Appendix G West Erregulla-2 Exploration Well – Groundwater Monitoring Plan

West Erregulla-2 Exploration Well

Groundwater Monitoring Plan

Prepared for
EP469 Joint Venture

30 September 2018

DOCUMENT TRACKING

Item	Detail
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1 Purpose

This Groundwater Monitoring plan has been prepared for Strike West Pty Ltd (Strike Energy), Operator of Exploration Permit EP469, to drill the West Erregulla-2 exploration well within Exploration Permit EP469. This plan aims to establish good practice requirements for groundwater monitoring for Strike Energy.

2 Introduction

2.1 Background

The West Erregulla-2 drill site is located approximately 50km southeast of Dongara and 230km north of Perth in Western Australia. The primary objective of the well is to intersect and test the Permian Kingia and Highcliff Sandstones in the West Erregulla field. Secondary to this, the Permian Dongara/Wagina tight gas interval and Jurassic age Cattamarra Coal Measures oil target will be evaluated.

2.2 Climate

The climate of the Geraldton Sandplain bioregion is described as Mediterranean with hot dry summers and cool wet winters. Climate data from Eneabba weather station, approximately 43 km south of EP469, shows the warmest period in the region is from December to March, with average maximum temperatures from 1972 to 2017 ranging from 33.6 to 36.5°C. The lowest temperatures generally occur between June and September, with average minimum temperatures ranging from 8.9 to 10.1°C during these months (ELA 2018).

Majority of rainfall is between May and August and ranges from 69.3 to 99.0 mm per month. The driest months are between November and March, with the average rainfall ranging from 7.5 to 14.8 mm in this period. The average annual rainfall at Eneabba is 489.4 mm (ELA 2018).

2.3 Geology

As described by RPS (2011), EP469 is located in the northern part of the onshore Northern Perth Basin. Structurally, the Study Area straddles the transition between the Allanooka High and the Dandaragan Trough between the Eneabba and Urella Faults (Figure 1).

The general description for the onshore Northern Perth Basin is of a deep trough (Dandaragan Trough) up to 12km thick that rises gently northwards towards the Allanooka High and then steps up via a series of terraces and shelves at its northern and western extremities. To the east it warps up against the Darling Fault System. The Northern Perth Basin is an extensional basin, containing mainly continental clastic rocks ranging in age from Permian to Recent, deposited in a developing rift system that culminated with the break-up of the Gondwana supercontinent in the Early Neocomian (Lower Cretaceous) approximately 146 million years ago. Most of the sedimentary section preserved onshore pre-dates the separation.

On the Allanooka High, the basement shallows to the north from approximately 5500 to 2000m. The Allanooka High is distinguished from the Dandaragan Trough by the change in structural style from northerly striking faults in the Dandaragan Trough to east-northeasterly and easterly striking faults in the Allanooka High. To the west the boundary between the Allanooka High and the Greenough Shelf is marked by the Mountain Bridge Fault. The eastern boundary is represented by the Urella Fault, while to the south there is a gradual transition to the Dandaragan Trough. Within the Allanooka High the Mesozoic succession progressively thickens to the south, in contrast to the Permian succession which thins in that direction.

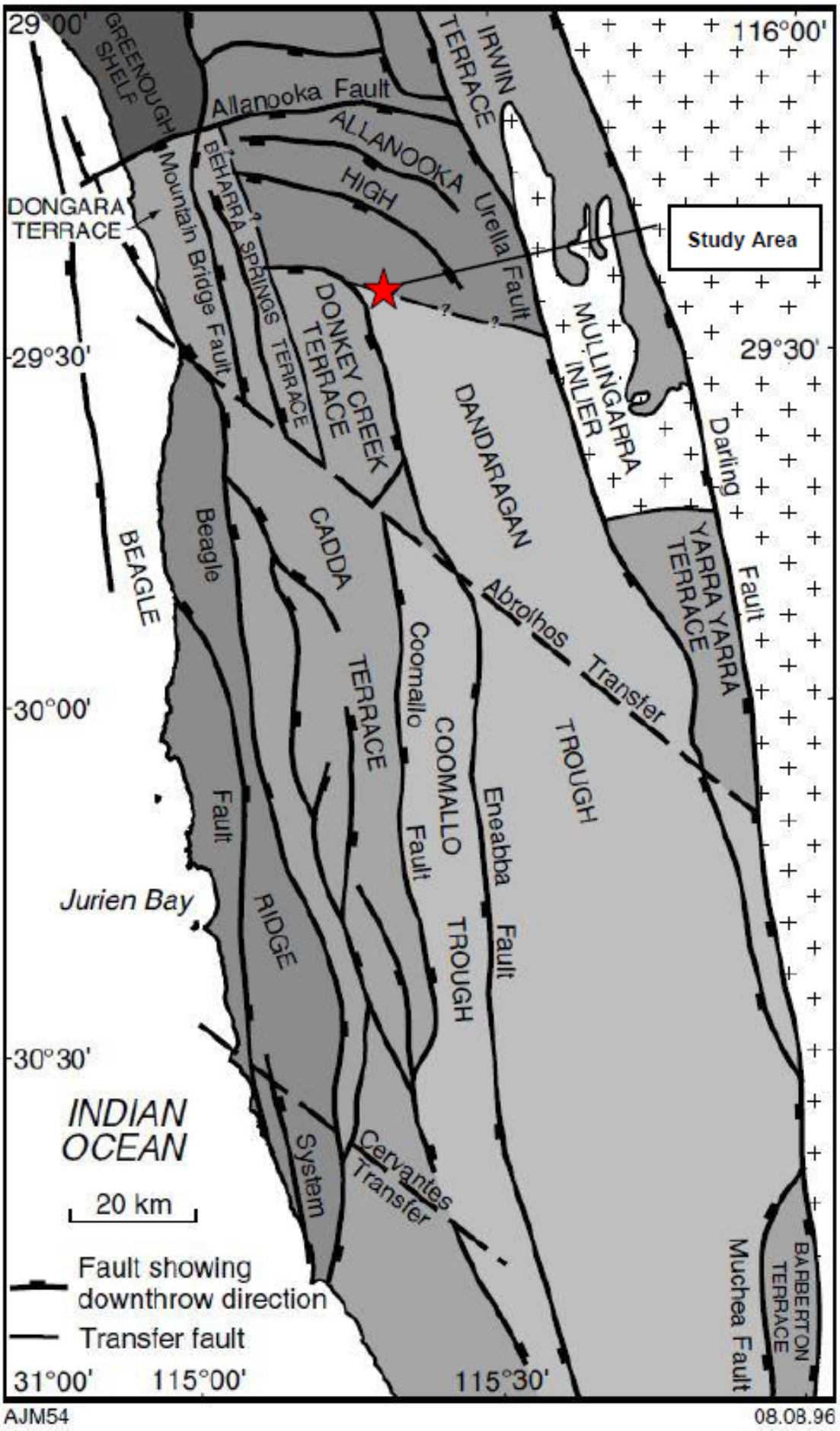


Figure 1: Northern Perth Basin Structural Divisions (RPS, 2011)

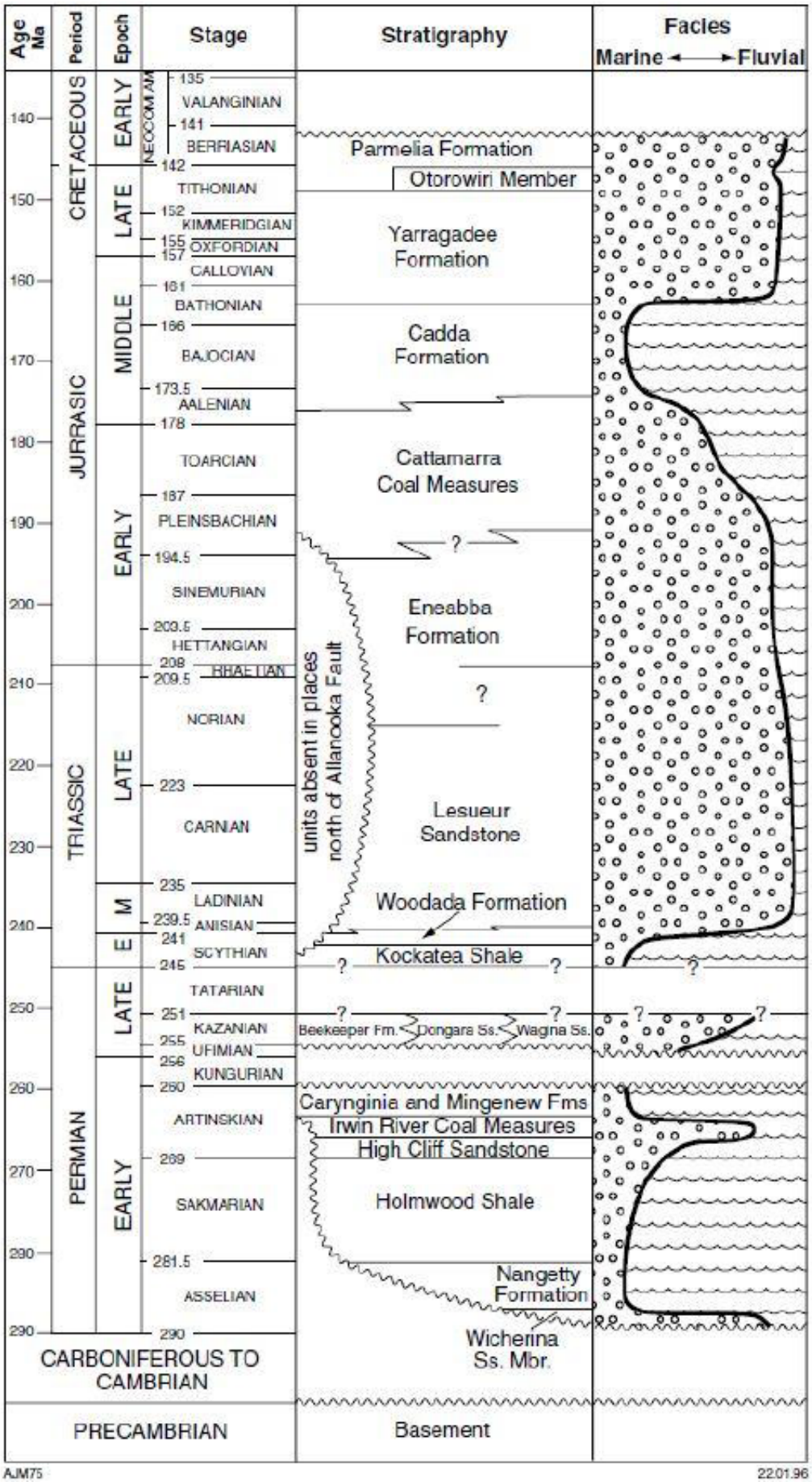
2.4 **Stratigraphy**

The stratigraphic succession in the Study Area consists of Phanerozoic sediments up to Permian age, resting on undifferentiated Proterozoic crystalline basement rocks. The West Erregulla-1 well commenced in the Late-Middle Jurassic Yarragadee Formation, penetrated the Middle Jurassic Cadda Formation, the Early-Middle Jurassic Cattamarra Coal Measures, the Early Jurassic Eneabba Formation, the Late Triassic Lesueur Sandstone, the Middle Triassic Woodada Formation, the Early Triassic Kockatea Shale, the Basal Triassic Sandstone and Late Permian Wagina Formation. Both the Basal Triassic Sandstone and Wagina Formation are now collectively referred to as the Dongara Sandstone. (RPS 2011)

A generalised pre-Cainozoic stratigraphy within the area is presented on Figure 2. The following stratigraphic descriptions are summarised from Mory and Iasky (1996) as cited by RPS (2011). Pre Cainozoic-geology is presented on Figure 3 and Figure 4, with regional geological sections shown on Figure 5 and Figure 6 (RPS 2011).

2.4.1 Yarragadee Formation

The stratigraphy of interest in the study area is the Yarragadee Formation. This formation is a predominantly sandy formation of the Middle to Late Jurassic Age and lies conformably over the Cadda Formation. To the east, the Yarragadee Formation is conformably overlain by the Otorowiri Siltstone and Parmelia Formation. Within the Study Area these units are absent and west of the Gingin Scarp, the Yarragadee is unconformably overlain by Cainozoic sediments. The Yarragadee Formation consists of interbedded fine to coarse feldspathic sandstone, siltstone and claystone, with minor conglomerate and coal. Beds are typically discontinuous and correlation of units within the formation is difficult. The Yarragadee is up to 6000m thick against the Darling fault in the Dandaragan Trough and thins to the north and west. Within the Study Area the Yarragadee is almost 2000m thick (Figure 6). The unit is essentially a fluvial deposit in which silt and clay deposits may represent a lacustrine or overbank environment (RPS 2011).



Source: Mory and Iasky, 1996.

Figure 2: Northern Perth Basin Stratigraphy (RPS, 2011)

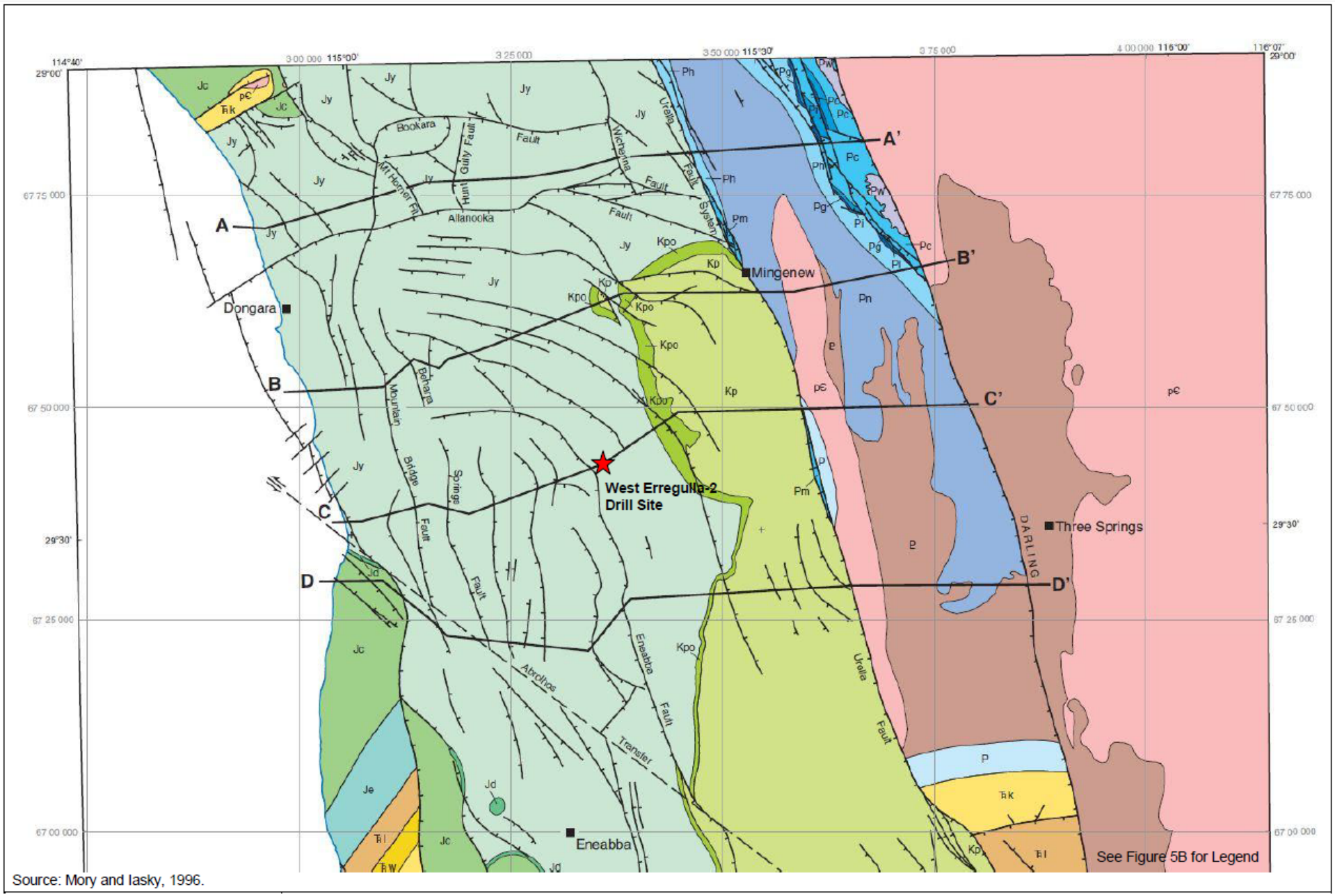
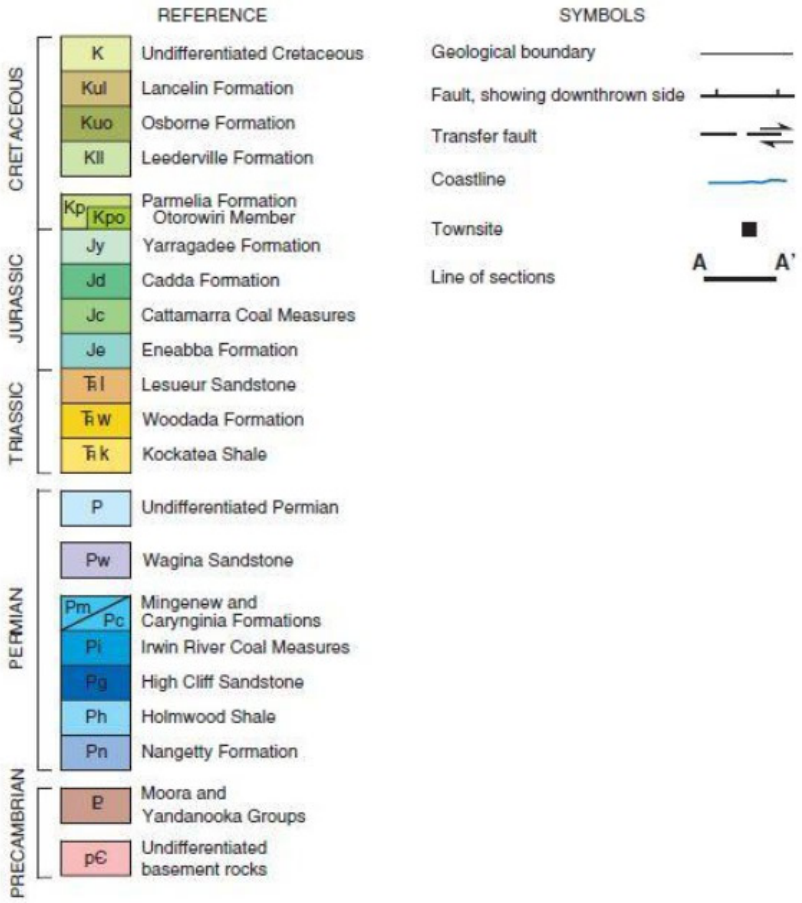


Figure 3: Pre-Cainozoic Geology (RPS, 2011)



Source: Mory and Iasky, 1996.

Figure 4: Pre-Cainozoic Geology Legend (RPS, 2011)

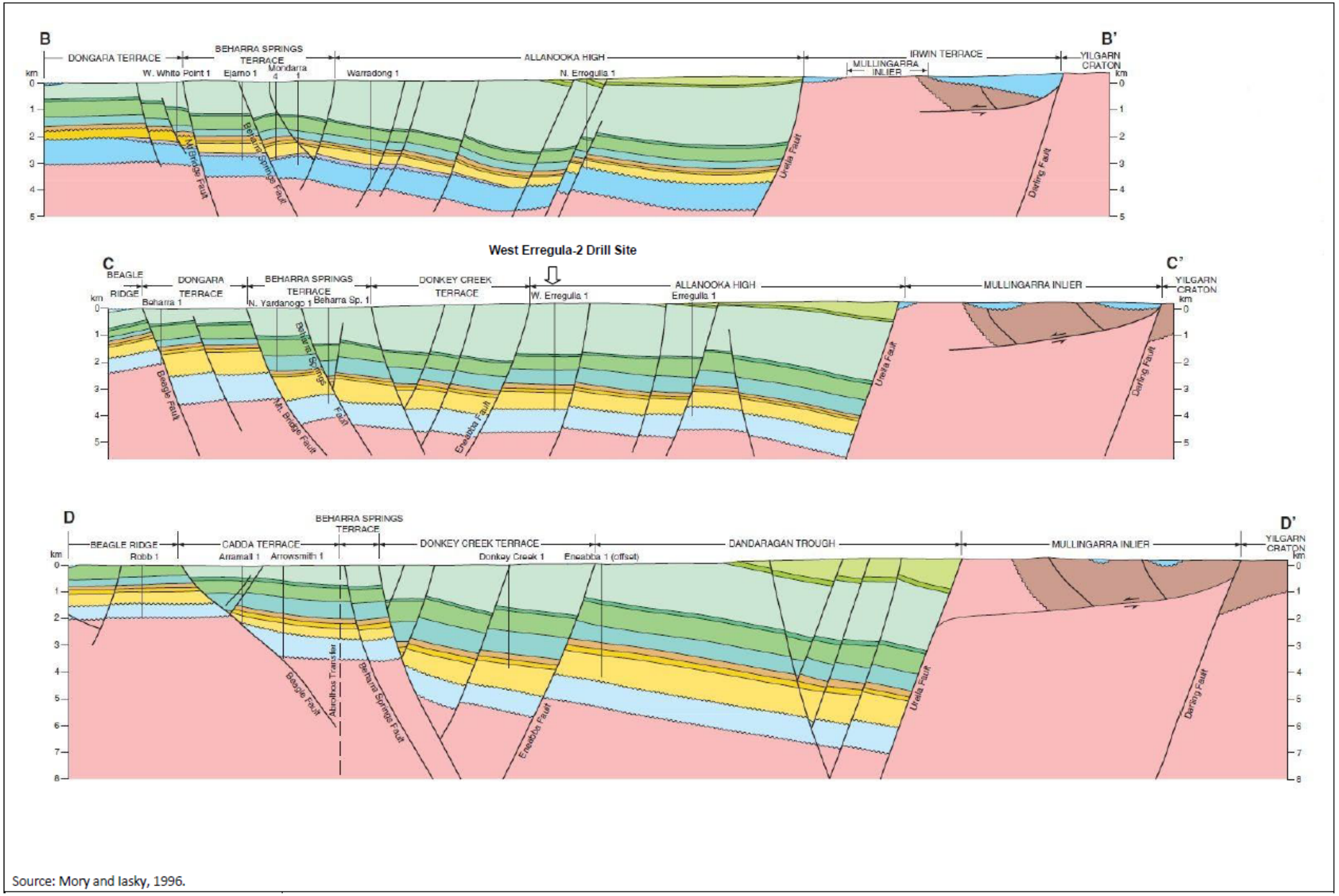


Figure 5: Northern Perth Basin Sections (RPS, 2011)

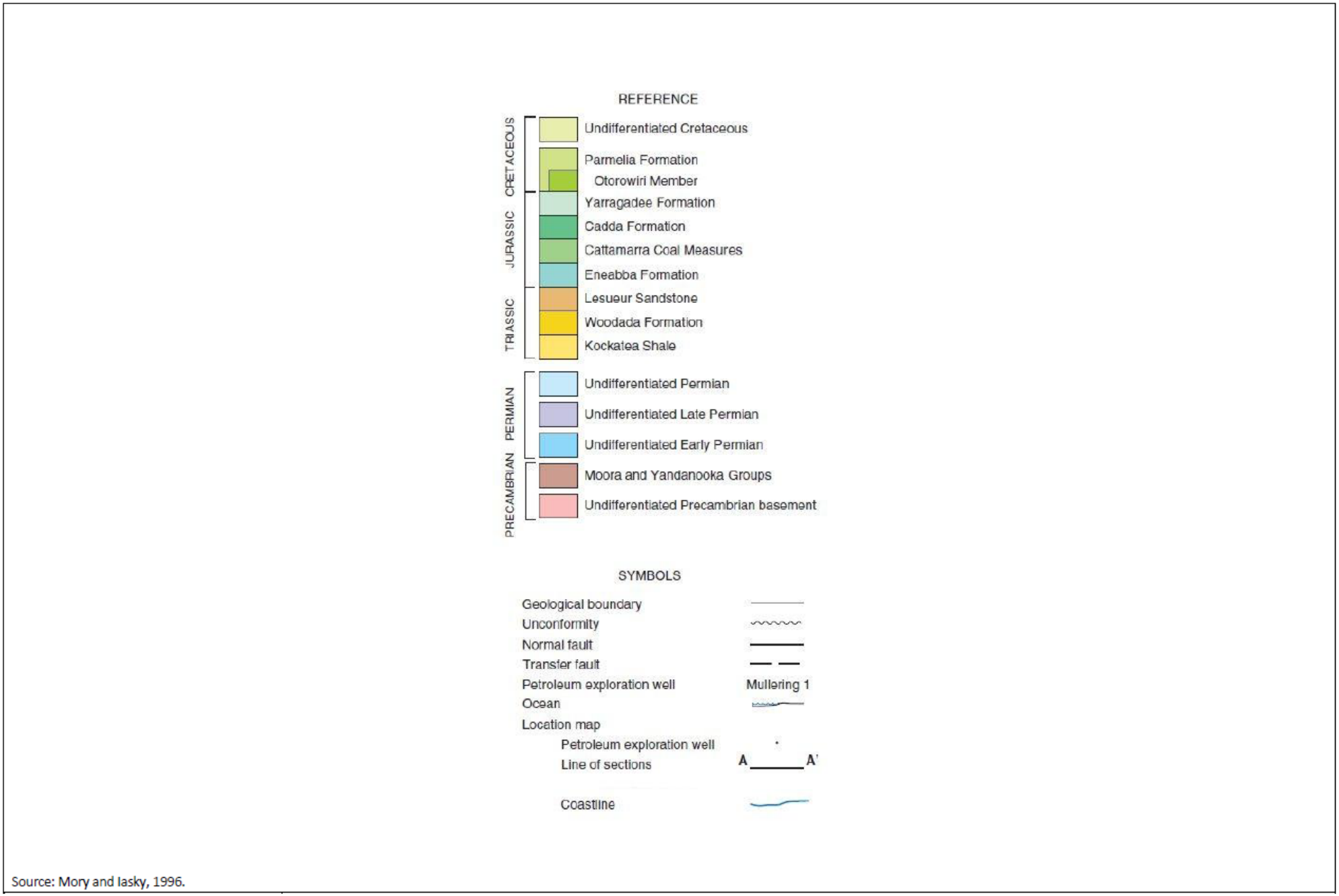


Figure 6: Northern Basin Sections Legend (RPS, 2011)

3 Hydrogeology and Hydrology

3.1 Regional drainages

The project area is devoid of any significant permanent surface water features. Numerous small watercourses dissect the surrounding area, draining either westwards from the Arrowsmith Region onto the Swan Coastal Plain, or north or south towards the two nearest river systems (RPS, 2011). The most significant surface water features in the vicinity of the project are two regional drainage systems – the Arrowsmith River, about 15 km to the south of the project area, and the Irwin and Lockier Rivers, approximately 22km to the north of the project area (Figure 7) (RPS, 2011).

There are also several small ephemeral creeks within EP469 but these are not a feature of the project area (Figure 7). The nearest watercourse is Sand Plain Creek, located approximately 6 km north of the well site.

3.2 Regional Aquifer

The Yarragadee Formation and Lesueur Sandstone are the only major regional groundwater resources, with the Cattamarra Coal Measures and the Eneabba Formation, hosting smaller aquifers.

3.2.1 Yarragadee Formation

The project area overlies the Yarragadee Formation aquifer, which is the largest aquifer in the Perth Basin. The formation is present at surface within the study area and unconfined in its upper parts and become increasingly confined at depth due to the layered nature of the formation. The Yarragadee Formation is comprised mainly of sand with minor shale and siltstone interbedded within it and lies over the Cadda Formation. It covers an area from north of Dongara to the Serpentine area south of Perth (RPS, 2011).

The geological units likely to be encountered by the well include (in order of increasing depth) the Yarragadee Formation, Cadda Formation, Cattamarra Coal Measures, Eneabba Formation, Lesueur Formation, Woodada Formation, Kockatea Shale, Dongara/Wagina Sandstone, Irwin River Coal Measures, Kingia Sandstone, Bit Basher Shale, High Cliff Sandstone reaching total depth in the Holmwood shale.

The upper water table in the Yarragadee Formation is more than 100m below ground level and given the layered nature, little direct rainfall recharge is expected to reach the regional water table. RPS (2011) reported recharge rates for the Yarragadee Formation (based on a rainfall infiltration study of the Parmelia Formation, 20km northeast of the study area) to be in the region of 4% to 11% of annual rainfall.

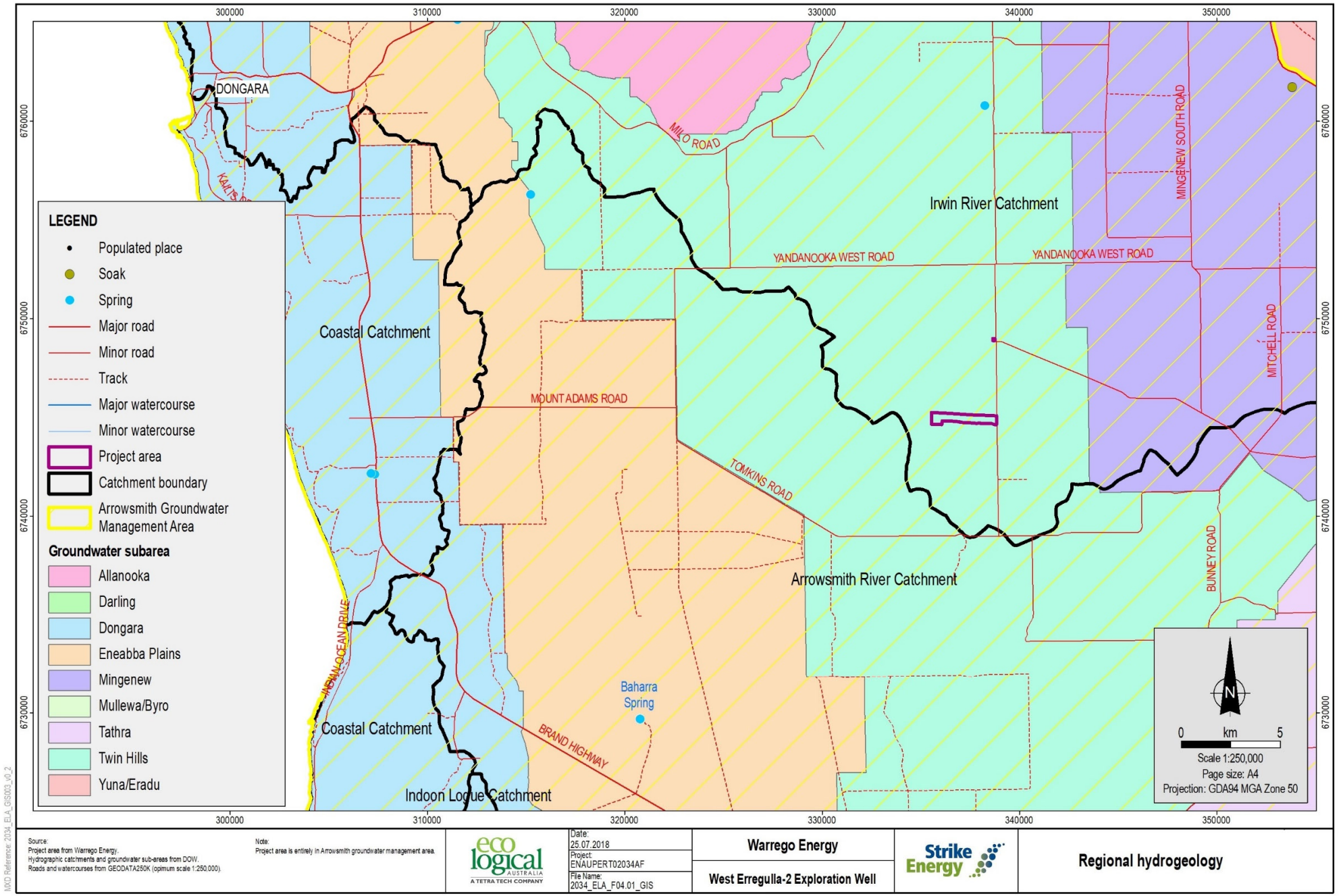
The water quality in the Yarragadee Aquifer is fresh to brackish, with salinity in the aquifer ranging between 500 to 1,000 mg/L and increasing with depth (RPS, 2011).

The Cadda Formation underlies the Yarragadee Formation at around 1,700 mAHD. It hosts minor permeable horizons but is generally of very low permeability and acts as a regional aquiclude, separating the Yarragadee Formation above from the Cattamarra Coal Measures below.

3.3 Regional Groundwater Levels and Groundwater Flow

A generalised overview of the dominant groundwater flow patterns for the upper Yarragadee, as presented in Figure 8, indicate flow in a general westerly direction beneath the Study area. The water table is mostly flat above the 80m contour but dramatically drops off to the west towards the Swan Coastal Plain. The water table is expected to be around 75mAHD or 145mbgl at the drill site (DL3 - Figure 9).

According to RPS (2011) a close correlation between the regional water table configuration and the major regional faults can be observed in areas with more detailed water level data. This suggest that the major faults may inhibit groundwater flow and compartmentalise the main aquifers with water levels “stepping down” to the west.



Source:
Project area from Warrego Energy.
Hydrographic catchments and groundwater sub-areas from DOW.
Roads and watercourses from GEODATA250K (opimum scale 1:250,000).

Note:
Project area is entirely in Arrowsmith groundwater management area.

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Date: 25.07.2018
Project: ENAUPERT02034AF
File Name: 2034_ELA_F04.01_GIS

Warrego Energy

West Erregulla-2 Exploration Well

Strike Energy

Regional hydrogeology

MXD Reference: 2034_ELA_GIS003_v0.2

Figure 7: Regional Hydrogeology (ELA, 2018)

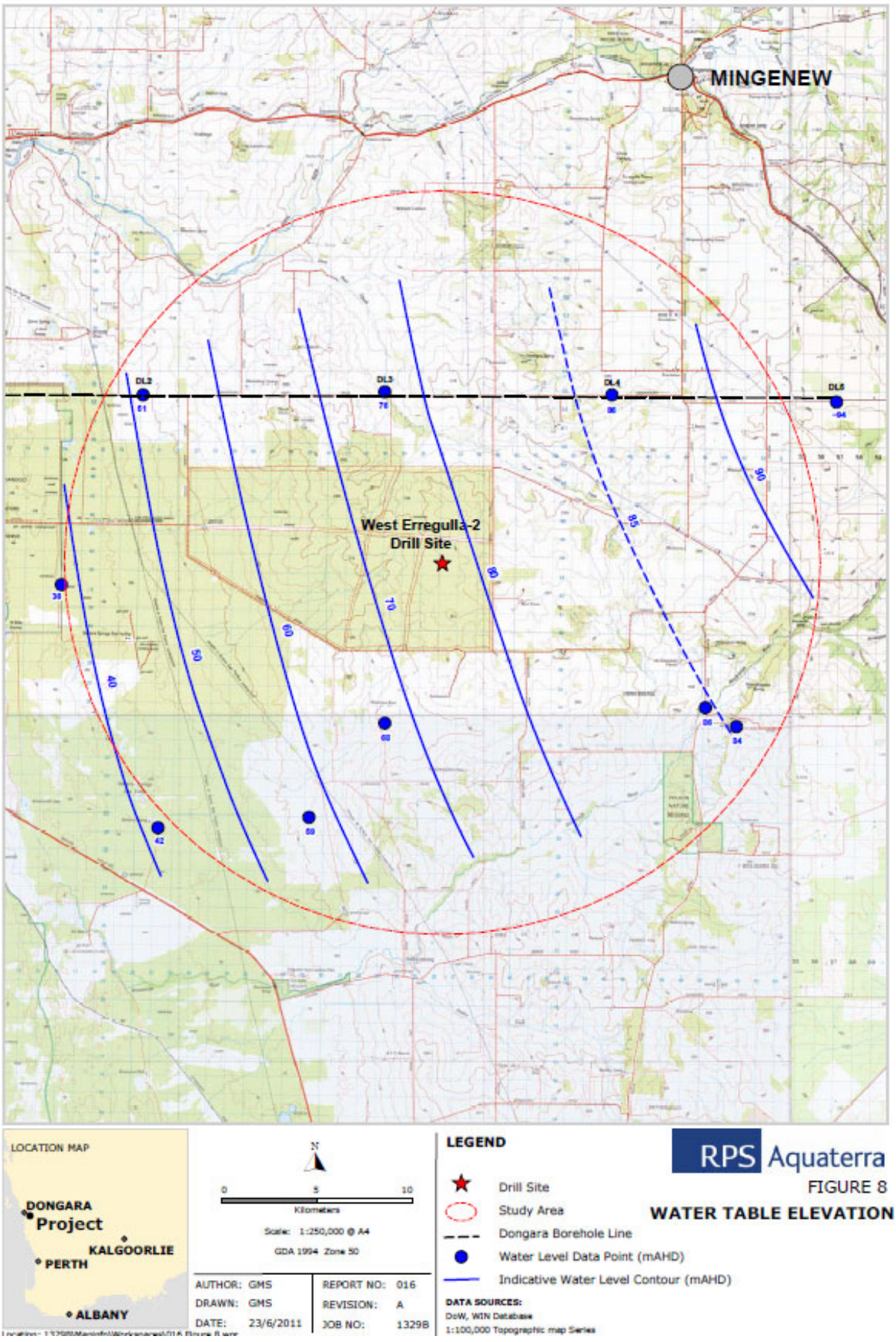

Figure 8: Water table elevation (RPS, 2011)

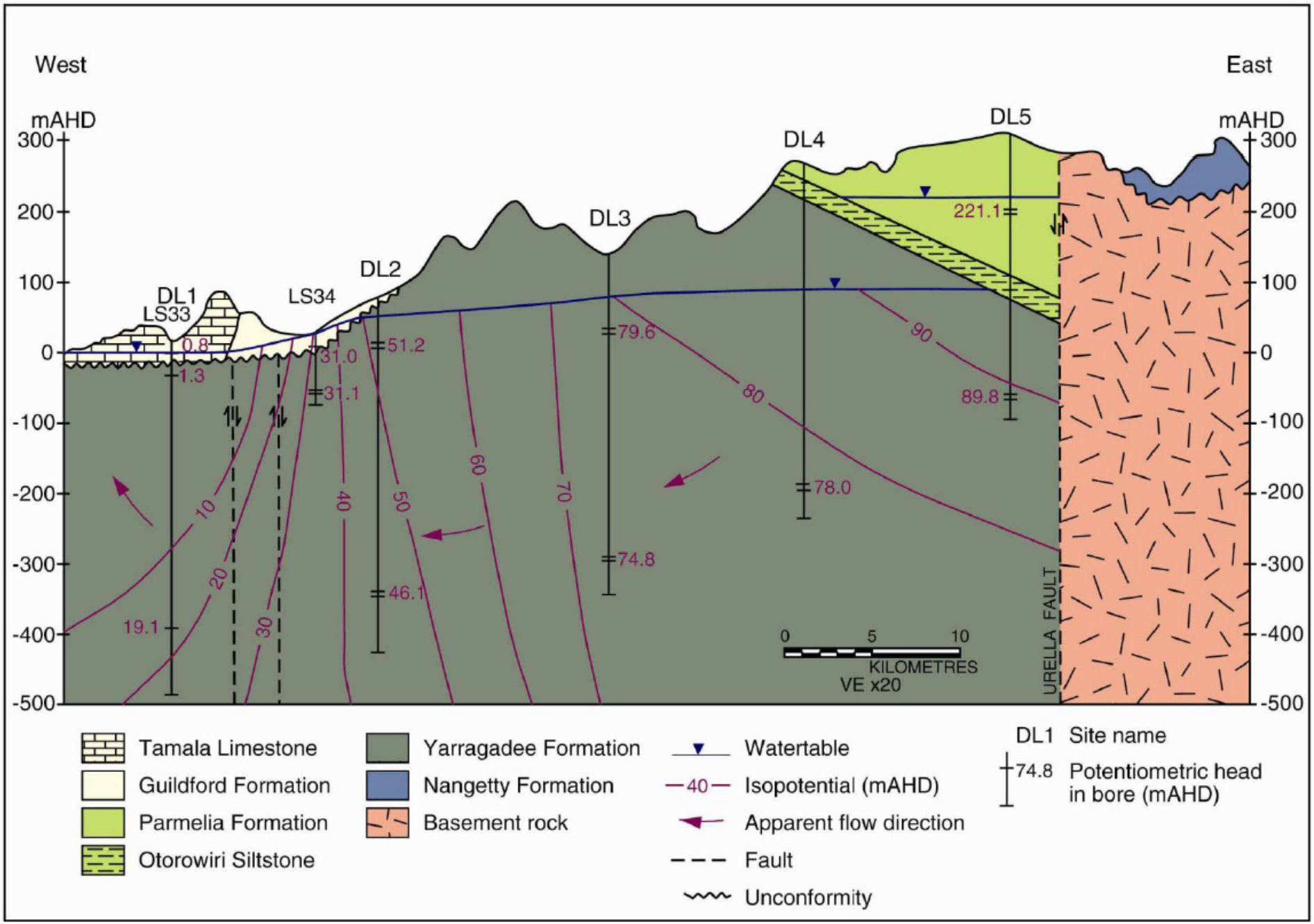

Figure 9: Groundwater Levels – relative to the Drill location DL3 (RPS, 2011)

4 Regional Groundwater Use

The project is located within the Arrowsmith Groundwater Management Area, as proclaimed under the *Rights in Water and Irrigation Act 1914* (RPS, 2011). Under the Act a licence is required from the DWER before water can be taken from a watercourse or groundwater aquifer. For licensing and allocation purposes, the project area is located within the Twin Hills sub-area of the Arrowsmith groundwater area (RPS, 2011) (Figure 7).

The main use of groundwater in the area from the Yarragadee Formation aquifer is related to irrigation and cattle grazing (RPS, 2011).

5 Monitoring Program

In May 2015, MDW Environmental Services (MDWES) on behalf of Warrego Energy conducted initial landholder groundwater bore sampling and testing to obtain an initial baseline dataset of landholder bores in the vicinity of the proposed exploration drill site. The five landholder bores sampled were between 4.5km and 11km from the original proposed drill site covering most directions of water flow (Figure 10). The new borehole location has moved slightly SE since the map was generated in 2015. These bore sites are however not close enough to the proposed drill site to be utilised for short term groundwater monitoring and assessment of potential impacts from drilling activities.

The outcomes of the 2015 groundwater testing and a proposed groundwater monitoring program have previously been presented to personnel from the Mid West Gascoyne Region of DWER. The groundwater monitoring (in accordance with DMIRS and DWER Guidelines for Groundwater Monitoring in the Onshore Petroleum and Geothermal Industry) program proposed for the EP469 exploration project has considered the Yarragadee Aquifer formation and the proposed activities associated with the earthworks and drilling program. Discussions with DBCA have agreed that the location of the bores at the edge of existing firebreaks and cleared areas within the Mt Adams UCL is acceptable.

5.1 **Objectives for monitoring**

A Groundwater Monitoring Program will be implemented via newly installed monitoring bores at the drill site. The purpose of this program is to established site-based water quality parameters, and if possible a baseline water quality data sets as well as to identify any influence or potentially contaminating impacts to the groundwater quality in the underlying aquifers resulting from the exploration drilling. The monitoring results will be reviewed against the baseline data collected during 2015 as well as the ANZECC and ARMCANZ, 2000 guidelines. The data obtained will be used to determine if any changes need to be made to the management of the project.

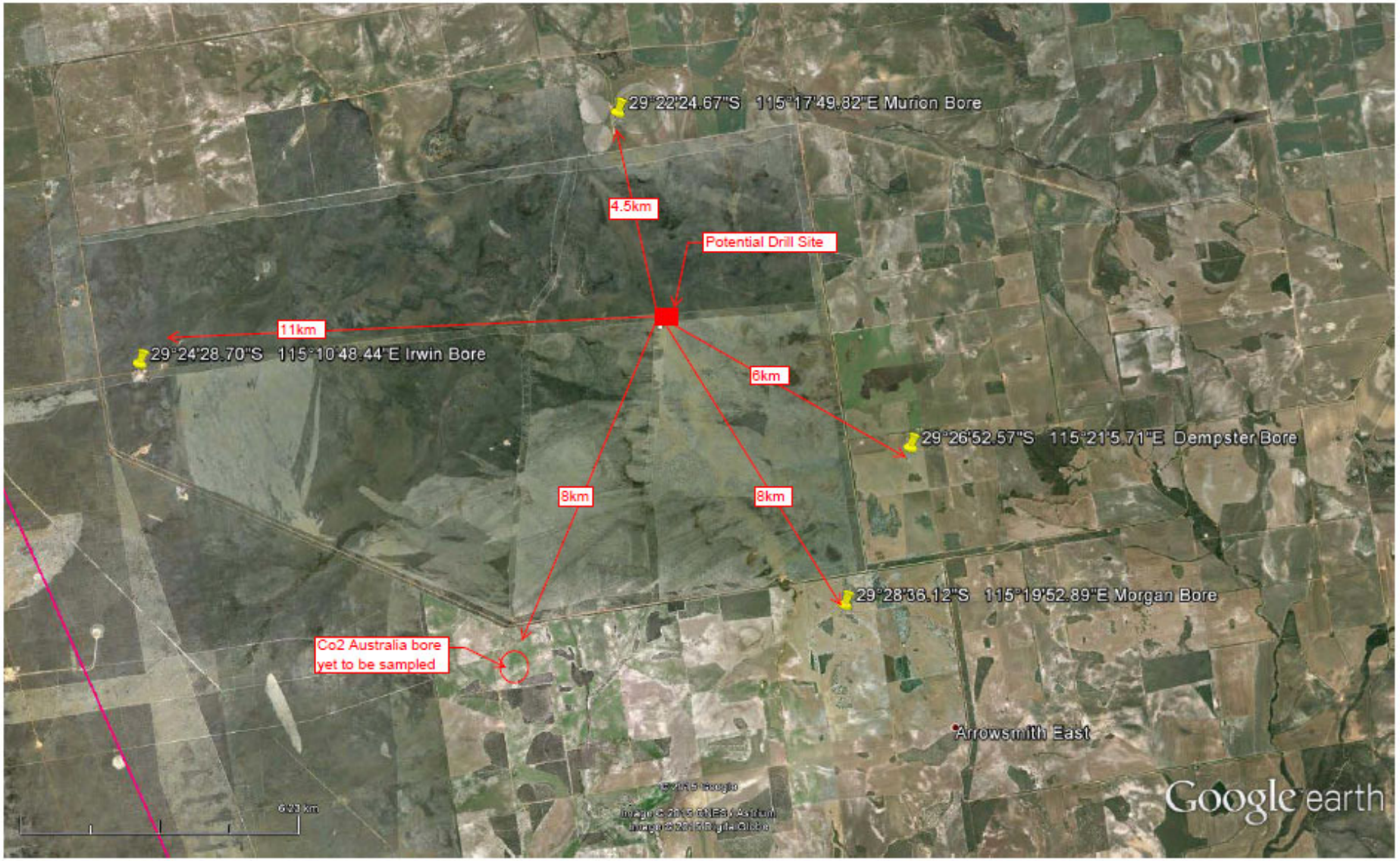

Figure 10: Sampled bores in the vicinity of the Potential Drill Site (MDWES, 2015)

5.2 Commencement and duration of monitoring

The Australian guidelines for groundwater monitoring recommend two years of baseline water quality sampling to adequately characterise groundwater variability (ANZECC and ARMCANZ, 2000). In the case of the drill site, baseline data has been collected from regional third party bores during 2015 and site specific data will be collected from the newly installed monitoring bores during Q4, 2018.

A groundwater monitoring program will commence as soon as the groundwater bores are installed. This will enable the collection of groundwater quality information to be obtained prior to drilling and be used as site specific baseline data. During and after the drilling program the groundwater monitoring program will continue on a quarterly basis with the groundwater monitoring ceasing after one quarter post completion of the drilling if no impact has been observed during the drilling. If potential impact is identified or observed, the groundwater monitoring program will continue on a quarterly basis for a period to be assessed (potentially up to two years) (Groundwater Monitoring In The Onshore Petroleum And Geothermal Industry, August 2016) (also see **Section 3.3.8** the EP469 West Erregulla-2 Environment Plan).

Groundwater is influenced by many factors and it is therefore proposed that the baseline information collected over the seasons leading up to the drilling program be used to determine site specific trigger values for comparison of any potential impacts resulting from the drilling. Determining site specific trigger values will ensure that any groundwater monitoring results obtained during or post drilling can be compared to the baseline and ensure that any fluctuations in water quality that are natural to the area will be considered in the assessment of the results.

5.3 Monitoring sites and bore design

The proposed groundwater monitoring program for EP469 includes the installation of 2 dedicated groundwater monitoring bores, in addition to sampling from a future groundwater production bore on the drill site established to supply water for use during earthworks and drilling activities. The location of groundwater monitoring bores has considered the existing terrain, the Yarragadee Aquifer formation, the proposed activities and the existing cleared areas of the Mt Adams UCL remnant vegetation. The location of the groundwater monitoring bores, which do not require a DWER licence to construct, will be in a triangular formation surrounding the proposed drill site (Figure 11). This will ensure that the groundwater monitoring bores are installed within appropriate proximity to the drill site allowing for an eastern location (upstream from the proposed production bore) and a south west location. Figure 11 below provides the proposed locations and Table 1 the approximate coordinates for the installation of the monitoring bores. The bores will be drilled in already cleared/disturbed areas (where practical) and final locations will be verified prior to drilling of the monitoring bores.

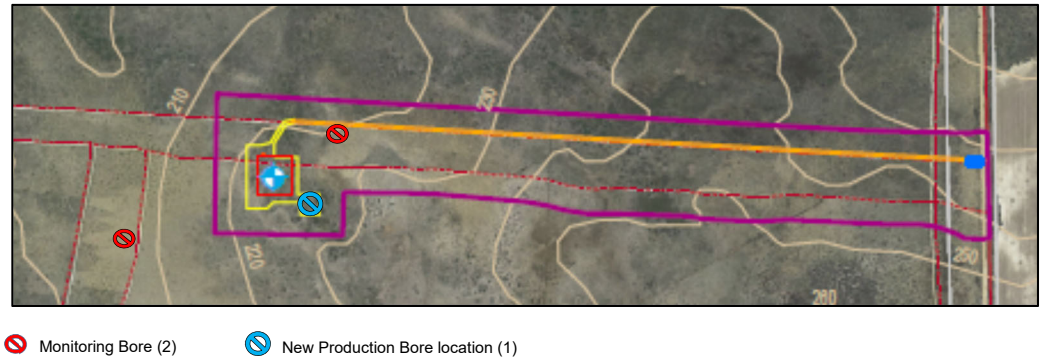

Figure 11: Proposed monitoring bore locations

Table 1: Approximate monitoring bore locations

Bore ID	Northing	Easting
NE Monitoring Bore	6745063	336047
SW Monitoring Bore	6744625	335125

The groundwater monitoring bores will be installed in the Yarragadee Formation only to a depth that is 10m below the depth to water in accordance with DWER groundwater monitoring well guidelines – an approximate borehole depth between 150m and 200m per borehole, dependent of the depth where water is intersected during drilling. The location of these bores will be such that they maximise the use of existing cleared areas to enable ongoing access and minimise native vegetation impact.

Details of the existing regional bores (where available) and new monitoring bores will be recorded and include:

- Construction details: Borehole depth, casing size, materials used, screen location and aperture size, grouting/formation packing.
- Geological details (lithology) and geophysical logs
- Hydrogeological details: first water strike, static water level, water quality data

Based on the current conceptual understanding, it is recommended the monitoring bores to be constructed as shown in Figure 12. Detailed (as constructed) designs will be provided following the installation of the monitoring bores.

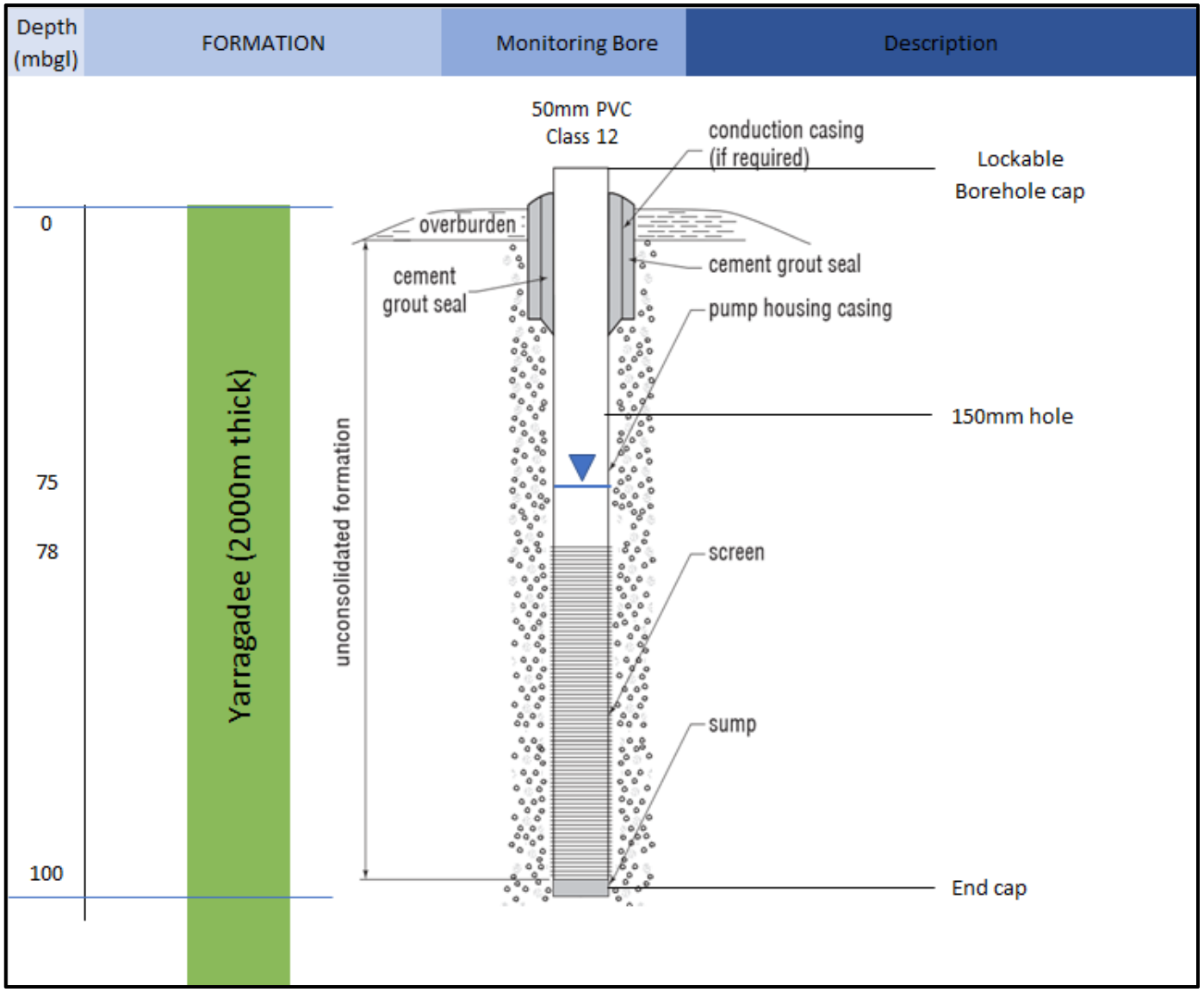

Figure 12: Proposed monitoring borehole construction (adapted from Minimum Construction Requirements for Water Bores in Australia, 2012)

5.4 Approvals

The EP469 production groundwater bore will require a 26D licence to construct prior to installation and subsequently a 5C licence to abstract water prior to utilisation for earthworks and drilling activities. The depth of the production groundwater bore is currently being discussed with DWER. The two exclusive monitoring bores (i.e., not the water supply bore) do not require approval and may be installed prior to ground disturbance in order to collect baseline information.

5.5 Monitoring frequency

The Australian guidelines for groundwater monitoring recommend monthly sampling as an initial baseline frequency to establish groundwater quality and levels for the first two years before drilling activities for the exploration bore commence and during drilling. Given the circumstances of the drilling of the exploration well, water levels and site physio-chemical parameters will be collected on a monthly basis with more detailed sample collection occurring on a quarterly basis to track any deviation from the baseline conditions over time (Sundaram et.al, 2009). The monitoring will act as surveillance monitoring and if / when a notable deviation from the baseline data is observed, more frequent investigative monitoring will be undertaken that is likely to comprise a repeat monitoring event following the detection of the deviation and a frequency to be determined following the assessment of the data (e.g. monthly).

Monitoring will continue for the duration of the activity on the drill site and will cease after the next quarterly monitoring round post completion of the exploration drilling if no impact has been identified, or for up to a maximum of two years if an impact has been identified.

5.6 Water quality monitoring parameters

All sampling at the drill site will be undertaken in accordance with the Australian Standard (AS/NZS 5567) and as recommended in The Guideline for Groundwater Monitoring (2016). Collected samples will be sent to a National Association of Testing Authorities (NATA) registered laboratory to undertake chemical analyses using NATA-accredited analysis methods.

The Contaminants of Potential Concern (CoPC) as presented in Table 2, is suggested to be analysed for during the monitoring of the bores at the drilling site as these contaminants have an association with the proposed activities and are more likely to present a risk to human health and the environment:

Table 2: Contaminants of Potential Concern

Frequency	Parameter
Monthly	• Water Level • Temperature • Conductivity
Quarterly	• Physical parameters • Total and dissolved metals • Nutrients • Organochlorine and Organophosphorous Pesticides (OC/OP) • Monocyclic Aromatic Hydrocarbons (MAH) • Halogenated Aliphatic & Aromatic Compounds (HAC) • Polynuclear Aromatic Hydrocarbons (PAH) • Phenolic Compounds • Total Petroleum Hydrocarbon / Total Recoverable Hydrocarbon (TPH/TRH) • Benzene, Toluene, Ethyl Benzene, Xylene and Naphthalene (BTEXN) • Volatile Organic Compounds (VOC) • Semi Volatile Organic Compounds (SVOC)

5.7 Data Analysis and Reporting

A database will be developed for the capturing of the monitoring data and will include the following:

- Date of monitoring event
- Monitoring bore details
- Measured groundwater levels
- Field measured physiochemical parameters
- Sampling results for laboratory analysed parameters
- Hydrographs and analyte graphs for each monitoring bore
- Site specific (calculated from monitoring results according to ANZECC 2000) trigger values

The sampling data will be, as a minimum, compared against the following guideline documents, but also against site specific trigger values calculated for the drill site:

- Australian Drinking Water Guidelines (NHRMC, NRMMC, 2011) – for use where petroleum activities occur within or in proximity to groundwater used for drinking water supplies
- Water Quality Guidelines for the Protection of Aquatic Ecosystems (ANZECC and ARMCANZ, 2000) – for general use in relation to the protection of aquatic ecosystem health and beneficial uses
- Contaminated Sites Guidelines (Department of Environment and Conservation, 2012) – for use in conjunction with the *National Environment Protection (Assessment of Site Contamination)* Measure *1999*

A monitoring report will also be compiled and submitted to the DMIRS and DEW. The monitoring report will contain, as a minimum, the following information:

- Summary of conditions during sampling
- Confirmation of sampling techniques
- Summary of results (tabulated)
- Updated hydrographs and analyte graphs
- Laboratory certificates
- Chain of Custody documentation

References

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ISO 14001 Environmental Management

AS/NZS 4801:2001 Occupational Health and Safety Management

ISO 9001 Quality Management

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