Ltd
	* OMV Australia Pty Ltd
WA-388-P	Bharat PetroResources Limited
	Gujarat State Petroleum Corporation Limited
	Hindustan Petroleum Corporation Ltd
	Oilex Limited
	Sasol Petroleum Australia Ltd
	Videocon Industries Ltd
WA-389-P	Cue Exploration Pty Ltd
	Woodside Burrup Pty Ltd
WA-390-P	Hess Exploration Australia Pty Limited
WA-391-P	OMV Australia Pty Ltd
WA-392-P	Chevron Australia (WA-392-P) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Shell Development (Australia) Proprietary Limited

Table 7. List of Petroleum and Geothermal Titles and Holders in Western Australia as at 1 July 2011

WA-394-P	Shell Development (Australia) Proprietary Limited
WA-396-P	Mitsui E&P Australia Pty Limited
	PTTEP Australasia (Ashmore Cartier) Pty Ltd
	Toyota Tsusho Gas E&P Browse Pty Ltd
	Woodside Energy Ltd
WA-397-P	Mitsui E&P Australia Pty Limited
	PTTEP Australasia (Ashmore Cartier) Pty Ltd
	Toyota Tsusho Gas E&P Browse Pty Ltd
	Woodside Energy Ltd
WA-398-P	ConocoPhillips (Browse Basin) Pty Ltd
	Karoon Gas Browse Basin Pty Ltd
WA-399-P	Carnarvon Petroleum Limited
	Jacka Resources Limited
	Rialto Energy Limited
	* Apache Northwest Pty Ltd
WA-401-P	Woodside Energy Ltd
WA-402-P	Petronas Carigali (Australia) Pty Ltd
	Total E & P Australia
WA-403-P	Petronas Carigali (Australia) Pty Ltd
	Total E & P Australia
WA-404-P	Woodside Energy Ltd
WA-405-P	Reliance Exploration & Production DMCC
WA-406-P	CNOOC Australia E&P Pty Ltd
WA-407-P	Goldsborough Energy Pty Ltd
WA-408-P	Total E & P Australia
WA-409-P	Cue Exploration Pty Ltd
	Rankin Trend Pty Ltd
WA-410-P	Chevron Australia (WA-410-P) Pty Ltd
	Inpex Browse Ltd
	Santos Offshore Pty Ltd
WA-411-P	Beach Energy Limited
	Inpex Browse Ltd
	Santos Offshore Pty Ltd
WA-412-P	Japan Energy E&P Australia Pty Ltd
WA-413-P	Hunt Oil Australia Permit 413 Holding Company Pty Ltd
WA-414-P	Mitsui E&P Australia Pty Limited
	* Hunt Oil Australia Permit 414 Holding Company Pty Ltd
WA-415-P	Woodside Energy Ltd
WA-416-P	Woodside Energy Ltd
WA-417-P	Woodside Energy Ltd
WA-418-P	Finder Exploration Pty Ltd
	* Apache Northwest Pty Ltd
WA-419-P	Emerald Gas Pty Ltd
WA-420-P	Goldsborough Energy Pty Ltd
WA-421-P	Goldsborough Energy Pty Ltd
WA-422-P	National Oil Corporation Pty Ltd
WA-423-P	Diamond Resources Australia Pty Ltd
	PTTEP Australia Offshore Pty Ltd
	* Murphy Australia Oil Pty Ltd
WA-424-P	IPM WA 424P Pty Ltd
WA-425-P	Hunt Oil Australia Permit 425 Holding Company Pty Ltd
	Mitsui E&P Australia Pty Limited
	SK Energy Co., Ltd
WA-426-P	Apache Northwest Pty Ltd
WA-427-P	Apache Northwest Pty Ltd
	Kufpec Australia Pty Ltd
WA-428-P	Mitsui E&P Australia Pty Limited
	Woodside Energy Ltd
WA-429-P	Mitsui E&P Australia Pty Limited
	Woodside Energy Ltd
WA-430-P	Mitsui E&P Australia Pty Limited
	Woodside Energy Ltd
WA-431-P	Hunt Oil Australia Permit 431 Holding Company Pty Ltd
	Mitsui E&P Australia Pty Limited
	SK Energy Co., Ltd
WA-432-P	Mitsui E&P Australia Pty Limited
	Woodside Energy Ltd
WA-433-P	Mitsui E&P Australia Pty Limited
	Woodside Energy Ltd
WA-434-P	Woodside Energy Ltd
WA-435-P	Carnarvon Petroleum Limited
	Finder Exploration Pty Ltd
WA-436-P	Carnarvon Petroleum Limited
	Finder Exploration Pty Ltd
WA-437-P	Carnarvon Petroleum Limited
	Finder Exploration Pty Ltd
WA-438-P	Carnarvon Petroleum Limited
	Finder Exploration Pty Ltd
WA-439-P	Chevron Australia (WA-439-P) Pty Ltd
	Shell Development (Australia) Proprietary Limited
WA-440-P	Goldsborough Energy Pty Ltd
WA-441-P	Goldsborough Energy Pty Ltd
WA-442-P	Ansbachall Pty Limited
	Tangiers Petroleum Limited
WA-443-P	Carnarvon Petroleum Limited
WA-444-P	Chevron Australia (WA-444-P) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Shell Development (Australia) Proprietary Limited
WA-445-P	Finder No 2 Pty Limited
WA-446-P	Finder No 1 Pty Limited
WA-447-P	Mitsui E&P Australia Pty Limited
	Woodside Energy Ltd
WA-448-P	Japan Australia LNG (MIMI) Pty Ltd
	Woodside Energy Ltd
WA-449-P	Mitsui E&P Australia Pty Limited
	Woodside Energy Ltd
WA-450-P	Finder No 4 Pty Limited
	* Apache Northwest Pty Ltd
WA-451-P	Woodside Energy Ltd
WA-452-P	Riverina Energy Ltd
WA-453-P	Apache Energy Limited
WA-454-P	MEO Australia Ltd

Table 7. List of Petroleum and Geothermal Titles and Holders in Western Australia as at 1 July 2011

OFFSHORE PETROLEUM AND GREENHOUSE GAS STORAGE ACT 2006 Infrastructure Licence	
Title	Registered Holders (* denotes Nominee)
WA-1-IL	Kansai Electric Power Australia Pty Ltd
	Tokyo Gas Pluto Pty Ltd
	Woodside Burrup Pty Ltd
WA-2-IL	Shell Development (Australia) Proprietary Limited

OFFSHORE PETROLEUM AND GREENHOUSE GAS STORAGE ACT 2006 Pipeline Licence	
Title	Registered Holders (* denotes Nominee)
WA-1-PL	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	Chevron Australia Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	* Woodside Energy Ltd
WA-2-PL	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	Chevron Australia Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	* Woodside Energy Ltd
WA-3-PL	Inpex Alpha Ltd
	Mobil Exploration & Producing Australia Pty Ltd
	* BHP Billiton Petroleum (Australia) Pty Ltd
WA-4-PL	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	Chevron Australia Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	* Woodside Energy Ltd
WA-5-PL	Apache East Spar Pty Ltd
	Apache Kersail Pty Ltd
	Santos (BOL) Pty Ltd
	* Apache Oil Australia Pty Ltd
WA-6-PL	Apache Northwest Pty Ltd
	Santos (GLOBE) Pty Ltd
	Santos Offshore Pty Ltd
WA-7-PL	Apache Northwest Pty Ltd
	Santos Limited
WA-8-PL	ConocoPhillips Pipeline Australia Pty Ltd
	Eni Gas & Power LNG Australia B.V.
	Inpex DLNGPL Pty Ltd
	Santos Timor Sea Pipeline Pty Ltd
	TEPCO Darwin LNG Pty Ltd
	Tokyo Gas Darwin LNG Pty Ltd
WA-9-PL	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	Chevron Australia Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	* Woodside Energy Ltd
WA-10-PL	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	Chevron Australia Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	* Woodside Energy Ltd
WA-11-PL	Apache Northwest Pty Ltd
	Santos (BOL) Pty Ltd
WA-12-PL	ARC (Offshore PB) Limited
	AWE Oil (Western Australia) Pty Ltd
	Cieco Energy Australia Pty Ltd
	Roc Oil (WA) Pty Limited
WA-13-PL	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	Chevron Australia Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Woodside Energy Ltd
WA-14-PL	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	Chevron Australia Holdings Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Woodside Energy Ltd
WA-15-PL	Eni Australia B.V.
WA-16-PL	Kansai Electric Power Australia Pty Ltd
	Tokyo Gas Pluto Pty Ltd
	Woodside Burrup Pty Ltd
WA-17-PL	Kansai Electric Power Australia Pty Ltd
	Tokyo Gas Pluto Pty Ltd
	Woodside Burrup Pty Ltd
WA-18-PL	Apache Northwest Pty Ltd
	Santos Offshore Pty Ltd
WA-19-PL	Chevron (TAPL) Pty Ltd
	Chevron Australia Pty Ltd
	Chubu Electric Power Gorgon Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Osaka Gas Gorgon Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Tokyo Gas Gorgon Pty Ltd
WA-20-PL	Chevron (TAPL) Pty Ltd
	Chevron Australia Pty Ltd
	Chubu Electric Power Gorgon Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Osaka Gas Gorgon Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Tokyo Gas Gorgon Pty Ltd
WA-21-PL	Apache East Spar Pty Ltd
	Apache Kersail Pty Ltd
	Apache Oil Australia Pty Ltd

Table 7. List of Petroleum and Geothermal Titles and Holders in Western Australia as at 1 July 2011

	Santos (BOL) Pty Ltd
WA-22-PL	Inpex Browse Ltd
	Total E & P Australia

OFFSHORE PETROLEUM AND GREENHOUSE GAS STORAGE ACT 2006
Production Licence

Title	Registered Holders (* denotes Nominee)
WA-1-L R1	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	CNOOC NWS Private Limited
	Chevron Australia Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Woodside Energy Ltd
WA-2-L R1	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	CNOOC NWS Private Limited
	Chevron Australia Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Woodside Energy Ltd
WA-3-L R1	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	CNOOC NWS Private Limited
	Chevron Australia Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Woodside Energy Ltd
WA-4-L R1	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	CNOOC NWS Private Limited
	Chevron Australia Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Woodside Energy Ltd
WA-5-L R1	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	CNOOC NWS Private Limited
	Chevron Australia Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Woodside Energy Ltd
WA-6-L R1	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	CNOOC NWS Private Limited
	Chevron Australia Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Woodside Energy Ltd
WA-8-L R1	Kufpec Australia Pty Ltd
	Tap (Shelfal) Pty Ltd
	* Santos Limited
WA-9-L	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	CNOOC NWS Private Limited
	Chevron Australia Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Woodside Energy Ltd
WA-10-L	Inpex Alpha Ltd
	Mobil Exploration & Producing Australia Pty Ltd
	* BHP Billiton Petroleum (Australia) Pty Ltd
WA-11-L	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	CNOOC NWS Private Limited
	Chevron Australia Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Woodside Energy Ltd
WA-12-L	Mobil Australia Resources Company Pty Limited
	* BHP Billiton Petroleum (Australia) Pty Ltd
WA-13-L	Apache East Spar Pty Ltd
	Apache Kersail Pty Ltd
	Santos (BOL) Pty Ltd
	* Apache Oil Australia Pty Ltd
WA-14-L	Vermilion Oil & Gas Australia Pty Ltd
WA-15-L	Santos Offshore Pty Ltd
	* Apache Northwest Pty Ltd
WA-16-L	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	CNOOC NWS Private Limited
	Chevron Australia Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Woodside Energy Ltd
WA-17-L	ConocoPhillips Australia Gas Holdings Pty Ltd
	* Mobil Australia Resources Company Pty Limited
WA-18-L	Talisman Oil & Gas (Australia) Pty Ltd
WA-20-L	Apache Northwest Pty Ltd
	Santos Limited
WA-22-L	Mobil Australia Resources Company Pty Limited
	Tap West Pty Ltd
	* Eni Australia Limited
WA-23-L	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	CNOOC NWS Private Limited
	Chevron Australia Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Woodside Energy Ltd
WA-24-L	BHP Billiton Petroleum (North West Shelf) Pty Ltd

Table 7. List of Petroleum and Geothermal Titles and Holders in Western Australia as at 1 July 2011

	BP Developments Australia Pty Ltd
	CNOOC NWS Private Limited
	Chevron Australia Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Woodside Energy Ltd
WA-25-L	Mobil Australia Resources Company Pty Limited
	Tap West Pty Ltd
	* Eni Australia Limited
WA-26-L	Kufpec Australia Pty Ltd
	Nippon Oil Exploration (Dampier) Pty Ltd
	Woodside Energy Ltd
	* Santos Limited
WA-27-L	Kufpec Australia Pty Ltd
	Nippon Oil Exploration (Dampier) Pty Ltd
	Woodside Energy Ltd
	* Santos Limited
WA-28-L	Mitsui E&P Australia Pty Limited
	* Woodside Energy Ltd
WA-29-L	Apache Northwest Pty Ltd
	Santos (BOL) Pty Ltd
WA-30-L	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	CNOOC NWS Private Limited
	Chevron Australia Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Woodside Energy Ltd
WA-31-L	ARC (Offshore PB) Limited
	AWE Oil (Western Australia) Pty Ltd
	Cieco Energy Australia Pty Ltd
	Roc Oil (WA) Pty Limited
WA-32-L	BHP Billiton Petroleum (Australia) Pty Ltd
	Woodside Energy Ltd
WA-33-L	Eni Australia B.V.
WA-34-L	Kansai Electric Power Australia Pty Ltd
	Tokyo Gas Pluto Pty Ltd
	Woodside Burrup Pty Ltd
WA-35-L	Apache Permits Pty Ltd
	Inpex Alpha Ltd
WA-36-L	Chevron (TAPL) Pty Ltd
	Chevron Australia Pty Ltd
	Chubu Electric Power Gorgon Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Osaka Gas Gorgon Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Tokyo Gas Gorgon Pty Ltd
WA-37-L	Chevron (TAPL) Pty Ltd
	Chevron Australia Pty Ltd
	Chubu Electric Power Gorgon Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Osaka Gas Gorgon Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Tokyo Gas Gorgon Pty Ltd
WA-38-L	Chevron (TAPL) Pty Ltd
	Chevron Australia Pty Ltd
	Chubu Electric Power Gorgon Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Osaka Gas Gorgon Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Tokyo Gas Gorgon Pty Ltd
WA-39-L	BP Exploration (Alpha) Ltd
	Chevron (TAPL) Pty Ltd
	Chevron Australia Pty Ltd
	Chubu Electric Power Gorgon Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Osaka Gas Gorgon Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Tokyo Gas Gorgon Pty Ltd
WA-40-L	BP Exploration (Alpha) Ltd
	Chevron (TAPL) Pty Ltd
	Chevron Australia Pty Ltd
	Chubu Electric Power Gorgon Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Osaka Gas Gorgon Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Tokyo Gas Gorgon Pty Ltd
WA-41-L	Apache Northwest Pty Ltd
	Santos Offshore Pty Ltd
WA-42-L	Apache PVG Pty Ltd
	BHP Billiton Petroleum (Australia) Pty Ltd
WA-43-L	Apache PVG Pty Ltd
	Inpex Alpha Ltd
	* BHP Billiton Petroleum (Australia) Pty Ltd
WA-44-L	Shell Development (Australia) Proprietary Limited

OFFSHORE PETROLEUM AND GREENHOUSE GAS STORAGE ACT 2006
Retention Lease

Title	Registered Holders (* denotes Nominee)
WA-1-R R4	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	* Esso Australia Resources Pty Ltd
WA-4-R R2	Apache East Spar Pty Ltd
	Apache Kersail Pty Ltd
	Apache Oil Australia Pty Ltd
	Santos Offshore Pty Ltd
WA-5-R R3	Chevron (TAPL) Pty Ltd
	Chevron Australia Pty Ltd
	Chubu Electric Power Gorgon Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Osaka Gas Gorgon Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Tokyo Gas Gorgon Pty Ltd
WA-6-R R2	Bonaparte Gas & Oil Pty Limited

Table 7. List of Petroleum and Geothermal Titles and Holders in Western Australia as at 1 July 2011

	GDF SUEZ Bonaparte Pty Ltd
	Origin Energy Bonaparte Pty Limited
	Santos Limited
WA-7-R R2	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	CNOOC NWS Private Limited
	Chevron Australia Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	* Woodside Energy Ltd
WA-9-R R1	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	CNOOC NWS Private Limited
	Chevron Australia Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Woodside Energy Ltd
WA-10-R R1	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	CNOOC NWS Private Limited
	Chevron Australia Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Woodside Energy Ltd
WA-14-R R1	Chevron (TAPL) Pty Ltd
	Chevron Australia Pty Ltd
	Chubu Electric Power Gorgon Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Osaka Gas Gorgon Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Tokyo Gas Gorgon Pty Ltd
WA-15-R R1	Chevron (TAPL) Pty Ltd
	Chevron Australia Pty Ltd
	Chubu Electric Power Gorgon Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Osaka Gas Gorgon Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Tokyo Gas Gorgon Pty Ltd
WA-16-R R1	Chevron (TAPL) Pty Ltd
	Chevron Australia Pty Ltd
	Shell Development (Australia) Proprietary Limited
WA-17-R R1	Chevron (TAPL) Pty Ltd
	* Chevron Australia Pty Ltd
WA-19-R R1	Chevron (TAPL) Pty Ltd
	Chevron Australia Pty Ltd
	Chubu Electric Power Gorgon Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Osaka Gas Gorgon Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Tokyo Gas Gorgon Pty Ltd
WA-20-R R1	Chevron (TAPL) Pty Ltd
	Chevron Australia Pty Ltd
	Chubu Electric Power Gorgon Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Osaka Gas Gorgon Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Tokyo Gas Gorgon Pty Ltd
WA-21-R R1	Chevron (TAPL) Pty Ltd
	Chevron Australia Pty Ltd
	Chubu Electric Power Gorgon Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Osaka Gas Gorgon Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Tokyo Gas Gorgon Pty Ltd
WA-22-R R1	BP Exploration (Alpha) Ltd
	Chevron (TAPL) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Shell Development (Australia) Proprietary Limited
	* Chevron Australia Pty Ltd
WA-23-R R1	BP Exploration (Alpha) Ltd
	Chevron (TAPL) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Shell Development (Australia) Proprietary Limited
	* Chevron Australia Pty Ltd
WA-24-R R1	BP Exploration (Alpha) Ltd
	Chevron (TAPL) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Shell Development (Australia) Proprietary Limited
	* Chevron Australia Pty Ltd
WA-27-R R1	Bonaparte Gas & Oil Pty Limited
	Santos Limited
	* GDF SUEZ Bonaparte Pty Ltd
WA-28-R R1	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	Chevron Australia Pty Ltd
	Shell Development (Australia) Proprietary Limited
	* Woodside Energy Ltd
WA-29-R R1	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	Chevron Australia Pty Ltd
	Shell Development (Australia) Proprietary Limited
	* Woodside Energy Ltd
WA-30-R R1	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	Chevron Australia Pty Ltd
	Shell Development (Australia) Proprietary Limited
	* Woodside Energy Ltd
WA-31-R R1	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	Chevron Australia Pty Ltd
	Shell Development (Australia) Proprietary Limited
	* Woodside Energy Ltd
WA-32-R R1	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	Chevron Australia Pty Ltd
	Shell Development (Australia) Proprietary Limited

Table 7. List of Petroleum and Geothermal Titles and Holders in Western Australia as at 1 July 2011

	* Woodside Energy Ltd
WA-33-R R1	Apache Oil Australia Pty Ltd
	Pan Pacific Petroleum (South Aust) Pty Ltd
	Santos (BOL) Pty Ltd
	Tap (Shelfal) Pty Ltd
	WM Petroleum Limited
WA-34-R R1	Encana International (Australia) Pty Ltd
	Eni Australia B.V.
	SK Energy Co., Ltd
	Tap (Shelfal) Pty Ltd
WA-35-R	Japan Australia LNG (MIMI) Pty Ltd
	Woodside Energy Ltd
WA-36-R	Mitsui E&P Australia Pty Limited
	* Woodside Energy Ltd
WA-37-R	Inpex Browse Ltd
	Total E & P Australia
WA-38-R	Apache Northwest Pty Ltd
	Santos Offshore Pty Ltd
WA-39-R	Chevron (TAPL) Pty Ltd
	Chevron Australia Pty Ltd

PETROLEUM (SUBMERGED LANDS) ACT 1982
Exploration Permit

Title	Registered Holders (* denotes Nominee)
TP/7 R3	Apache Oil Australia Pty Ltd
	Pan Pacific Petroleum (South Aust) Pty Ltd
	Santos (BOL) Pty Ltd
	Tap (Shelfal) Pty Ltd
TP/8 R3	Apache Northwest Pty Ltd
	Kufpec Australia Pty Ltd
	Tap (Harriet) Pty Ltd
TP/15 R1	Bharat PetroResources Limited
	* Westranch Holdings Pty Ltd
TP/23	Apache Northwest Pty Ltd
TP/24	Emerald Gas Pty Ltd

PETROLEUM (SUBMERGED LANDS) ACT 1982
Pipeline Licence

Title	Registered Holders (* denotes Nominee)
TPL/1 R1	Kufpec Australia Pty Ltd
	Tap (Harriet) Pty Ltd
	* Apache Northwest Pty Ltd
TPL/2 R1	Kufpec Australia Pty Ltd
	Tap (Harriet) Pty Ltd
	* Apache Northwest Pty Ltd
TPL/3 R1	Apache Oil Australia Pty Ltd
	Pan Pacific Petroleum (South Aust) Pty Ltd
	Santos (BOL) Pty Ltd
	Tap (Shelfal) Pty Ltd
TPL/4 R1	Apache Oil Australia Pty Ltd
	Pan Pacific Petroleum (South Aust) Pty Ltd
	Santos (BOL) Pty Ltd
	Tap (Shelfal) Pty Ltd
TPL/5 R1	Kufpec Australia Pty Ltd
	Tap (Harriet) Pty Ltd
	* Apache Northwest Pty Ltd
TPL/6 R1	Chevron (TAPL) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Santos Offshore Pty Ltd
	* Chevron Australia Pty Ltd
TPL/7 R2	Apache Oil Australia Pty Ltd
	Pan Pacific Petroleum (South Aust) Pty Ltd
	Santos (BOL) Pty Ltd
	Tap (Shelfal) Pty Ltd
TPL/8	Kufpec Australia Pty Ltd
	Tap (Harriet) Pty Ltd
	* Apache Northwest Pty Ltd
TPL/9 R1	Chevron (TAPL) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Santos Offshore Pty Ltd
	* Chevron Australia Pty Ltd
TPL/10	Inpex Alpha Ltd
	Mobil Exploration & Producing Australia Pty Ltd
	* BHP Billiton Petroleum (Australia) Pty Ltd
TPL/11	Chevron (TAPL) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Santos Offshore Pty Ltd
	* Chevron Australia Pty Ltd
TPL/12	Apache East Spar Pty Ltd
	Apache Kersail Pty Ltd
	Santos (BOL) Pty Ltd
	* Apache Oil Australia Pty Ltd
TPL/13	Apache East Spar Pty Ltd
	Apache Kersail Pty Ltd
	Apache Northwest Pty Ltd
	Apache Oil Australia Pty Ltd
	Kufpec Australia Pty Ltd
	Santos (BOL) Pty Ltd
	Tap (Harriet) Pty Ltd
TPL/14	Kufpec Australia Pty Ltd
	Tap (Harriet) Pty Ltd
	* Apache Northwest Pty Ltd
TPL/15	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	Chevron Australia Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	* Woodside Energy Ltd
TPL/16	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	Chevron Australia Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	* Woodside Energy Ltd
TPL/17	Apache Northwest Pty Ltd
	Santos (BOL) Pty Ltd

Table 7. List of Petroleum and Geothermal Titles and Holders in Western Australia as at 1 July 2011

TPL/18	ARC (Offshore PB) Limited
	AWE Oil (Western Australia) Pty Ltd
	Cieco Energy Australia Pty Ltd
	Roc Oil (WA) Pty Limited
TPL/19	Kansai Electric Power Australia Pty Ltd
	Tokyo Gas Pluto Pty Ltd
	Woodside Burrup Pty Ltd
TPL/20	Apache Northwest Pty Ltd
	Santos Offshore Pty Ltd
TPL/21	Chevron (TAPL) Pty Ltd
	Chubu Electric Power Gorgon Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Osaka Gas Gorgon Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Tokyo Gas Gorgon Pty Ltd
TPL/22	Chevron (TAPL) Pty Ltd
	Chubu Electric Power Gorgon Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Osaka Gas Gorgon Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Tokyo Gas Gorgon Pty Ltd

PETROLEUM (SUBMERGED LANDS) ACT 1982
Production Licence

Title	Registered Holders (* denotes Nominee)
TL/1 R1	Kufpec Australia Pty Ltd
	Tap (Harriet) Pty Ltd
	* Apache Northwest Pty Ltd
TL/2 R1	Apache Oil Australia Pty Ltd
	Pan Pacific Petroleum (South Aust) Pty Ltd
	Santos (BOL) Pty Ltd
	Tap (Shelfal) Pty Ltd
TL/3 R1	Chevron (TAPL) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Santos Offshore Pty Ltd
	* Chevron Australia Pty Ltd
TL/4 R1	Chevron (TAPL) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Santos Offshore Pty Ltd
	* Chevron Australia Pty Ltd
TL/5	Kufpec Australia Pty Ltd
	Tap (Harriet) Pty Ltd
	* Apache Northwest Pty Ltd
TL/6	Kufpec Australia Pty Ltd
	Tap (Harriet) Pty Ltd
	* Apache Northwest Pty Ltd
TL/7	Chevron (TAPL) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Santos Offshore Pty Ltd
	* Chevron Australia Pty Ltd
TL/8	Kufpec Australia Pty Ltd
	Tap (Harriet) Pty Ltd
	* Apache Northwest Pty Ltd
TL/9	Kufpec Australia Pty Ltd
	Tap (Harriet) Pty Ltd
	* Apache Northwest Pty Ltd

PETROLEUM (SUBMERGED LANDS) ACT 1982
Retention Lease

Title	Registered Holders (* denotes Nominee)
TR/1 R2	Kufpec Australia Pty Ltd
	Tap (Harriet) Pty Ltd
	* Apache Northwest Pty Ltd
TR/2 R1	Kufpec Australia Pty Ltd
	Tap (Harriet) Pty Ltd
	* Apache Northwest Pty Ltd
TR/3 R1	Apache Northwest Pty Ltd
TR/4 R1	Chevron (TAPL) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Santos Offshore Pty Ltd
	* Chevron Australia Pty Ltd
TR/5 R1	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	Chevron Australia Pty Ltd
	Shell Development (Australia) Proprietary Limited
	* Woodside Energy Ltd
TR/6	Chevron (TAPL) Pty Ltd
	Chevron Australia Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Santos Offshore Pty Ltd

PETROLEUM AND GEOTHERMAL ENERGY RESOURCES ACT 1967
Access Authority to Deviated Well

Title	Registered Holders (* denotes Nominee)
ADW 1/10-1	Arc Energy Limited
ADW 8/90-1	Chevron (TAPL) Pty Ltd
ADW 12/91-2	Kufpec Australia Pty Ltd
ADW 10/92-3	Kufpec Australia Pty Ltd
ADW 8/90-1	Mobil Australia Resources Company Pty Limited
ADW 1/10-1	Origin Energy Developments Pty Limited
ADW 8/90-1	Santos Offshore Pty Ltd
ADW 10/92-3	Tap (Harriet) Pty Ltd
ADW 12/91-2	Tap (Harriet) Pty Ltd
ADW 1/10-1	Westranch Holdings Pty Ltd
ADW 12/91-2	* Apache Northwest Pty Ltd
ADW 10/92-3	* Apache Northwest Pty Ltd
ADW 8/90-1	* Chevron Australia Pty Ltd

PETROLEUM AND GEOTHERMAL ENERGY RESOURCES ACT 1967
Drilling Reservation

Title	Registered Holders (* denotes Nominee)
DR 9	Backreef Oil Limited
DR 11	Westralian Gas and Power Limited

Table 7. List of Petroleum and Geothermal Titles and Holders in Western Australia as at 1 July 2011

PETROLEUM AND GEOTHERMAL ENERGY RESOURCES ACT 1967
Exploration Permit

Title	Registered Holders (* denotes Nominee)
EP 61 R7	Chevron (TAPL) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Santos Offshore Pty Ltd
	* Chevron Australia Pty Ltd
EP 62 R7	Chevron (TAPL) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Santos Offshore Pty Ltd
	* Chevron Australia Pty Ltd
EP 104 R5	Arc Energy Limited
	First Australian Resources Limited
	Gulliver Productions Pty Ltd
	Indigo Oil Pty Ltd
	Pancontinental Oil & Gas NL
	Phoenix Resources PLC
EP 110 R4	Pancontinental Oil & Gas NL
	Strike Energy Limited
EP 129 R5	Buru Energy Limited
EP 307 R5	Kufpec Australia Pty Ltd
	Tap (Harriet) Pty Ltd
	* Apache Northwest Pty Ltd
EP 320 R3	ARC (Beharra Springs) Pty Ltd
	* Origin Energy Developments Pty Limited
EP 321 R3	Latent Petroleum Pty Ltd
EP 325 R3	Advent Energy Ltd
	Bow Energy Ltd
	Rough Range Oil Pty Ltd
	Strike Energy Limited
EP 357 R3	Chevron (TAPL) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Santos Offshore Pty Ltd
	* Chevron Australia Pty Ltd
EP 358 R2	Apache Northwest Pty Ltd
	Kufpec Australia Pty Ltd
	Tap (Harriet) Pty Ltd
EP 359 R2	Bounty Oil & Gas NL
	Lansvale Oil & Gas Pty Ltd
	Pace Petroleum Pty Ltd
	Phoenix Resources PLC
	Rough Range Oil Pty Ltd
EP 368 R3	Empire Oil Company (WA) Limited
	Westranch Holdings Pty Ltd
EP 371 R1	Buru Energy Limited
EP 381 R2	Whicher Range Energy Pty Ltd
EP 386 R3	Advent Energy Ltd
EP 389 R1	ERM Gas Pty Ltd
	Sunset Power Holdings Pty Ltd
	Wharf Resources PLC
	* Empire Oil Company (WA) Limited
EP 390 R2	Buru Energy Limited
EP 391 R2	Buru Energy Limited
EP 407 R1	Latent Petroleum Pty Ltd
EP 408 R1	Whicher Range Energy Pty Ltd
EP 412 R1	Bounty Oil & Gas NL
	* Rough Range Oil Pty Ltd
EP 413 R2	Arc Energy Limited
	Bharat PetroResources Limited
	Geary, John Kevin
	* Norwest Energy NL
EP 416 R1	Allied Oil & Gas Plc
	ERM Gas Pty Ltd
	* Empire Oil Company (WA) Limited
EP 417 R1	Buru Energy Limited
	New Standard Onshore Pty Ltd
EP 419	Exoma Energy Limited
EP 424	Pancontinental Oil & Gas NL
	Strike Energy Limited
EP 426	Allied Oil & Gas Plc
	ERM Gas Pty Ltd
	Empire Oil Company (WA) Limited
EP 428	Buru Energy Limited
EP 429	Kingsway Oil Limited
EP 430	Empire Oil Company (WA) Limited
EP 431	Buru Energy Limited
EP 432	Allied Oil & Gas Plc
	ERM Gas Pty Ltd
	* Empire Oil Company (WA) Limited
EP 433	Lansvale Oil & Gas Pty Ltd
	Pace Petroleum Pty Ltd
EP 434	Pace Petroleum Pty Ltd
	Rough Range Oil Pty Ltd
	* Lansvale Oil & Gas Pty Ltd
EP 435 R1	Australian Oil Company No 3 Pty Limited
	Bounty Oil & Gas NL
	Rough Range Oil Pty Ltd
EP 436	Buru Energy Limited
EP 437	CalEnergy Resources (Australia) Limited
	Key Petroleum (Australia) Pty Ltd
EP 438	Gulliver Productions Pty Ltd
	Indigo Oil Pty Ltd
	* Buru Energy Limited
EP 439	Falcore Pty Ltd
	Indigo Oil Pty Ltd
	Jurassica Oil & Gas Plc
	Longreach Oil Limited
	Vigilant Oil Pty Ltd
	* Rough Range Oil Pty Ltd
EP 440	Empire Oil Company (WA) Limited
EP 441	Apache Northwest Pty Ltd
EP 443	New Standard Onshore Pty Ltd
EP 444	Rough Range Oil Pty Ltd
EP 445	Red Mountain Energy Pty Ltd
EP 447	GCC Methane Pty Ltd

Table 7. List of Petroleum and Geothermal Titles and Holders in Western Australia as at 1 July 2011

EP 448	Buru Energy Limited
	Gulliver Productions Pty Ltd
	Indigo Oil Pty Ltd
	United Orogen Limited
EP 449	Kingsway Oil Limited
EP 450	New Standard Onshore Pty Ltd
EP 451	New Standard Onshore Pty Ltd
EP 453	Budside Pty Limited
	Pobelo Pty Ltd
EP 454	Empire Oil Company (WA) Limited
EP 455	Westralian Gas and Power Limited
	* Arc Energy Limited
EP 456	New Standard Onshore Pty Ltd
EP 457	Rey Resources Ltd
EP 458	Rey Resources Ltd
EP 460	Falcore Pty Ltd
	Indigo Oil Pty Ltd
	Jurassica Oil & Gas Plc
	Longreach Oil Limited
	Vigilant Oil Pty Ltd
	* Rough Range Oil Pty Ltd
EP 461	Falcore Pty Ltd
	Indigo Oil Pty Ltd
	Jurassica Oil & Gas Plc
	Longreach Oil Limited
	Vigilant Oil Pty Ltd
	* Rough Range Oil Pty Ltd
EP 463	Emerald Gas Pty Ltd
EP 464	Exceed Energy (Australia) Pty Ltd
EP 465	Global International (Australia) Pty Ltd
EP 466	Rough Range Oil Pty Ltd
EP 467	ERM Gas Pty Ltd
EP 468	Officer Petroleum Pty Ltd
EP 469	Warrego Energy Pty Ltd
EP 470	Energetica Resources Pty Ltd
EP 471	Buru Energy Limited
EP 472	Buru Energy (Acacia) Pty Ltd
	Buru Energy Limited
EP 473	Buru Energy Limited
EP 474	Buru Energy Limited
EP 475	Energetica Resources Pty Ltd
EP 476	Arc Energy Limited
EP 477	Buru Energy (Acacia) Pty Ltd
	Buru Energy Limited
EP 478	Buru Energy (Acacia) Pty Ltd
	Buru Energy Limited

PETROLEUM AND GEOTHERMAL ENERGY RESOURCES ACT 1967
Geothermal Exploration Permit

Title	Registered Holders (* denotes Nominee)
GEP 1	The University of Western Australia
	* Green Rock Energy Limited
GEP 2	Green Rock Energy Limited
GEP 3	Green Rock Energy Limited
GEP 4	Green Rock Energy Limited
GEP 5	Granite Power Limited
GEP 6	Granite Power Limited
GEP 7	GT Power Pty Ltd
GEP 8	GT Power Pty Ltd
GEP 9	GT Power Pty Ltd
GEP 10	BHP Billiton Worsley Alumina Pty Ltd
	Green Rock Energy Limited
GEP 11	BHP Billiton Worsley Alumina Pty Ltd
	Green Rock Energy Limited
GEP 12	BHP Billiton Worsley Alumina Pty Ltd
	Green Rock Energy Limited
GEP 13	New World Energy Limited
GEP 14	New World Energy Limited
GEP 15	New World Energy Limited
GEP 16	New World Energy Limited
GEP 17	New World Energy Limited
GEP 18	New World Energy Limited
GEP 19	New World Energy Limited
GEP 20	New World Energy Limited
GEP 21	New World Energy Limited
GEP 22	AAA Energy Pty Ltd
GEP 23	Green Rock Energy Limited
GEP 24	Green Rock Energy Limited
GEP 25	Green Rock Energy Limited
GEP 26	Green Rock Energy Limited
GEP 27	Green Rock Energy Limited
GEP 28	Green Rock Energy Limited
GEP 29	Geothermal Energy Pty Ltd
GEP 30	New World Energy Limited
GEP 31	New World Energy Limited
GEP 32	New World Energy Limited
GEP 33	New World Energy Limited
GEP 34	New World Energy Limited
GEP 35	New World Energy Limited
GEP 36	New World Energy Limited
GEP 37	Greenpower Energy Limited
GEP 38	Greenpower Energy Limited
GEP 39	Green Rock Energy Limited
GEP 40	Green Rock Energy Limited
GEP 41	Green Rock Energy Limited
GEP 42	GT Power Pty Ltd
GEP 43	Kagara Ltd

PETROLEUM AND GEOTHERMAL ENERGY RESOURCES ACT 1967
Production Licence

Title	Registered Holders (* denotes Nominee)
L 1 R1	APT Parmelia Pty Ltd
	Arc Energy Limited
	Origin Energy Developments Pty Limited
L 2 R1	Origin Energy Developments Pty Limited
	* Arc Energy Limited

Table 7. List of Petroleum and Geothermal Titles and Holders in Western Australia as at 1 July 2011

L 4 R1	Arc Energy Limited
L 5 R1	Arc Energy Limited
L 6 R1	Buru Energy Limited
L 7 R1	Arc Energy Limited
L 8 R1	Buru Energy Limited
L 9 R1	BHP Billiton Petroleum (Australia) Pty Ltd
L 10 R1	Chevron (TAPL) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Santos Offshore Pty Ltd
	* Chevron Australia Pty Ltd
L 11	ARC (Beharra Springs) Pty Ltd
	* Origin Energy Developments Pty Limited
L 12	Chevron (TAPL) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Santos Offshore Pty Ltd
	* Chevron Australia Pty Ltd
L 13	Chevron (TAPL) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Santos Offshore Pty Ltd
	* Chevron Australia Pty Ltd
L 14	Arc Energy Limited
	Geary, John Kevin
	Norwest Energy NL
	Origin Energy Developments Pty Limited
	Roc Oil (WA) Pty Limited
L 15	Buru Energy Limited
	First Australian Resources Limited
	Gulliver Productions Pty Ltd
	Indigo Oil Pty Ltd
	Pancontinental Oil & Gas NL
L 16	Rough Range Oil Pty Ltd
L 1H R2	Chevron (TAPL) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Santos Offshore Pty Ltd
	* Chevron Australia Pty Ltd

PETROLEUM AND GEOTHERMAL ENERGY RESOURCES ACT 1967
Retention Lease

Title	Registered Holders (* denotes Nominee)
R 1 R1	Arc Energy Limited
	First Australian Resources Limited
	Gulliver Productions Pty Ltd
	Indigo Oil Pty Ltd
	Pancontinental Oil & Gas NL
	Phoenix Resources PLC
R 2 R1	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	Chevron Australia Pty Ltd
	Shell Development (Australia) Proprietary Limited
	* Woodside Energy Ltd
R 3	Oil Basins Ltd
R 4	Chevron (TAPL) Pty Ltd
	Chevron Australia Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Santos Offshore Pty Ltd
R 5	Apache Oil Australia Pty Ltd
	OMV Australia Pty Ltd

PETROLEUM PIPELINES ACT 1969
Pipeline Licence

Title	Registered Holders (* denotes Nominee)
PL 1 R1	APT Parmelia Pty Ltd
PL 2 R1	APT Parmelia Pty Ltd
PL 3 R1	APT Parmelia Pty Ltd
PL 5 R1	APT Parmelia Pty Ltd
PL 6 R3	Arc Energy Limited
PL 7 R1	Buru Energy Limited
PL 8 R1	Mitsui Iron Ore Development Pty Ltd
	Nippon Steel Australia Pty Limited
	North Mining Limited
	Sumitomo Metal Australia Pty Ltd
	* Robe River Mining Co Pty Ltd
PL 12 R1	Kufpec Australia Pty Ltd
	Tap (Harriet) Pty Ltd
	* Apache Northwest Pty Ltd
PL 14 R1	Apache Oil Australia Pty Ltd
	Pan Pacific Petroleum (South Aust) Pty Ltd
	Santos (BOL) Pty Ltd
	Tap (Shelfal) Pty Ltd
PL 15	Chevron (TAPL) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Santos Offshore Pty Ltd
	* Chevron Australia Pty Ltd
PL 16	BHP Petroleum (Ashmore Operations) Pty Ltd
PL 17	Kufpec Australia Pty Ltd
	Tap (Harriet) Pty Ltd
	* Apache Northwest Pty Ltd
PL 18	ARC (Beharra Springs) Pty Ltd
	* Origin Energy Developments Pty Limited
PL 19	BHP Petroleum (Ashmore Operations) Pty Ltd
PL 20	Inpex Alpha Ltd
	Mobil Exploration & Producing Australia Pty Ltd
	* BHP Billiton Petroleum (Australia) Pty Ltd
PL 21	Chevron (TAPL) Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Santos Offshore Pty Ltd
	* Chevron Australia Pty Ltd
PL 22	Epic Energy (Pilbara Pipeline) Pty Ltd
PL 23	APT Parmelia Pty Ltd
PL 24	Alinta DEWAP Pty Ltd
	Southern Cross Pipelines (NPL) Australia Pty Ltd
	* Southern Cross Pipelines Australia Pty Limited
PL 25	Southern Cross Pipelines Australia Pty Limited
PL 26	Southern Cross Pipelines Australia Pty Limited
PL 27	Southern Cross Pipelines Australia Pty Limited
PL 28	Southern Cross Pipelines (NPL) Australia Pty Ltd

Table 7. List of Petroleum and Geothermal Titles and Holders in Western Australia as at 1 July 2011

PL 29	Apache East Spar Pty Ltd
	Apache Kersail Pty Ltd
	Santos (BOL) Pty Ltd
	* Apache Oil Australia Pty Ltd
PL 30	Apache East Spar Pty Ltd
	Apache Kersail Pty Ltd
	Santos (BOL) Pty Ltd
	* Apache Oil Australia Pty Ltd
PL 31	Epic Energy (Pilbara Pipeline) Pty Ltd
PL 32	APT Pipelines (WA) Pty Limited
PL 33	APT Pipelines (WA) Pty Limited
PL 34	Newmont Yandal Operations Pty Ltd
PL 35	Plutonic Operations Limited
PL 36	Australian Pipeline Limited
PL 37	Norilsk Nickel Cawse Pty Ltd
PL 38	Epic Energy (Pilbara Pipeline) Pty Ltd
PL 39	Origin Energy Pipelines Pty Limited
PL 40	DBNGP (WA) Nominees Pty Limited
PL 41	DBNGP (WA) Transmission Pty Limited
PL 42	Apache East Spar Pty Ltd
	Apache Kersail Pty Ltd
	Apache Northwest Pty Ltd
	Apache Oil Australia Pty Ltd
	Kufpec Australia Pty Ltd
	Santos (BOL) Pty Ltd
	Tap (Harriet) Pty Ltd
PL 43	Western Power Corporation
	* APT Pipelines (WA) Pty Limited
PL 44	APT Parmelia Pty Ltd
PL 45	APT Parmelia Pty Ltd
PL 46	APT Parmelia Pty Ltd
PL 47	DBNGP (WA) Transmission Pty Limited
PL 48	Energy Generation Pty Ltd
PL 52	APT Parmelia Pty Ltd
PL 53	APT Parmelia Pty Ltd
PL 54	Western Power Corporation
	* APT Pipelines (WA) Pty Limited
PL 55	Global Advanced Metals Wodgina Pty Ltd
PL 56	Epic Energy (WA) One Pty Ltd
PL 57	Australian Gold Reagents Pty Ltd
PL 58	BHP Billiton Petroleum (North West Shelf) Pty Ltd
	BP Developments Australia Pty Ltd
	Chevron Australia Pty Ltd
	Japan Australia LNG (MIMI) Pty Ltd
	Shell Development (Australia) Proprietary Limited
	* Woodside Energy Ltd
PL 59	Esperance Pipeline Co. Pty Limited
PL 60	Gas Transmission Services WA (Operations) Pty Ltd
PL 61	APT Parmelia Pty Ltd
PL 62	Kufpec Australia Pty Ltd
	Tap (Harriet) Pty Ltd
	* Apache Northwest Pty Ltd
PL 63	Gas Transmission Services WA (Operations) Pty Ltd
PL 64	Arc Energy Limited
	Origin Energy Developments Pty Limited
PL 65	Dalrymple Resources NL
	LionOre Australia (Wildara) NL
PL 67	Hamersley Iron Pty Ltd
PL 68	Gas Transmission Services WA (Operations) Pty Ltd
PL 69	DBNGP (WA) Nominees Pty Limited
PL 70	ARC (Offshore PB) Limited
	AWE Oil (Western Australia) Pty Ltd
	Cieco Energy Australia Pty Ltd
	Roc Oil (WA) Pty Limited
PL 72	EDL NGD (WA) PTY LTD
PL 73	Redback Pipelines Pty Ltd
PL 74	EDL LNG (WA) PTY LTD
PL 75	EIT Neerabup Power Pty Ltd
	ERM Neerabup Pty Ltd
PL 76	APA Group
PL 77	Sino Iron Pty Ltd
PL 78	Hamersley Iron Pty Ltd
PL 80	Latent Petroleum Pty Ltd
PL 81	Apache Northwest Pty Ltd
PL 82	Epic Energy (Pilbara Pipeline) Pty Ltd
PL 83	WA Gas Networks Pty Ltd
PL 84	Chevron (TAPL) Pty Ltd
	Chubu Electric Power Gorgon Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Osaka Gas Gorgon Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Tokyo Gas Gorgon Pty Ltd
PL 85	Chevron (TAPL) Pty Ltd
	Chubu Electric Power Gorgon Pty Ltd
	Mobil Australia Resources Company Pty Limited
	Osaka Gas Gorgon Pty Ltd
	Shell Development (Australia) Proprietary Limited
	Tokyo Gas Gorgon Pty Ltd
PL 86	Apache Northwest Pty Ltd
	Santos Offshore Pty Ltd
PL 87	Apache PVG Pty Ltd
	BHP Billiton Petroleum (Australia) Pty Ltd
PL 88	Apache PVG Pty Ltd
	BHP Billiton Petroleum (Australia) Pty Ltd
PL 89	Crosslands Resources Ltd
PL 90	Apache PVG Pty Ltd
	BHP Petroleum (Australia) Pty Ltd

Please consult DMP's online Petroleum and Geothermal Register for the most current information on Titles and Holdings.

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