Appendix H West Erregulla Groundwater Assessment

RPS Aquaterra

WEST ERREGULLA GROUNDWATER ASSESSMENT

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EXECUTIVE SUMMARY

BACKGROUND

Warrego Energy Pty Ltd (Warrego Energy) intend to drill a gas appraisal well (West Erregulla 2) as part of their West Erregulla Gas Project. The well is to be drilled within Onshore Exploration Permit EP 469 at the site of the West Erregulla 1 discovery well, which is located 40km southeast of Dongara in Western Australia. The well is targeting low porosity Permian sandstones below 3,750m total vertical depth (TVD) and depending on the gas flows encountered in the primary hole; a side track hole may be initiated and subjected to fracture stimulation. The appraisal well will be used to collect data pertaining to the commercial potential of a tight-gas reserve.

WATER DEMANDS

A water supply will be required on site to supply water for drilling operations, camp supplies and for hydrofracturing of the appraisal well. The Yarragadee aquifer underlies the study area and has been identified as a favourable aquifer for the installation of a water supply bore for the project. The average demand over the duration of the project for drilling and camp water is less than 3L/s. The hydraulic fracturing operation will require a greater volume of water and prior to testing a Turkey Nest will be filled to supply the required water. A peak demand of 21L/s is anticipated in order to be able to fill the Turkey Nest (3,750kL) over a two day period. The drilling and Fraccing operations will last approximately 70 days.

In total a volume of 15,000kL is anticipated to be required, however, in order to cover unforeseen eventualities such as zones of lost circulation during drilling it is recommended that a volume of up to 40,000kL be applied for. The average demand over the 70 days is 6.4L/s with a peak demand of 21L/s to fill the turkeys nest. Due to the small abstraction volumes and short term use, the Department of Water has advised that test pumping of the water supply bore will not be required, assuming that during bore development airlift yields indicate sufficient bore capacity to provide project water demands.

RISK ASSESSMENT

A risk assessment has been undertaken to assess potential contamination to the Yarragadee aquifer from the hydrofracturing operation, which will take place at a depth in excess of 3750m below ground. The assessment has found that the risks posed to the Yarragadee aquifer due to hydro-fracturing are negligible.

LICENCING AND APPROVALS

Wherever a groundwater source is to be drilled (including both the associated exploration drilling and production bore construction), then a 26D Groundwater Licence (GWL) will be required. The 26D GWL normally requires legal right of access to the ground (for example an Exploration Lease would be sufficient for exploration drilling).

In addition, before any of the sources can be used for water supply, a 5C Groundwater Well Licence (GWL) will be required. The 5C GWL normally requires formal ownership of the tenement on which the groundwater source exists, with a licence that is consistent with the use to which the water will be put.

SCHEDULE, TENURE AND COSTS

Costs estimates and a schedule have been prepared for the installation of the water supply bore prior to the drilling of the appraisal well. A notional schedule for the fieldwork component of the project is presented in Section 5.7. The duration of licensing, drilling and testing activities is based on our recent experience. The timing to complete the licensing process and the potential for difficult ground conditions to be encountered during drilling means that the overall duration of the work cannot be guaranteed.

Salient points that must be noted in relation to the schedule are:

- Licensing and approvals should be considered a priority; notably land tenure, environmental clearance and heritage clearance which will be required to allow access and ground disturbance in the proposed drilling area.
- With current industry conditions, drilling contractors are in high-demand and the availability of a drilling contractor within the project time frame cannot be guaranteed. It will be prudent to contractually engage a suitable drilling contractor as soon as it is confirmed when the water supply will be required by.

Based on our notional schedule of preliminary works commencing in November 2011 and site works commencing in March 2012, the water supply would be installed, licensed and available by the end of May 2012.

TABLE OF CONTENTS

TABLES

FIGURES (compiled at end of report)

APPENDICES

1. INTRODUCTION

1.1 Background

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The appraisal well will be used to collect data pertaining to the commercial potential of a tight-gas reserve. Coffey Environments have been engaged by Warrego Energy as the lead environmental consultant for the project and have identified the need for a groundwater assessment to support the design and implementation of the project and to provide supporting information for the Environmental Risk Assessment and Environmental Management Plan. RPS Aquaterra have been engaged by Warrego Energy to complete the groundwater assessment.

The key issues as outlined in the project brief are as follows:

- Potential impacts of drilling and well testing on the underlying aquifers where the appraisal well will be drilled, including potential water quality impacts from the use of drill and hydrofracturing fluids.
- Identification of a groundwater source to provide 4ML of water over a relatively short time period and storage and transport of the water.
- Potential impacts from water supply abstraction on the surrounding aquifer.

The following report presents the findings of this initial desktop hydrogeological review and presents recommendations for further investigations in order to be able to meet with both operational and regulatory requirements.

1.2 Area of Investigation

The extents of the area of investigation for this study are described by a 20km radius surrounding the appraisal well (Figure 1).

For the purposes of this assessment the area described above will be referred to as the “Study Area” and the location of the planned appraisal well, West Erregulla 2, will be referred to as the “Drill Site”.

1.3 Climate

The Study Area, which lies to the southeast of the township of Dongara area experiences hot dry summers and cool wet winters. Average monthly rainfall data from the Arena rainfall stations (BoM Website) are provided in Figure 2. The Arena automated rain gauge is located approximately 15km east-northeast of the Drill Site and has 30 years of data. Other climatic data is obtained from Eneabba, located approximately 43km south, Morawa located 72km east-northeast and Geraldton located 100km to the northwest. At Eneabba, January and February are the hottest months with mean monthly maximums of 36.1°C to 36.2°C. July and August have the lowest mean minimum temperature of 9°C.

The majority of rain falls during the cooler months of June and July with a distinct wet season from May to August. Average annual rainfall within the project area (Arena) is around 409mm. There is also a large rainfall gradient between coastal and inland areas; the mean annual rainfall at Geraldton and Eneabba is 447m and 500mm respectively, while the long term average at Morawa is 332mm. Evaporation data is only available for Geraldton where the average annual pan evaporation is 2,445mm, more than five times greater than average annual rainfall. Peak evaporation occurs in January with an average of 334.8mm (10.8mm/day) and the lowest evaporation occurs in July with an average of 93mm (3mm/day).

1.4 Physiography

The physiographic units of the Northern Perth Basin are described in detail by Playford *et.al.* (1976). The project area is located within the Arrowsmith Region and is characterised as a deeply dissected and undulating part of the Victoria Plateau at an elevation of around 100m to 200m above sea level. The boundary with the Victoria Plateau is generally a steep breakaway up to 10m high. The area contains hills of Jurassic sediments capped by a laterite surface which has formed post-erosion; remnants of the Victoria Plateau are preserved as Mesas and Buttes. The present day drainages are not considered to be sufficient to have resulted in the current landscape, and the dissection and erosion are inferred to have taken place in a more humid climate, possibly during the Pleistocene. The Arrowsmith Region is bordered to the west by the Gingin Scarp, the eastern limit of marine erosion and former Quaternary or Late Tertiary shoreline.

2. GEOLOGY

2.1 Regional Setting

The Study Area 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 3).

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 (Mory and Iasky, 1996).

On the Allanooka High, 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.

2.2 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 (Moray and Iasky, 1996).

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

2.2.1 Jurassic Sediments

Yarragadee Formation

The Yarragadee Formation is a predominantly sandy formation of 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. The unit is essentially a fluvial deposit in which silt and clay deposits may represent a lacustrine or overbank environment.

Cadda Formation

The Cadda Formation is a Middle Jurassic, clastic and fossiliferous limestone unit that lies conformably between the Cattamarra Coal measures and the Yarragadee Formation. The Cadda

formation consists of shale, siltstone and medium to very coarse sandstone, grading in places to sandy, shelly limestone. The depocentre for the Cadda Formation is in the centre of the onshore Northern Perth Basin where it reaches a thickness of up to 290m, thinning to the north, east and west. The Cadda Formation is regarded as a shallow marine to near shore deposit and represents a short lived, shallow marine transgression in the Middle Jurassic period.

Cattamarra Coal Measures

The Cattamarra Coal Measures are an Early to Middle Jurassic age coal bearing unit that rest conformably between the underlying Eneabba Formation and the Cadda Formation. The formation consists of fine-grained to coarse-grained sandstones, interbedded with dark carbonaceous siltstone and claystone and seams of coal up to 11m thick. The unit thickens southwards from less than 100m on the Greenough Shelf to nearly 1,500m near Cataby 1 drill hole, approximately 175km south of the project area. Within the Study Area, the Cattamarra Coal Measures are around 500m thick. The depositional setting of the Cattamarra Coal Measures is interpreted as deltaic, with the fine grained carbonaceous lithologies and the coal seams representing low, marshy mudflats, cut by small narrow channels of slow-moving water. Thicker sandstone beds, especially those which overlie the coal seams, are probably fluvial in origin, with deposition inferred in an upper delta plain environment.

Eneabba Formation

The Eneabba Formation is an Early Jurassic terrigenous unit and consists of fine to coarse grained feldspathic sandstone interbedded with multi-coloured siltstone and claystone. Minor grey carbonaceous clay and thin coal seams are also present. The Eneabba Formation thickens to the south and reaches a maximum observed thickness of 854m in the vicinity of the Study Area. The unit lies conformably between the underlying Lesueur Sandstone and the Cattamarra Coal Measures. The multi coloured lithologies present in the unit, suggest oxidising conditions in a continental environment. The presence of thick lenticular sandstone bodies is interpreted as channel fill deposits in an alluvial setting.

2.2.2 Triassic Sediments

Lesueur Sandstone

The Lesueur Sandstone is a coarse grained unit of Middle to Late Triassic age and consists of coarse to very coarse feldspathic and pebbly sandstone with minor siltstone and conglomerate. Sandstone predominates through the unit and the proportion of fine-grained lithologies increases to up to 20% to the north of Eneabba. The Lesueur Sandstone ranges dramatically in thickness from 3000m in the southeast to 100m near Dongara. Deposition is inferred to be of fluvial origin, possibly in an alluvial fan setting as indicated by the dominance of coarse grained lithologies in the south. Palaeocurrent directions derived from planar cross-beds are predominantly to the northwest and the high proportion of feldspar indicates a granitic provenance, probably from immediately east of the Dandaragan Trough.

Woodada Formation

The Woodada Formation is an interbedded fine-grained sandstone and carbonaceous siltstone of Early to early-Middle Jurassic age with a maximum recorded thickness of 230m. Deposition is inferred to be in a deltaic environment and represents the commencement of a marine regression. Wireline logging indicates that the Woodada Formation shows a character intermediate between the underlying fine grained Kockatea Shale and overlying coarser material of the Lesueur Sandstone.

Kockatea Shale

The Kockatea Shale is an Early Triassic age unit comprised of dark shale, micaceous siltstone, and minor sandstone and limestone. Two sandy members are recognised in the Kockatea Shale. They are the Bookara Sandstone Member and the Arranoo Member. The Bookara Sandstone Member is restricted to the Greenough Shelf and is not anticipated to be represented in the Study

Area. The thinly bedded sandstone, siltstone, mudstone, and minor limestone in the upper part of the Kockatea Shale in the Dongara–Mount Horner area has been informally referred to as the Arranoo Member and Arranoo Sandstone Member. The Kockatea shale generally increases in thickness to the south and thicknesses of up to 1060m have been intersected. A local depocentre is inferred at Beharra Springs, approximately 17km to the west of the Study Area. The formation represents a period of shallow-marine deposition with sandstone bodies in the middle and lower part of the formation being ascribed to strandlines and offshore bars.

2.2.3 Permian Sediments

Dongara Sandstone

The Dongarra Sandstone is predominantly a Late Permian age silty sandstone below the Kockatea Shale. Two units have previously been distinguished and separately referred to as the Basal Triassic Sandstone and Wagina Sandstone. The Basal Triassic Sandstone referring to the clean, coarse grained unit directly below the Kockatea Shale, and the Wagina Sandstone referring to a largely bioturbatred marine sandstone of Late Permian age. No distinct age has been derived for the Basal Triassic Sandstone, and based on wire line logs the entire Dongara Sandstone unit consists of a series of upward coarsening cycles with the „Basal Triassic Sandstone" representing the upper part of the youngest cycle. For this reason the entire sandstone section is best regarded as one unit, the Dongara Sandstone, which is possibly all latest Permian in age.

The Dongara Sandstone consists predominantly of bioturbated medium to coarse sandstone with minor thin pebble bands, carbonaceous streaks and carbonaceous siltstone. The uppermost part of the unit contains a significant proportion of monazite (a potentially radioactive, reddish-brown phosphate mineral containing rare earth metals) and is noticeably cleaner and coarser grained with less carbonaceous material and little evidence of biotubation.

2.3 Structure

The geological structure of the Study Area is relatively well known as a result of extensive seismic surveying and exploration for oil and gas since the sixties. In the Study Area the Mesozoic and Permian sedimentary units thicken and deepen in a regional south easterly direction. This trend has been disrupted by a set of large north-south trending normal faults parallel to the Urella fault. To the north of the Study Area faulting generally trends in a northwest to southeasterly direction. The major fault traces are displayed on Figure 5, with the relative vertical displacement of the sediments along the faults shown on the geological sections in Figure 6. Numerous minor faults also occur that are not shown.

3. HYDROLOGY AND HYDROGEOLOGY

3.1 Regional Drainages

The northern and southern limits of the Study Area are bounded by two regional drainage systems, the Irwin and Lockier Rivers to the north and the Arrowsmith River to the south. The Study Area is also dissected by numerous small water courses that either drain westward from the Arrowsmith Region onto the Swan Coastal Plain, or north or south towards either of the two major drainage systems.

All three rivers begin inland on the Yilgarn Plateau where average rainfall is less than 250mm and most of the natural vegetation remains. The Irwin River discharges to the ocean and has a total length of approximately 160km and a catchment area of 6,072km^2. The Lockier River is a tributary to the Irwin River with their confluence in the north of the Study Area. The Arrowsmith River is much smaller at about 85km and has a catchment of 1,605km^2. The Arrowsmith River does not reach the ocean and discharges to wetlands and karstic aquifers approximately 5km from the coast. Both river systems run through the hilly terrain and agricultural areas of the Arrowsmith Region, before traversing the coastal plain and an area of coastal dunes and discharging to the ocean.

The Irwin and Arrowsmith Rivers flow intermittently, with significant flows predominantly through the winter months, but with some semi-permanent pools persisting through the summer. Water quality is generally brackish to saline with water quality in both Irwin and Lockier Rivers in the order of 3,500mg/L to 4,500mg/L.

Available river gauging data (DoW website), indicate that there is recharge to the groundwater system (losing streamflow) from the Irwin River across the Swan Coastal Plain.

Across the Arrowsmith Region, the Irwin and Arrowsmith Rivers are known to receive a small contribution of fresh groundwater from minor spring-fed tributaries such as Springy Creek (Irwin River) and at the sites of some semi permanent pools in the river.

3.2 Regional Aquifers

All of the sedimentary formations within the Study Area may be expected to contain groundwater to some degree. Major regional groundwater resources only occur within the Yarragadee Formation and Lesueur Sandstone, with lesser aquifers hosted in the Cattamarra Coal Measures and the Eneabba Formation. However, within the Study Area only the Yarragadee Aquifer is economically viable to exploit.

3.2.1 Yarragadee Formation

The Yarragadee Formation is widespread and is the largest aquifer in the Perth Basin. Within the Study Area the Yarragadee Formation is present at surface and is unconfined in its upper part. To the east the Yarragadee aquifer is confined beneath the Otorowiri Siltstone and is bounded by the Urella Fault.

The Yarragadee is a multilayered flow system and becomes increasingly confined at depth due to the layered nature of the formation. Irwin (2007) reports downwards head gradients beneath the Victoria Plateau and Arrowsmith Region and upwards head gradients beneath the Swan Coastal Plain.

Within the Study Area depths to the upper water table are generally in excess of 100m below ground level and given the layered nature of the formation, very little direct rainfall recharge is anticipated to reach the regional water table. Rather, the presence of interbedded siltstones and shales is likely to result in numerous perched water tables.

Bekele *et.al.* (2006) calculated recharge rates to the Parmelia Formation approximately 20km to the northeast of the Study Area from rainfall infiltration, to be 20mm to 50mm per year for cleared land south of Mingenew, and similar rates are expected for the Yarragadee Formation sub-cropping in the Arrowsmith Region. These recharge rates are equivalent to 4% to 11% of annual rainfall. Commander (1996) estimated a pre-clearing recharge rate to the Yarragadee for the Irwin

valley of 7% of 450mm annual rainfall, and stated that groundwater levels were in fact rising due to an increase in recharge, by a factor of two or three, as a result of land clearing in the region.

Minor recharge from stream flow infiltration in the upper reaches of the Irwin River is also expected.

Discharge from the Yarragadee Aquifer occurs as subsurface, artesian flow to the Superficial Aquifer on the Swan Coastal Plain. Discharge also occurs along the Irwin, Lockier and Arrowsmith Rivers as spring flow. Commander (1996) reports that heads in the Yarragadee Formation are at or above the Irwin River valley level between Irwin (in the west) and Warradong Spring Road (in the east) and groundwater discharges to the river over that reach. Upstream of Warradong Spring Road the potentiometric surface is below the river valley and so flows in the river are in fact a source of groundwater recharge. However, no gauging data is available along this section of the river to quantify potential volumes or rates of recharge.

Numerous springs that occur around the margin of the Victoria Plateau are discharge sites for groundwater flow from the perched aquifers and are not related to the main groundwater flow system (Allen, 1980).

Water quality in the Yarragadee Aquifer is fresh to brackish. The salinity of groundwater in the Yarragadee Formation generally increases with depth. Groundwater salinity along the Dongara Borehole Line (Irwin, 2007) is presented on Figure 7.

Sixteen kilometres to the south at the Eneabba No.1 oil exploration well, the formation water in the whole of the Yarragadee Formation was reported as fresh (Commander, 1978).

3.2.2 Cadda Formation

The Cadda Formation may host minor localised permeable horizons but is generally of very low permeability. The Cadda Formation, where present, is a regional aquiclude and acts as a confining bed to the underlying aquifers of the Cattamarra Coal Measures.

3.2.3 Cattamarra Coal Measures and Eneabba Formation

The Cattamarra Coal Measures and underlying Eneabba Formation are formerly known as the Cockleshell Gully Formation and the Department of Water still recognises the Cockleshell Gully Formation as one of the groundwater allocation units in the Perth Basin. The Cattamarra Coal Measures and Eneabba Formation comprise a multilayer flow system, confined by the Cadda Formation and internally confined by the thick mudstone sequences and coal seams of the coal measures. The flow system is isolated from the Yarragadee aquifer except for where faulting may have partially juxtaposed the two systems. The flow system of the Eneabba sandstones is also likely to be isolated from that of the sandstone units of the upper Cattamarra Coal Measures.

Within the Study Area both the Cattamarra Coal Measures and Eneabba Formation are too deep for economical exploitation. In the north of the basin the units outcrop and the confining Cadda Formation is not present, likewise the units also outcrop further south on the western margin of the basin. Groundwater flow in the unit will be confined, the configuration of the Potentiometric surface is not know but is presumed to be similar to that of the Yarragadee.

North of the Study Area, rainfall recharge is likely to occur along the area of outcrop south of the Greenough River. To the east of Ellendale Crossing, groundwater of the Cattamarra Formation is in hydraulic connection with the Greenough River and the aquifer is presumed to be locally recharged by the river.

Water quality elsewhere in the Northern Perth Basin where these aquifers are utilised is generally brackish with some minor fresh water restricted to the areas where rainfall recharge is thought to occur. At Erregulla 1, located approximately 10km east northeast of the Drill Site a groundwater salinity of 30,000mg/L NaCl was recorded from below the Cadda Formation and it is likely that within the Study Area water in this unit is hypersaline.

3.2.4 Lesueur Sandstone

As with the overlying Cattamarra Coal Measures and Eneabba Formation, the Lesueur Sandstone within the Study Area is beyond economic exploitation and is also likely to contain hypersaline

groundwater. The Lesueur Sandstone subcrops to the south of the Study Area from Leeman to Wedge Island and is overlain by Cainozoic sediments.

3.3 Regional Groundwater Levels and Groundwater Flow

Generalised water level contours for the upper Yarragadee are presented on Figure 8. The water table contours are a compilation from limited data sourced from the DoWs WIN database (DoW, 2011) and represent water levels collected between 1942 and 2009. Where no bore elevations were provided for calculating water table elevation, elevations have been derived from regional topographic data. As such the contours may not be entirely accurate but provide a generalised overview of the dominant groundwater flow patterns.

Groundwater flow is generally in a westerly direction beneath the Study Area. The water table is relatively flat above the 80m contour but steepens dramatically and drops off to the west towards the Swan Coastal Plan. At the Drill Site the water table is expected to be around 75mAHD or 145mbgl. The east west trend in water levels in the Yarragadee and distribution of head gradient is shown on Figure 9.

3.3.1 Structural Influence

The influence of structural control on groundwater flow in the Study Area is not readily apparent given the limited data available; however, elsewhere in the Northern Perth Basin studies have shown compartmentalisation of groundwater flow by faulting (Forth, 1971). In areas of more detailed water level data, a close correlation between the regional water table configuration and the major regional faults can be observed, indicating that the faults may be acting as inhibitors to groundwater flow and compartmentalising the major aquifers, with water levels “stepping down” to the west across major faults.

3.4 Groundwater Quality

As with regional water levels, available regional groundwater quality has been retrieved from the DoW's WIN Data Base (DoW, 2010). The water quality data is a compilation of available data irrespective of date of collection or depth. Groundwater salinity represented as total dissolved solids (TDS) is presented on Figure 10. Groundwater salinity gradients are apparent increasing to the north and east showing the influence of saline groundwater recharge along the Irwin River and Urella Fault. There is also a salinity gradient to the west toward the Swan Coastal Plain.

Away from these areas of elevated salinity within the Study Area, TDS concentrations in the vicinity of the Drill Site range from 530 to 700mg/L and at the drill site water quality in the upper Yarragadee is expected to be in this range.

Groundwater salinity within the Yarragadee is also shown to increase to the east towards the Urella Fault and with depth along the Dongara Borehole Line on Figure 7.

Sixteen kilometres to the south at the Eneabba No.1 oil exploration well, the formation water in the whole of the Yarragadee Formation was reported as fresh.

At Erregulla 1, located approximately 10km east northeast of the Drill Site a groundwater salinity of 30,000mg/L NaCl has been recorded from below the Cadda Formation.

3.5 Regional Groundwater Use

The Study Area is situated within a proclaimed groundwater area under the *Rights in Water and Irrigation Act 1914*. In proclaimed groundwater areas, a licence is required, to take water from a watercourse or groundwater aquifer. For licencing and allocation purposes, the project is located within the Twin Hills sub-area of the Arrowsmith groundwater area.

Licensed groundwater abstraction from the Yarragadee Aquifer within a 20km radius of the project area is presented in Figure 11 and summarised on Table 3.1. Groundwater use in the area is limited by the large depth to water and significant costs associated with exploiting the aquifer.

Five licenses for groundwater abstraction from the Yarragadee aquifer exist within a 20km radius of the project area.

The major use of groundwater in the area from the Yarragadee Aquifer is for irrigation and cattle grazing. The Murion Cattle Company hold a licence for 1,700,000kL/annum (approximately 54L/s). All other licences are for relatively small volumes and range from 0.35 to 3.6L/s.

Table 3.1: Twin Hills - Yarragadee Groundwater Abstraction Licences - 20km Radius from Drill Site

Licence Number	Holder	Allocation (kL/annum)	Number of Drawpoints	Distance of closest Drawpoint to Drill Site (km)
156102	Murion Cattle Company Pty Ltd	1,700,000	1	6
158844	C.A. Benson	35,000	2	10
155141	Origin Energy	17,200	5	15
156713	C. & B. Harding	11,000	1	17.5
64114	Milo Pty Ltd	113,000	2	19

4. POTENTIAL IMPACTS OF HYDRO-FRACTURING ON LOCAL AQUIFERS

Potential risks to groundwater from hydro-fracturing vary from site to site and are also dependant on the particular additives used in the fracturing process. Generally speaking, potential impacts are associated with the escape of toxic fracturing fluid and/or fluid additives into aquifers with resultant contamination of groundwater and presenting a hazard to either environmental values or to human health.

Hydraulic fracturing fluids are used to either initiate or expand fractures in the target formations, as well as to transport proppant (sand or other granular substance) into fractures to hold open (prop) formation fractures created by hydraulic fracturing. The objective is to increase the hydraulic conductivity and therefore the yield of a well, whether it be for water, oil, or gas.

The most basic fracturing fluid is simply fresh water and sand, however, more advanced oil and water-based fluids and treatments have been developed to more efficiently induce and maintain permeable and productive fractures. For ideal performance, fracturing fluids should possess the following four qualities (USEPA, 2004):

- Be viscous enough to create a fracture of adequate width.
- Maximise fluid travel distance to extend fracture length.
- Be able to transport large amounts of proppant into the fracture.
- Require minimal gelling agent to allow for easier degradation or “breaking” and reduced cost.

Some of the fluids and fluid additives commonly in use to provide these desirable fluid qualities may contain constituents of potential concern.

In general a proportion of the injected fluids are recovered as either flow-back as fluid is pushed out of fractures after injection and the fractures close back to the diameter of the proppant or close fully where no proppant is present. Addition fluid may also be recovered during flow testing of the well; however the hydraulic gradients and radius of influence during flow testing will be much lower than those in play during the hydro-fracturing and a lot of fluid will remain outside the capture zone of the flow test.

The fracturing fluids that flow beyond the capture zone are affected by regional groundwater flow and may be diluted by groundwater.

4.1 Well Design

An important factor in the assessment of risk is the proposed well design. The proposed design for the West Erregulla well is detailed below. From this it can be seen that the Yarragadee aquifer will be protected by three layers of grouted steel casing all independently pressure tested when the fraccing operations take place:

- A 20” conductor will be preset to approximately 20m below the surface.
- The 13-3/8” Surface casing string will be set at a depth of 500m and cemented in place. The purpose of this string is to establish a competent casing seat and allow full blow-out prevention protection when drilling at lower depths, and to isolate any ground water aquifers.
- The 9-5/8” intermediate casing will be set at 2000m and cemented in place. This will case off the upper wellbore and allow drilling of the lower (reservoir) sections in the 8-1/2” hole.
- The 7” casing will be set at around 4000m and cemented in place.
- Production tubing will probably be 3-1/2” OD and will be pressure tested to a pressure greater than will be utilised during fraccing operations.
- Frac fluid will be pumped down the production tubing and into the formation at +/- 4000m.

4.2 Potential Risks to Groundwater from West Erregulla-2 Appraisal Well

A qualitative risk assessment of potential contamination to groundwater resulting from hydraulic fracturing at the West Erregulla-2 appraisal well has been undertaken considering the well design and the specific local geology and hydrogeology at the drill site and in the wider Study Area.

The risk assessment is based on potential risk to the Yarragadee Aquifer as this is the only local aquifer with beneficial use in terms of water quality and economic accessibility.

For the risk assessment a number of potential mechanisms for fracturing fluid escape to groundwater were assessed as follows:

- Well failure allowing direct fluid escape to aquifer.
- Well grouting failure allowing annular escape of fluid to aquifer.
- Over-fracturing and cross-linking of fracture target with aquifer.
- Migration of fracture fluid beyond the well capture zone migrating to aquifer.
- Migration of fracture fluid along faults in the area.
- Surface spill of fracture fluids intercepting groundwater.
- Uncontained flow-back and discharge to surface resulting in fracture fluids intercepting groundwater.

The risk assessment has been undertaken based on the Risk Assessment Matrix and supporting tables presented in Appendix A, and presents an assessment of residual risk assuming standard industry procedures and protocols are in place.

An assessment of potential risks to groundwater associated with drilling and hydro-fracturing of the West Erregulla-2 appraisal well is presented on Table 4.1.

From Table 4.1 it is apparent that the greatest risk to groundwater is from the surface handling of the fracture fluids. As the gas appraisal well is to be drilled mid 2012, a detailed design of the fraccing setup, including spill containment measures and composition of the fraccing fluid, has not yet been completed. However for the purposes of this analysis, a maximum potential spill of 10 barrels of fracturing fluid (approximately 1590L) has been assumed. At a concentration of around 3% fraccing additives, this would amount to just under 50L of chemical being spilt. However, with suitable control/mitigation measures in place such as bunding, spill kits on hand, and a procedure in place for clean up etc, the likelihood and potential volume of a spill reaching soil or groundwater could be reduced with a subsequent reduction in likelihood and consequence, and a reduction of the overall risk ranking to moderate. Similarly if the concentration of hazardous chemicals is significantly less than 3% or the spill volume less than 10 barrels, the consequences may be reduced to high and the overall risk would be reduced to low.

Given the very large depth from the Yarragadee aquifer to the proposed test zone below 3750m depth, the risk of any escape of fluid from the test zone to the Yarragadee is considered to be negligible.

Table 4.1: Hydrofracturing Risk to Yarragadee Aquifer

No.	Activity/ Cause	Management measures applied				Comments
		Hazard	Residual Likelihood	Residual Conseq.	Residual Risk & Score	
1	Hydrofracturing of Target Formations					
	Handling / Pumping of Fluid	Pipe Burst / Surface spill of fracture fluids intercepting groundwater	Unlikely	Major	High (14)	Well head, pipe work and containment vessels should be appropriately bunded. The entire pipeline system will be pressure tested prior to operation so a spill is unlikely.
	Hydrofracturing Operation	Well failure allowing direct fluid escape to aquifer	Rare	Moderate	Low (3)	The test zone will be isolated and a pressure test of the isolation will be made before the operation commences. The upper sections of the hole will be cased and cemented so it is not possible for the frac fluid to enter another zone. The upper zones of the annulus will be open to surface and therefore impossible to pressurise. Therefore this is not expected to occur.
	Hydrofracturing Operation	Well grouting failure allowing annular escape of fluid to aquifer	Rare	Moderate	Low (3)	Given the large vertical distance from the test zone to the Yarragadee Aquifer, this is not expected to occur. In the event that it did occur, leakage volumes would be unlikely to be of concern.
	Hydrofracturing Operation	Over-fracturing and cross-linking of fracture target with aquifer	Rare	Moderate	Low (3)	Given the large vertical distance from the test zone to the Yarragadee Aquifer, and the low permeability formations in between, this is not expected to occur.
	Hydrofracturing Operation	Migration of fracture fluid beyond the well capture zone migrating to aquifer	Rare	Moderate	Low (3)	Given the large vertical distance from the test zone to the Yarragadee Aquifer, and the low permeability formations in between, this is not expected to occur.
	Hydrofracturing Operation	Migration of fracture fluid along faults	Rare	Moderate	Low (3)	Given that in areas of more detailed water level data, a close correlation between the regional water table configuration and the major regional faults can be observed, this indicates that the faults in the area may be acting as inhibitors to groundwater flow and compartmentalising the major aquifers. Therefore in addition to the effects of dilution from regional groundwater flow this is not expected to occur.
	Flow-back recovery	Uncontained flow-back and discharge to surface resulting in fracture fluids intercepting groundwater	Unlikely	Major	High (14)	Well head, pipe work and containment vessels should be appropriately bunded. During flowback the well will have a downhole safety valve and numerous control valves (Christmas Tree) at surface. The pipeline system will be pressure tested prior to operation reducing the likelihood of a spill.

Note: This risk assessment should be viewed in conjunction with the supporting tables supplied in Appendix A.

5. PROJECT WATER SUPPLY

5.1 Water Demand

Notional water demand for the supply of water for drilling, dust suppression and camp domestic supplies have been provided by Add Energy and are summarised on Table 5.1. The average demand over the duration of the project for drilling and camp water is less than 3L/s. The hydraulic fracturing operation will require a greater volume of water and prior to testing a Turkey Nest will be filled to supply the required water. A peak demand of 21L/s is anticipated in order to be able to fill the Turkey Nest (3,750kL) over a two day period.

In total a volume of 15,000kL is anticipated to be required, however, in order to cover unforeseen eventualities such as zones of lost circulation during drilling it is recommended that a volume of up to 40,000kL be applied for.

Table 5.1: Anticipated Water Demand

Activity	Duration (days)	Estimated Volume (m^3)	Average Rate (L/s)
WE-2 Vertical Hole	29	918	0.36
Camp Water	29	908	0.36
WE-2 Side track-Horizontal	21	510	0.28
Camp Water	21	667	0.37
Fraccing Operations	20	11,780	6.8
Camp Water	20	318	0.18
Total Volume	-	15,101	-

5.2 Water Supply Potential

The potential for locating a suitable water supply close to the drill site is considered to be very good, the only limiting factors being the large depth to water table and encountering sufficient sandstone units within the Yarragadee below the water table.

A hydraulic conductivity value of 10m^2/day is typically adopted as general value for the sandstone units of the Yarragadee, however, actual values for individual sand layers may vary significantly. Typical porosities are of the order of 30 to 40% and specific yields around 25%.

A cumulative intersection of 20m or more of clean sandstone below the water table (equivalent to an aquifer transmissivity of 200m^2/day) should provide sufficient transmissivity to supply the required water maximum demand without excessive drawdown.

Irwin (2007) reports sand beds ranging from less than 5m to greater than 20m along the Dongara Borehole Line and further North at Allanooka, Allen (1980) reports individual sandstone beds ranging from 1 to 30m.

If lithology from the original West Erregulla-1 was available for inspection it would be possible to design a notional water supply bore in advance of drilling. However, without the aid of such information, a more conservative approach must be undertaken. Based on the assumption that the Yarragadee will contain at least 20% clean sandstone beds, around 100m of saturated aquifer will need to be intercepted, resulting in a bore up to 250m deep.

The sourcing of 1.7GL/annum of water for the Murion Cattle Company from a single bore is equivalent to an average abstraction rate of approximately 54L/s which provides further confidence that sufficient permeability exists locally within the upper Yarragadee aquifer.

5.2.1 Bore and Pump Sizing

To deliver a maximum yield of 21L/s against an assumed head of up to 180m would require a 55kW, 8" diameter pump (based on Grundfos and Lowara pump curves).

Bore casing of 250mm ND would be required to house the pump, and given the bore depth, a completion of either steel or FRP (Fibre Reinforced Plastic) is recommended.

If lower pumping rates can be accommodated then it may be possible to reduce the bore size accordingly, thus saving on drilling and materials cost. Indicative maximum yields achievable by various pump sizes and bore diameters, assuming a 180m duty head, are summarised on Table 5.2.

Table 5.2: Indicative Pump Size and Pumping Rates

Pump/Motor Diameter (mm)	Pump Size (kW)	Minimum Bore Casing Diameter (mm)	Maximum Pumping Rate against 180m total head (L/s)	Grundfos Pump Model
101/95	7.5	150	2.5	SP 8A-50N
6 inch	37	200	16	SP 60-21
8 inch	55	250	26	SP77-13
8 inch	110	250	48	SP160-10

Note – Pump sizes and pumping rates based on Grundfos submersible pumps.

5.3 Potential Impacts from Abstraction

Given the relatively small water demand and short period of use no significant or long term impacts on groundwater levels or the aquifer are expected. Likewise, detrimental impacts on other groundwater users are also not expected.

Groundwater drawdown from other water supplies may already be occurring at the drill site, particularly due to abstraction from GWL156102 by the Murion Cattle Company. Assuming an aquifer transmissivity of the order of 100 to 200m^2/day, which would be required to limit drawdown at the pumping bore to manageable levels, after one year of operation, drawdown at the drill site will be of the order of 7 to 12m. Any return interference due to abstraction for water supply at the drill site would be insignificant in comparison.

5.4 Estimated Drilling Costs

An estimate of drilling costs based on typical industry rates has been undertaken. Costs are based on drilling to a total depth of 250m at 356mm diameter to accommodate 250mm ND steel bore casing. For the purposes of this assessment costs are based on the use of plain and slotted steel casing. Given the very short term nature of the bore, stainless steel screens are not warranted. A notional bore construction diagram is presented in Appendix B along with an estimate of the associated drilling costs.

The estimated cost for construction of a 250m deep water supply bore at the drill site is around $240,000. This cost is supplied for budgeting purposes only, actual costs will need to be confirmed with the drilling contractor via a formal quotation or tender process.

5.5 Test Pumping

The Department of Water would normally require a bore to be test pumped prior to approving a groundwater abstraction license, however given the relatively small volume of water required and the short term nature of the use of the bore, the DoW has confirmed that test pumping of the bore will not be required, assuming that during bore development airlift yields indicate sufficient bore capacity to provide project water demands.

5.6 Consultancy Costs

An estimate of consultancy costs for the installation of a water supply bore and associated licensing and reporting requirements, is provided in Table 5.3. A more detailed breakdown of these

costs is provided in Appendix D. We propose to undertake this project on a fees plus reimbursable expenses basis as per our attached standard terms and conditions (Appendix D).

A brief summary of the key elements of individual tasks is provided below.

5.6.1 Project Management

Day to day project management; tracking of budgets and schedules, progress reporting, attendance at progress meetings and compliance with Coffey Environments time and budget reporting and Health and Safety requirements.

5.6.2 DoW Liaison and Licensing

Consultation with the Department of Water regarding licensing requirements and ongoing liaison. Preparation and submitting of licence applications as required.

5.6.3 Drilling Contractor Scope of Work and Liaison

Preparation of scope of works for issue to drilling contractors for quotation, liaison with drilling contractors re availability and timing to commence the work.

5.6.4 Drilling Supervision

On site supervision of drilling and lithological logging of drill cuttings, casing design and supervision of installation and bore development. Collection of water sample and submitting to SGS laboratory for analysis. Costs are based on a 10 day drilling programme and include allowance for messing, accommodation and vehicle hire.

5.6.5 Bore Completion Report

Preparation of bore completion report and supporting data for a 5C license application to the satisfaction of the Department of Water.

Table 5.3: Estimated Consultancy Costs (ex GST)

Task	Consultancy Fees	Expenses
Project Management, DoW Liaison and Licensing	5,561	
Drilling Scope of Work and Liaison	5,737	
Drilling Supervision	28,106	4,815
Bore Completion Report	11,936	
Total	$51,341	$4,815

5.7 Schedule

A notional Schedule for the Tasks outlined in Section 5.6 is provided in Appendix C. Assuming a commencement date for the preliminary works of November 2011 and dependant on Contractor availability, it should be possible to have a water supply bore installed and licensed by May 2012.

6. REGULATORY REQUIREMENTS

6.1 Department of Water

As the proposed water demand is low and the bore will be used for short term use no significant or long term impacts on groundwater levels or the aquifer will be expected or detrimental impacts on other groundwater users. Considering this a number of questions were asked of the DoW in relation to the licensing, drilling and testing of the bore. The DoW confirmed the following in relation to the water supply bore:

- The borelog and other drilling information need to be supplied before the 5C Licence can be issued.
- The granting of the 5C Licence may take up to 2 weeks (15 days has been allowed in our proposed schedule).
- It was confirmed that considering the small abstraction, test pumping of the bore will not be needed.
- The bore does not need to be decommissioned. The DoW stated that they may be interested in using the bore for monitoring purposes (if Warrego Energy has no objections) or the Department of Environment may wish to use it for emergency fire fighting purposes.

6.2 Department of Minerals and Petroleum

Discussions with the Department of Minerals and Petroleum (DMP) were undertaken in regard to the qualitative risk assessment. An overview of the groundwater assessment and the associated environmental risks from the hydrofracturing operation was provided to the DMP. The DMP confirmed the following:

- The information supplied regarding the West Erregulla well site appears to be detailed and provide a comprehensive assessment of groundwater resources in the area.
- It was recommended that this information is included in Warrego Energy"s Environmental Management Plan as well as information regarding fraccing zones and the risks associated with the propagation of fraccing fluids through existing conjugates (i.e. fault lines, bore holes etc) into surrounding aquifers (this has now been assessed within the risk assessment).
- It was also confirmed that these will be some of the environmental risks that should be addressed by Coffey Environment as part of their work for Warrego Energy.

7. REFERENCES

Allen, A.D., 1980, *Geology and Hydrogeology of the Allanooka area (Geraldton water supply), Northern Perth Basin, Wester Australia*. Western Australia Geological Survey Annual Report for 1979.

Bekele, E.B., Salama, R.B., and Commander, D.P., 2006, *Impact of change in vegetation cover on groundwater recharge to a phreatic aquifer in Western Australia: assessment of several recharge estimation techniques*. Australian Journal of Earth Sciences 53, (905–917).

Commander D.P., 1978, *Hydrogeology of the Eneabba borehole line.* Western Australia Geological Survey, Annual Report for 1977, p 13-18

Commander, D.P., 1996, *Groundwater prospects for irrigation in the Irwin River valley*. Water and Rivers Commission Hydrogeology Report 10.

Forth, J.R., 1971, *An Appraisal of the Effects of Long Term Pumpingin the Lake Allanooka Area*: Western Australia Geological Survey Hydrogeological Report No. 1461.

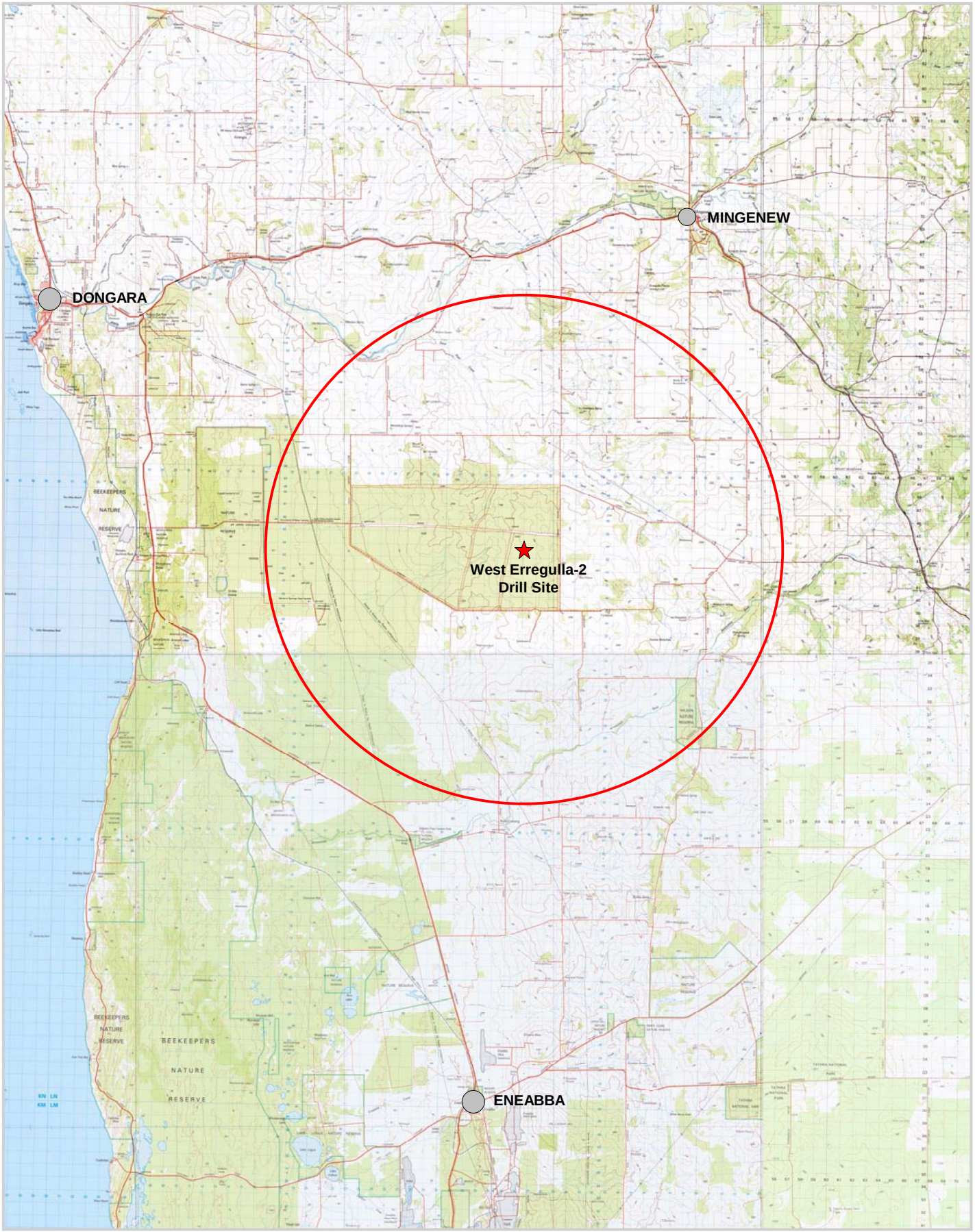
Irwin, R., 2007, *Hydrogeology of the Dongara Borehole Line*, Department of Water, Hydrogeological Record Series, HG4.

Mory, A.J. and Iasky, R.P., 1996, *Stratigraphy and Structure of the Onshore Northern Perth Basin, Western Australia*: Western Australia Geological Survey, Report 46.

Playford, P.E., Cockbain, A.E., and Low, G.H., 1976. *The Geology of the Perth basin, Western Australia*: Western Australia Geological Survey, Bulletin 124.

USEPA, 2004. *Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs*. United States Environmental Protection Agency, Report 816-R-04-003, June 2004.

FIGURES



LOCATION MAP

N

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Kilometers

Scale: 1:400,000 @ A4

GDA 1994 Zone 50

AUTHOR:	GMS	REPORT NO:	016
DRAWN:	GMS	REVISION:	A
DATE:	23/6/2011	JOB NO:	1329B

Location: 1329B\Mapinfo\Workspaces\016 Figure 1.wor

LEGEND

- Drill Site
- Study Area

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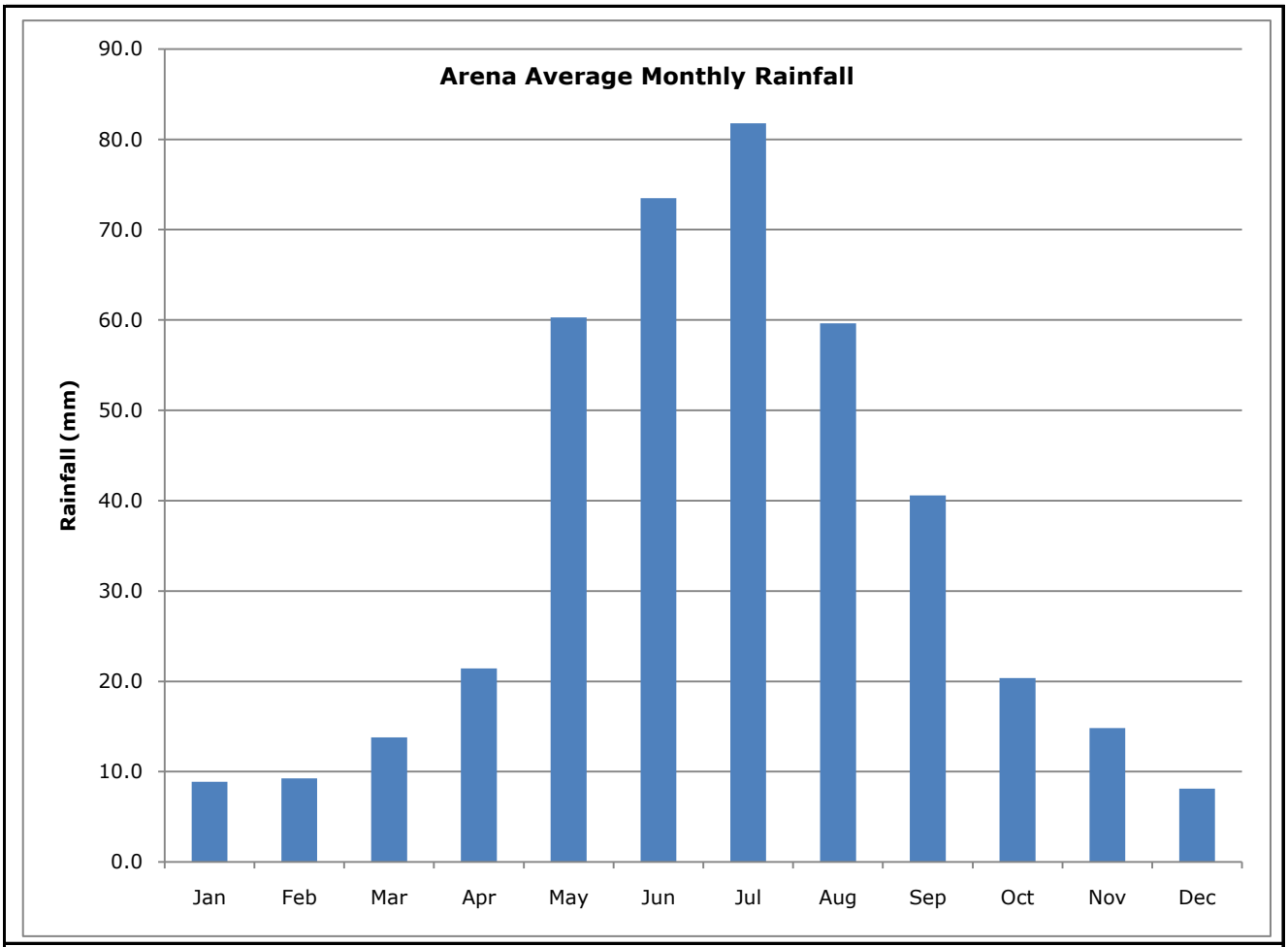
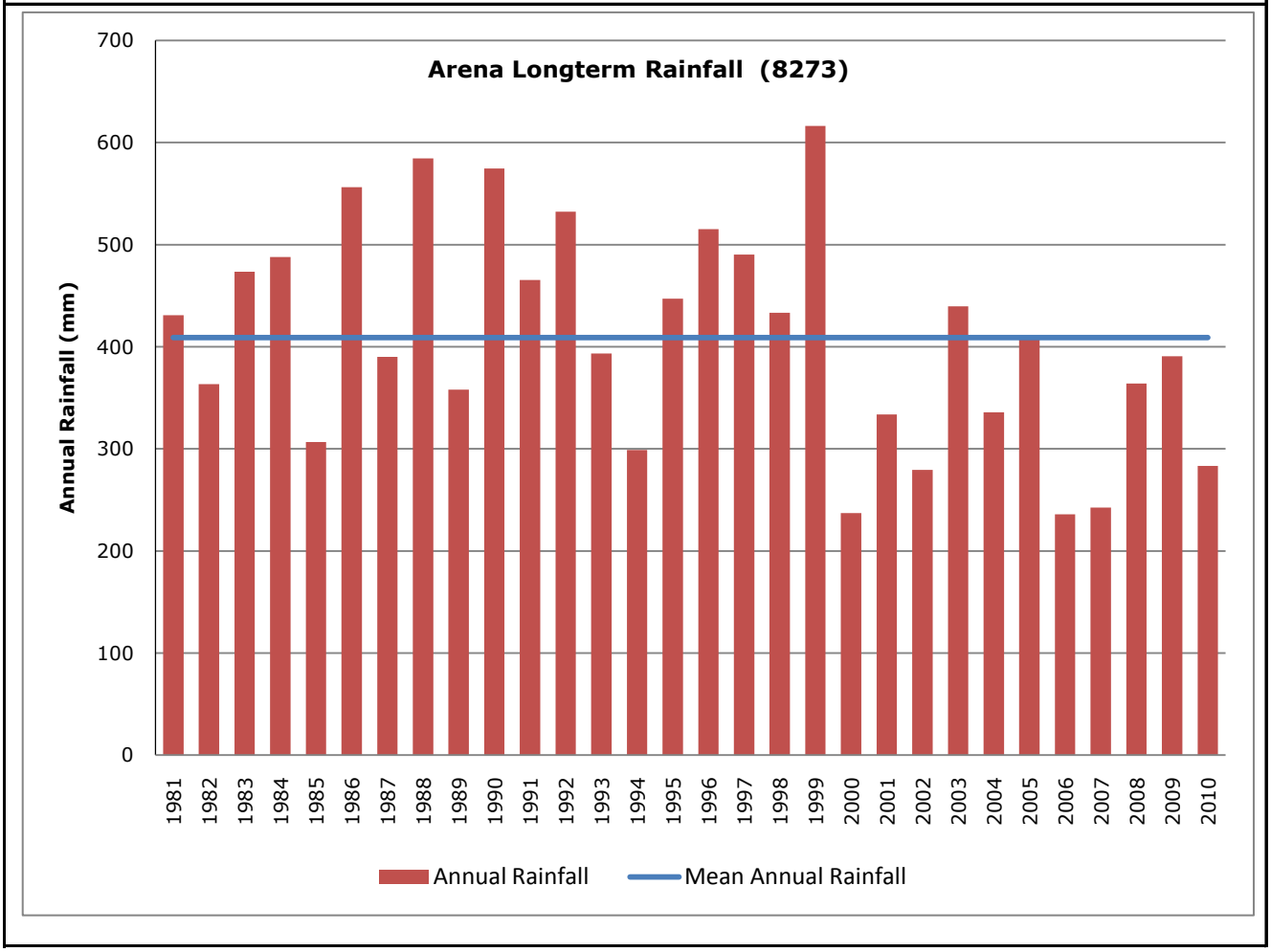
FIGURE 1

STUDY AREA

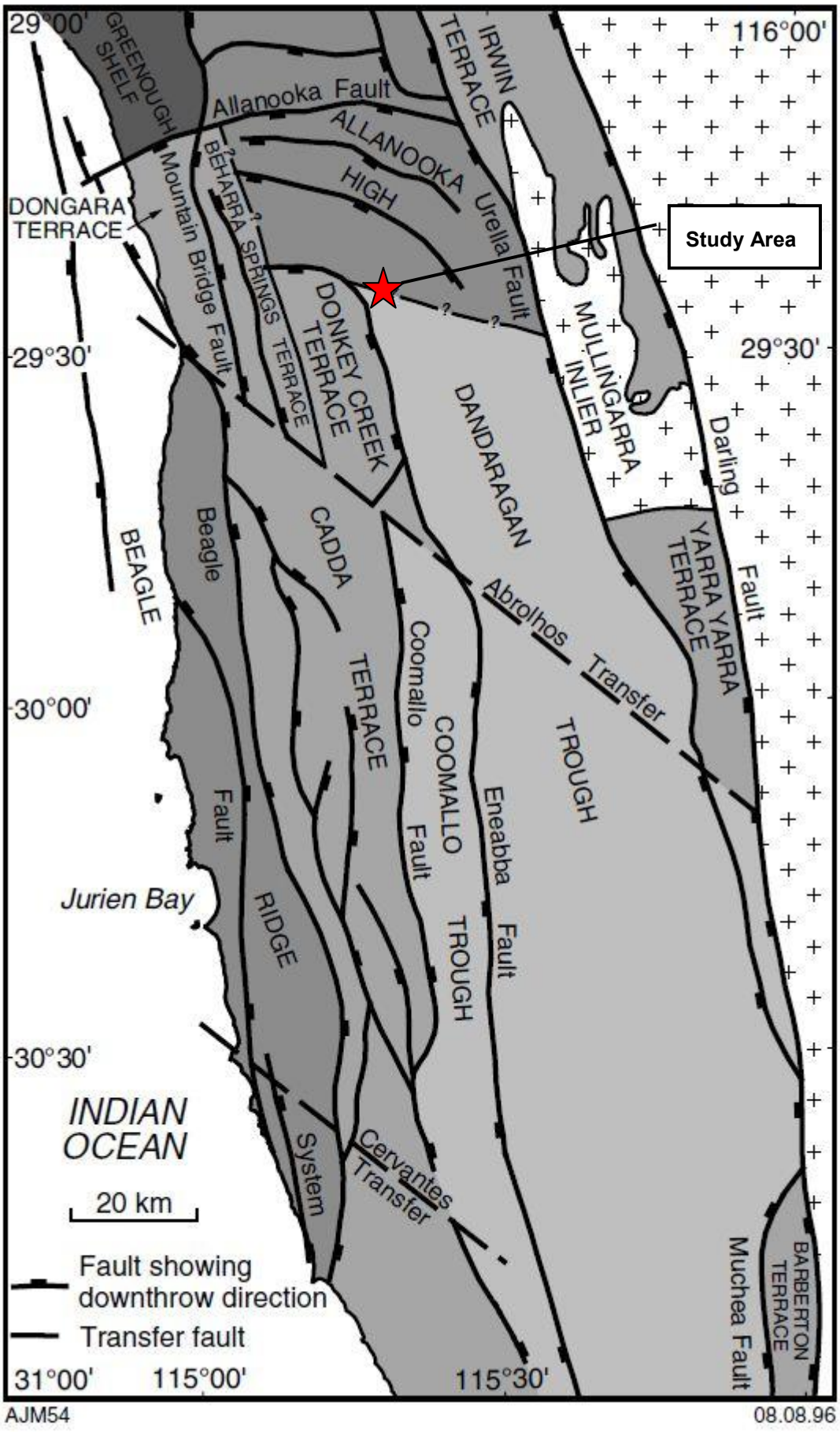
DATA SOURCES:
1:100,000 Topographic map Series





RPS Aquaterra

Arena Rainfall Data FIGURE 2



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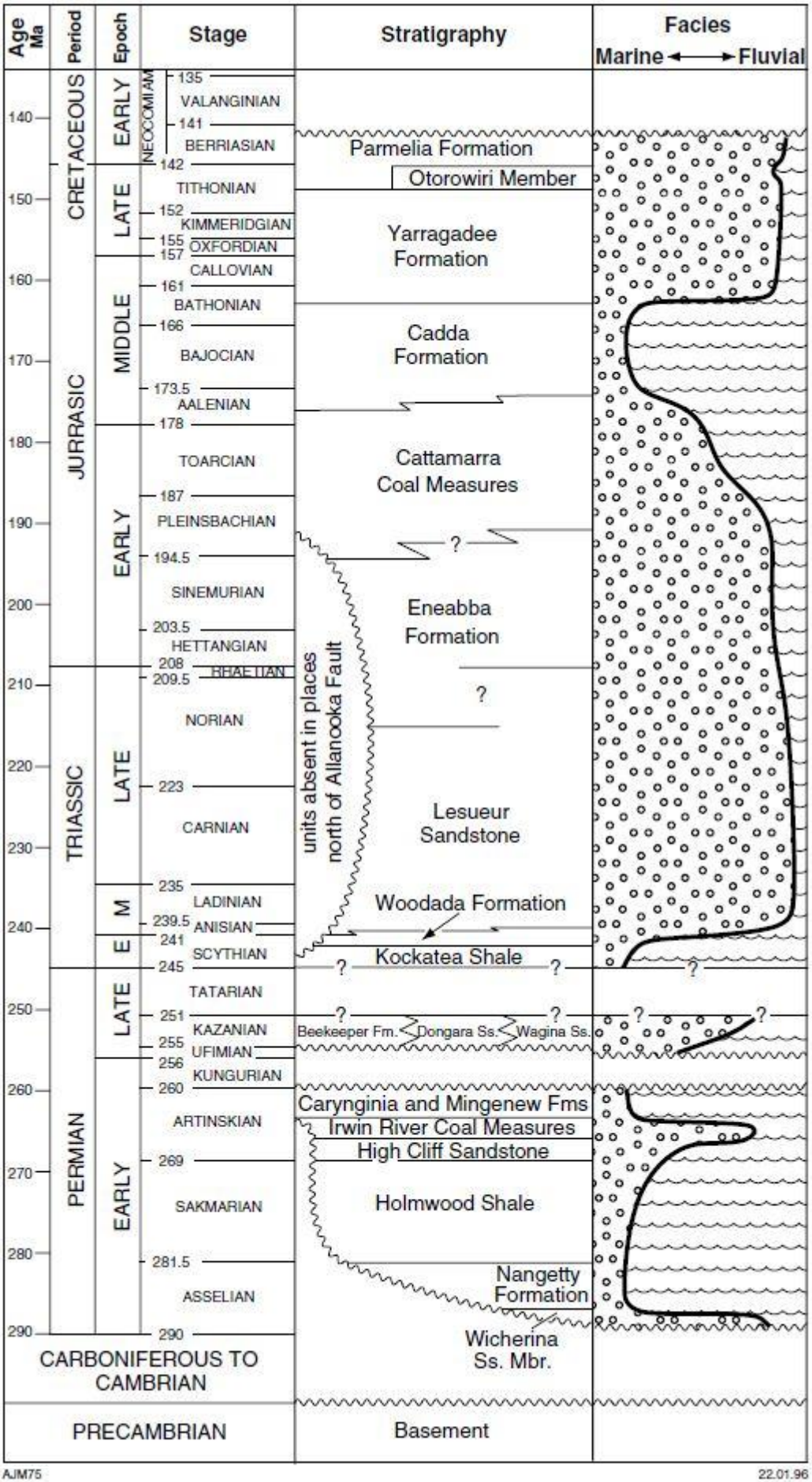

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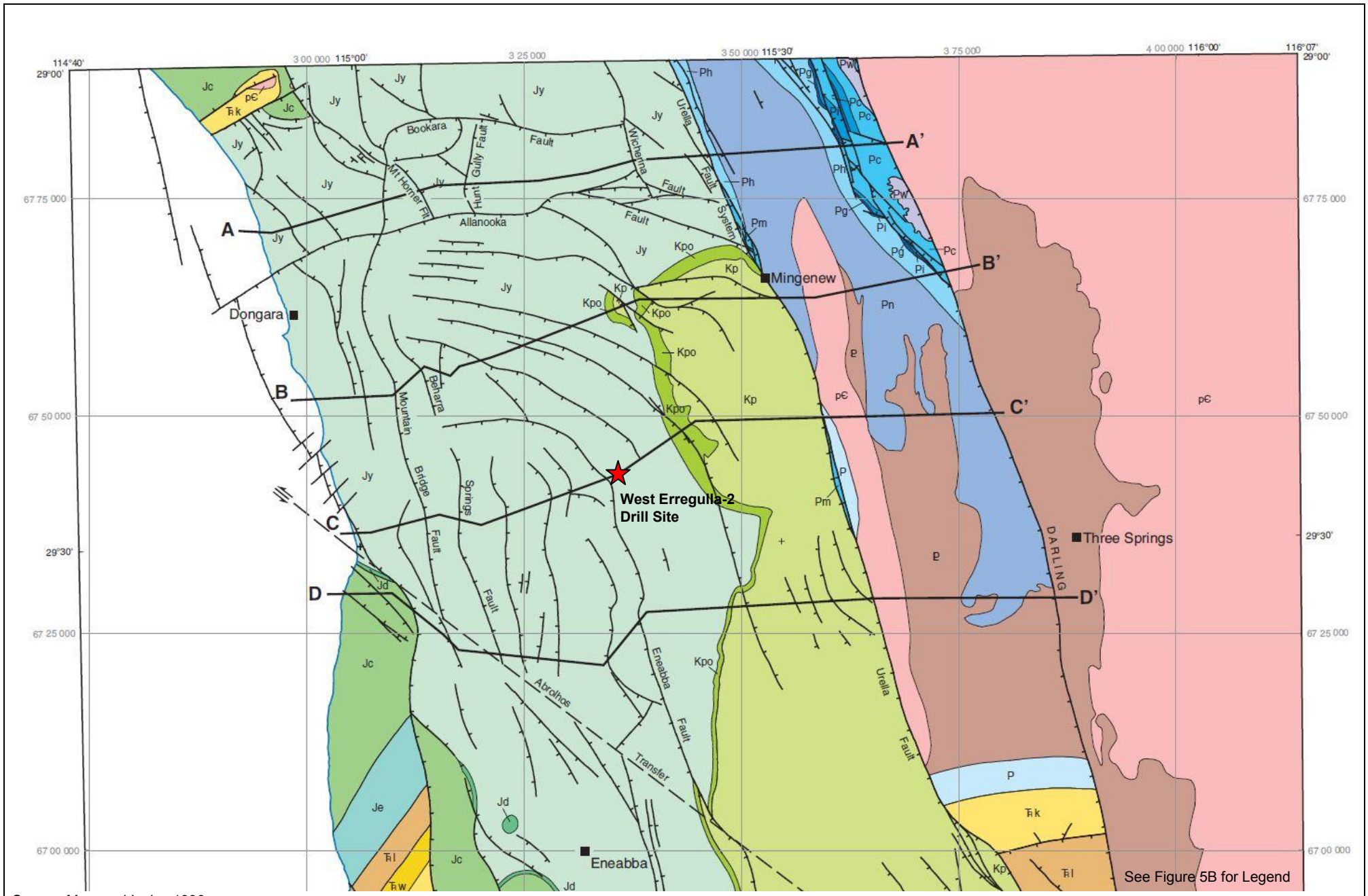

Source: Mory and Iasky, 1996.

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PRE CAINOZOIC GEOLOGY FIGURE 5A

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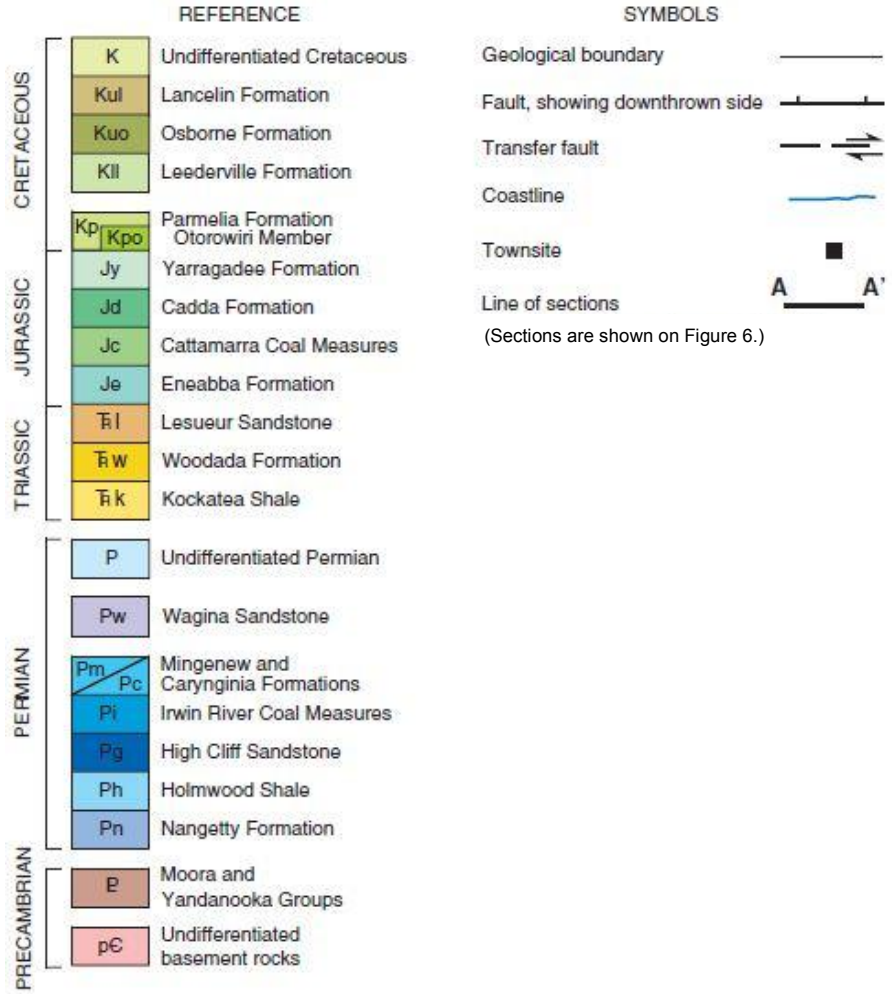

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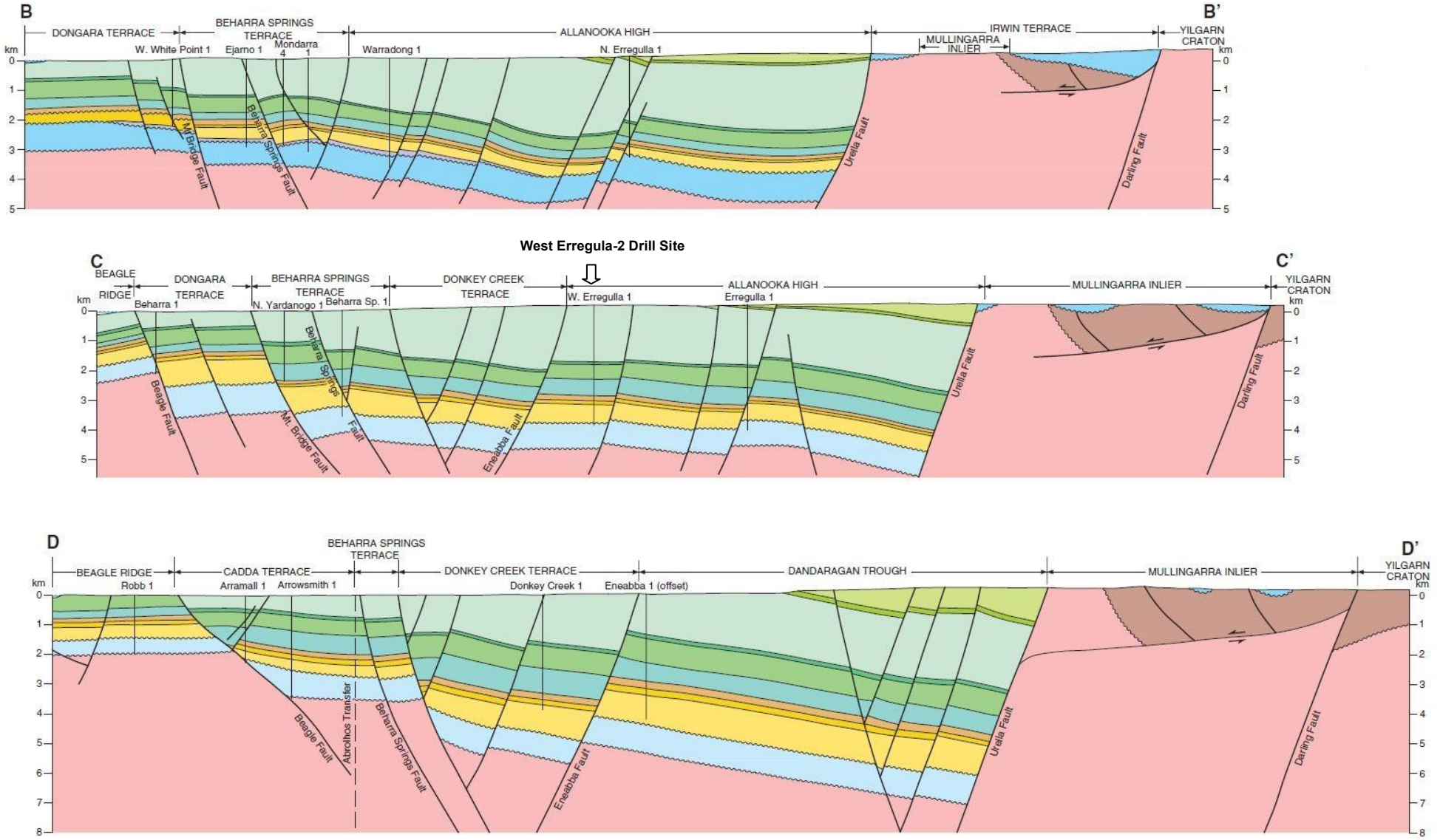

Source: Mory and Iasky, 1996.

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NORTHERN PERTH BASIN SECTIONS FIGURE 6A

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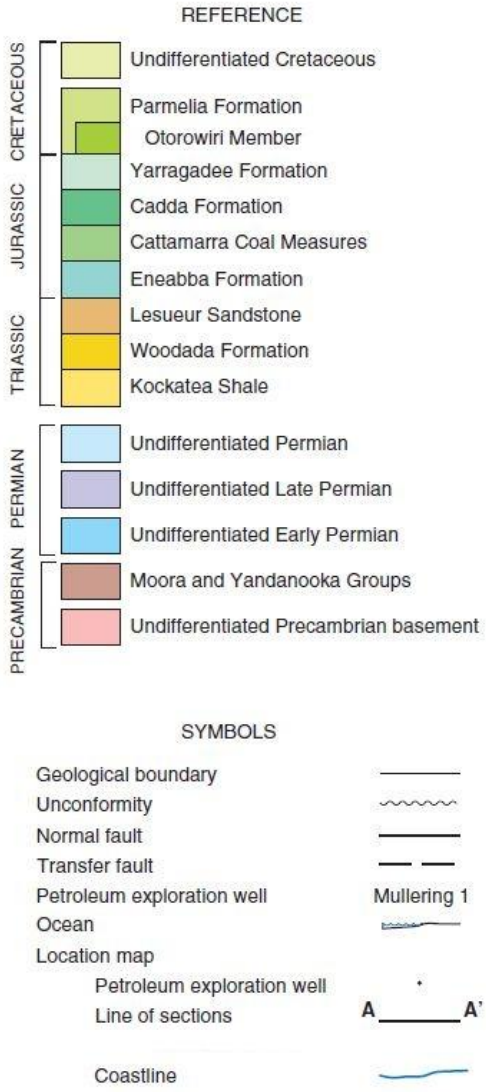

Source: Mory and Iasky, 1996.

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NORTHERN PERTH BASIN SECTIONS LEGEND FIGURE 6B

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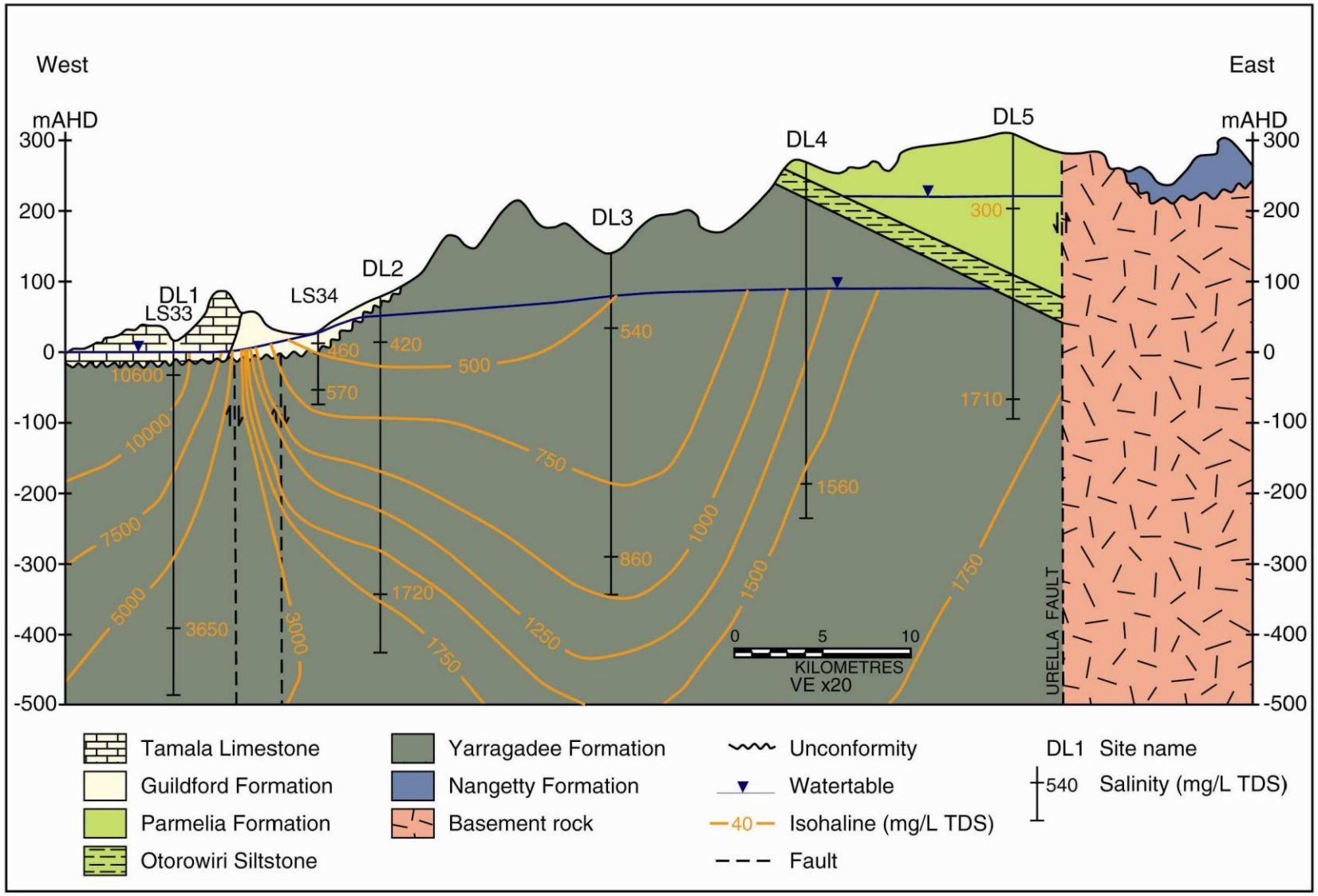

Source: Irwin, 2007.

RPS Aquaterra

GROUNDWATER SALINITY – DONGARA BOREHOLE LINE FIGURE 7

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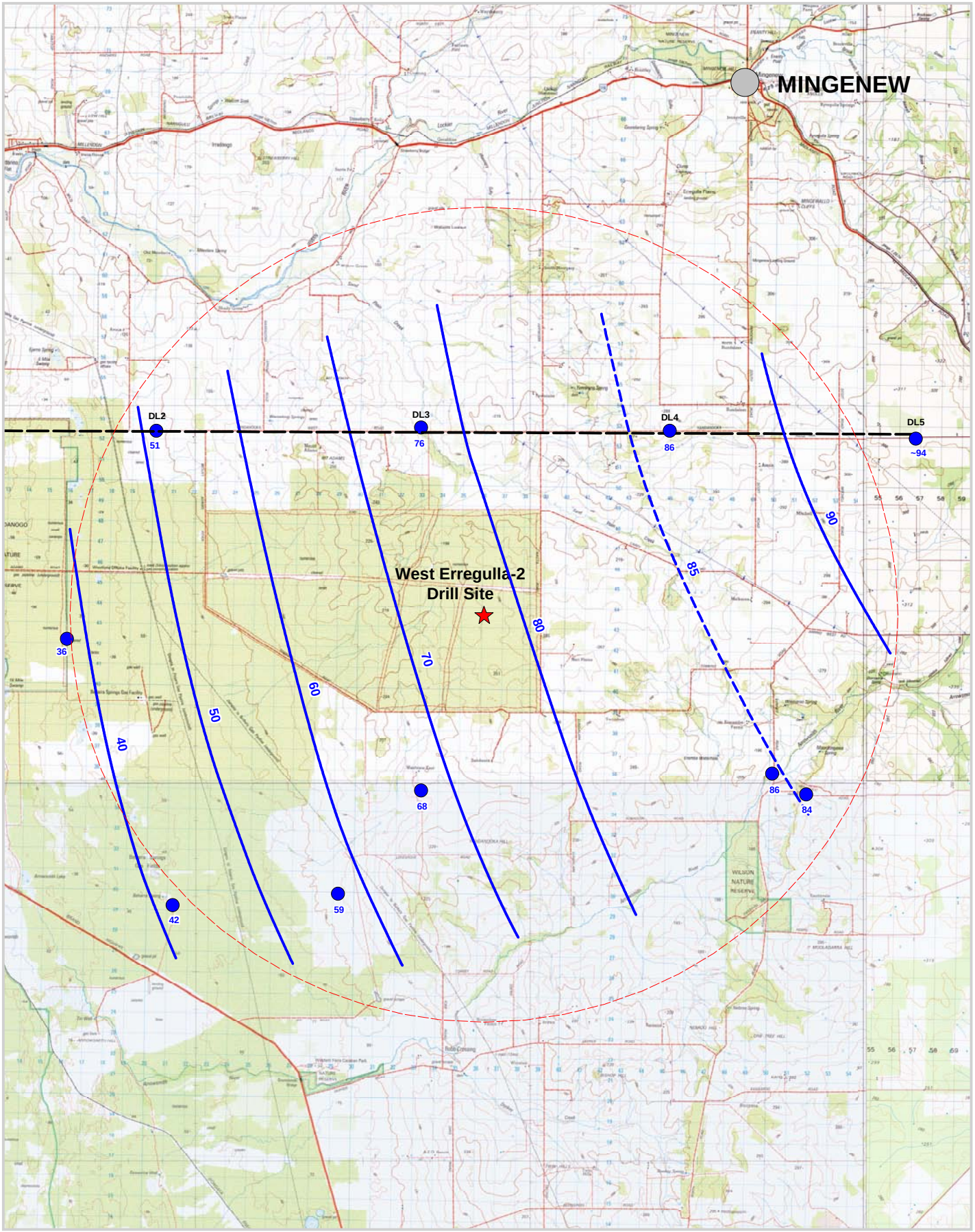

LOCATION MAP

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Kilometers

Scale: 1:250,000 @ A4

GDA 1994 Zone 50

AUTHOR:	GMS	REPORT NO:	016
DRAWN:	GMS	REVISION:	A
DATE:	23/6/2011	JOB NO:	1329B

Location: 1329B\Mapinfo\Workspaces\016 Figure 8.wor

LEGEND

- Drill Site
- Study Area
- Dongara Borehole Line
- Water Level Data Point (mAHD)
- Indicative Water Level Contour (mAHD)

DATA SOURCES:

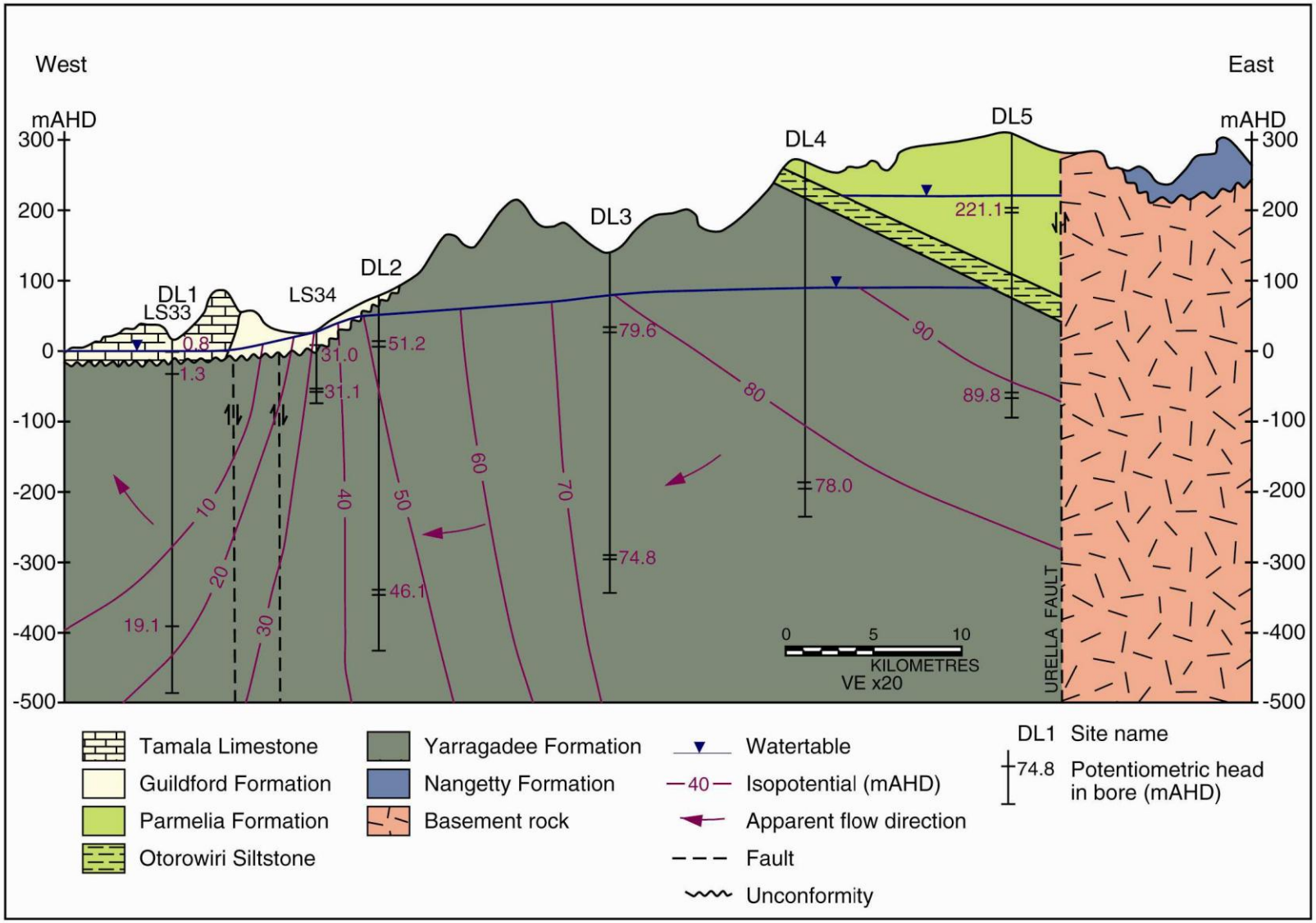
DoW, WIN Database

1:100,000 Topographic map Series

RPS Aquaterra

FIGURE 8

WATER TABLE ELEVATION



Source: Irwin, 2007.

GROUNDWATER LEVELS – DONGARA BOREHOLE LINE FIGURE 9

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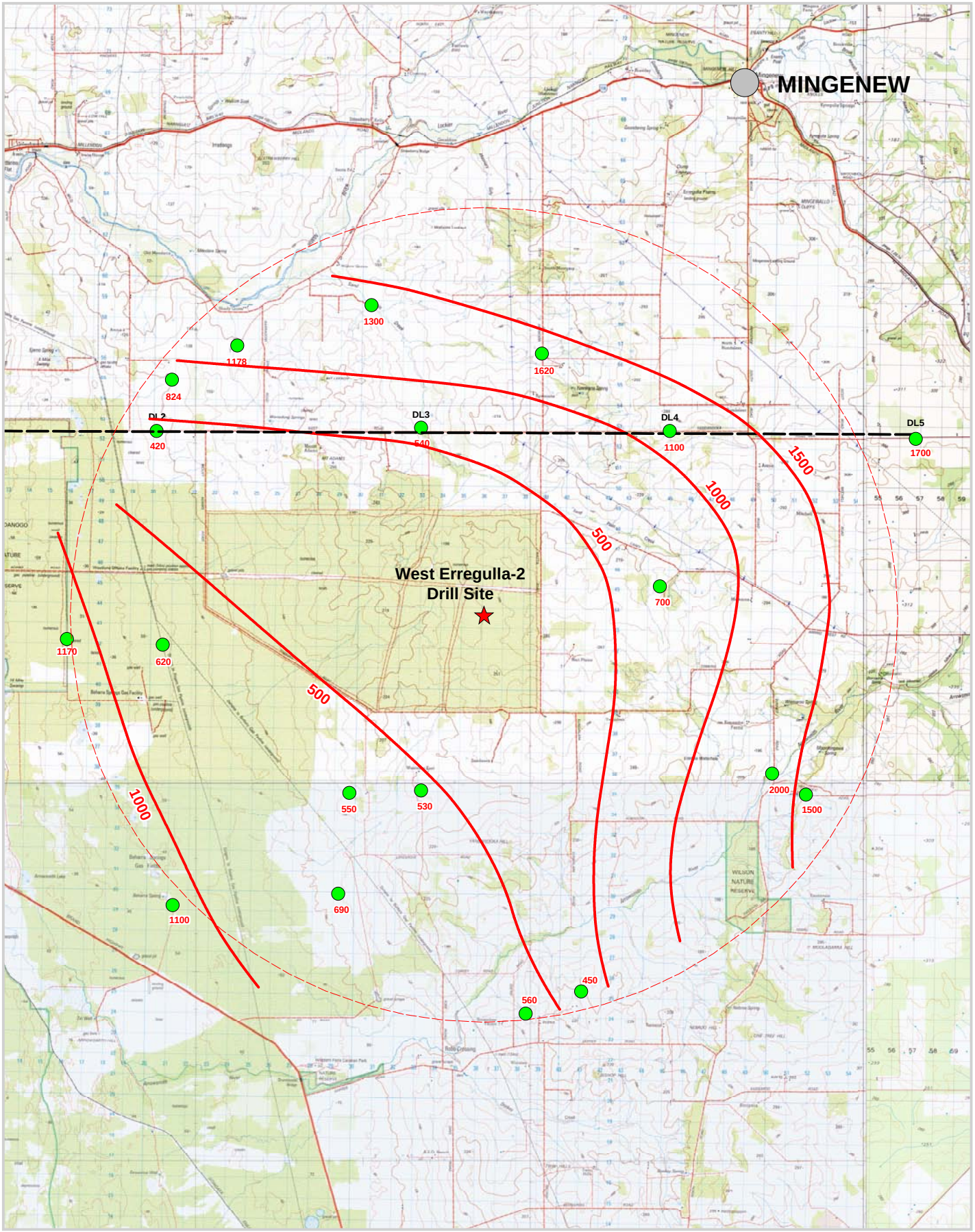

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Kilometers

Scale: 1:250,000 @ A4

GDA 1994 Zone 50

AUTHOR:	GMS	REPORT NO:	016
DRAWN:	GMS	REVISION:	A
DATE:	23/6/2011	JOB NO:	1329B

Location: 1329B\Mapinfo\Workspaces\016 Figure 10.wor

LEGEND

- Drill Site
- Study Area
- Dongara Borehole Line
- Salinity Data Point (mg/L TDS)
- Generalised Isohaline (mg/L TDS)

DATA SOURCES:

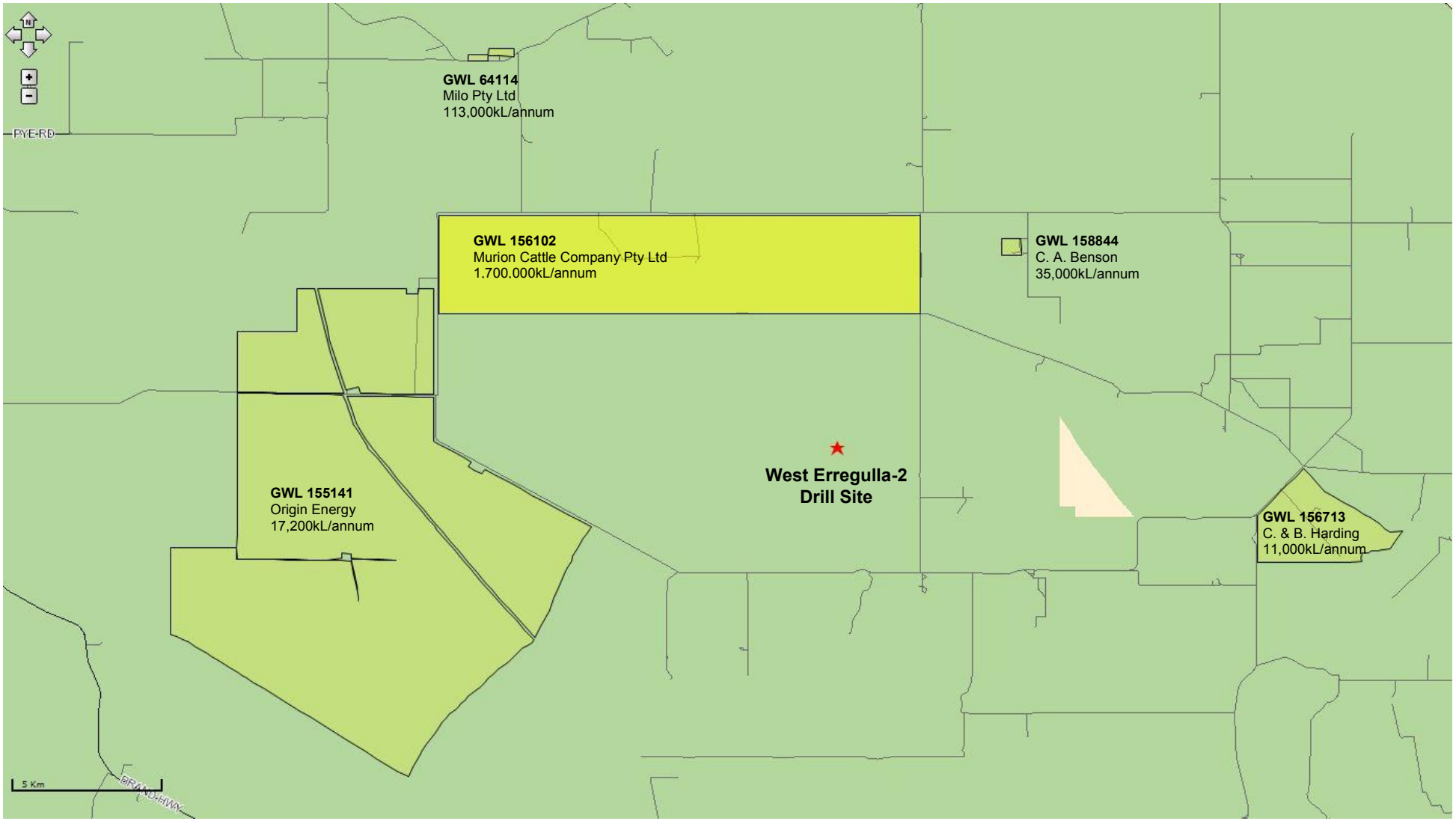
DoW, WIN Database

1:100,000 Topographic map Series

RPS Aquaterra

FIGURE 10

GROUNDWATER SALINITY YARRAGADEE AQUIFER



Source: DoW, Online Water Register.

RPS Aquaterra

LICENSED GROUNDWATER ABSTRACTION FIGURE 11

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APPENDIX A:
RISK ASSESSMENT MATRIX

AQUATERRA BUSINESS-WIDE RISK ASSESSMENT

CONSEQUENCE TABLE

Consequence	Injury / Illness	Environmental Harm / Other Incidents	Reputation (Aquaterra and/or Client)	Legal	Incurred Non-recoverable Cost
Low	Minor injury/illness, only first aid treatment / near miss[1] No Lost Time Injury (LTI)	Unauthorised clearing <100m^2 Hazardous material spill to: soil <2L; or water <1L [1]	No media interest / Local concern	None	<$5,000
Moderate	Medical treated injury/illness with no recovery period required LTI - 1 day or less [1]	Unauthorised clearing <500m^2 Hazardous material spill to: soil <10L; or water <5L [1]	Local media interest / Community concern	Breach of regulations leading to fine	>$5,000 <$25,000
High	Medical treated injury/illness with recovery period less than 2 weeks LTI <10 work days [1]	Unauthorised clearing <1000m^2 Hazardous material spill to: soil <20L; or water <10L [1]	Professional / Industry Association interest / Public outcry	Breach of regulations that leads to investigation by authorities and prosecution (ie requires legal advice)	>$25,000 <$100,000
Major	Permanent or serious injury/illness causing disability with recovery period greater than 2 weeks Government "reportable injury/disease" LTI >10 working days [2]	Unauthorised clearing >1000m^2 Hazardous materials spill to: soil >20L; or water >10L [2]	State media interest / Public outcry		>$100,000[3] <$200,000
Critical	Injury/illness leads to fatality Government "reportable injury/disease" LTI >20 working days [2]	Unauthorised clearing >10,000m^2 Hazardous materials spill to: soil >1000L; or water >200L [2]	National / International media interest	Class action suit and/or major prosecution by authorities (ie requires legal representation)	>$200,000

[1] Aquaterra General Incident Report [2] Aquaterra Serious Incident Report [3] Coincides with excess for PI Insurance Claim

LIKELIHOOD TABLE

Likelihood	Description
Highly Likely	Common or repeating occurrence (Will happen today or this week)
Likely	Known to occur (Will happen this month or this year)
Possible	Could occur (May happen more than once in 5 years)
Unlikely	Probably will not occur (Might happen in the next 5 to 10 years)
Rare	Not expected to occur (Might happen in the next 10 or more years)

RISK ASSESSMENT MATRIX

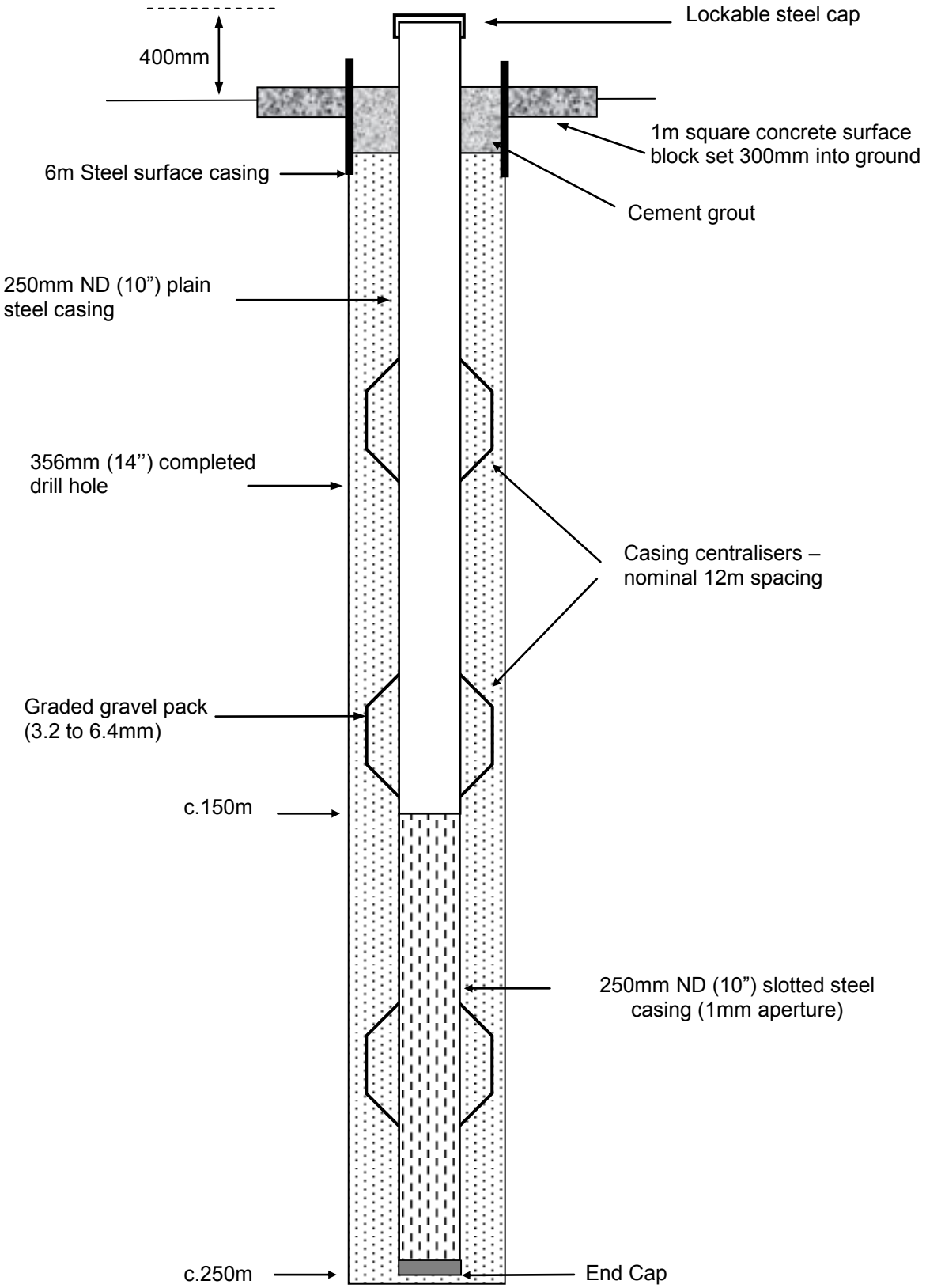
		CONSEQUENCE				
		Low	**Moderate**	**High**	**Major**	**Critical**
LIKELIHOOD	**Highly Likely**	**High (11)**	**High (16)**	**Extreme (20)**	**Extreme (23)**	**Extreme (25)**
	Likely	**Moderate (7)**	**High (12)**	**High (17)**	**Extreme (21)**	**Extreme (24)**
	Possible	**Low (4)**	**Moderate (8)**	**High (13)**	**Extreme (18)**	**Extreme (22)**
	Unlikely	**Low (2)**	**Low (5)**	**Moderate (9)**	**High (14)**	**Extreme (19)**
	Rare	**Low (1)**	**Low (3)**	**Moderate (6)**	**High (10)**	**High (15)**

	Immediate risk reduction required
✉	Risk reduction required
	Risk reduction required
	Further risk reduction is not required

Adapted from HB436:2004, Companion to AS/NZS 4360:2004

✉ - In some circumstances a level of high risk may be associated with activities which are commonly considered by society to be acceptable. In this regard, driving a vehicle and flying in commercial aircraft do not required special risk management strategies to be referred to a Director. However, travel to and work within areas where there are hazards associated with high crime rates, political unrest and/or infectious diseases must be have appropriate management strategies approved by a Director.

APPENDIX B:
NOTIONAL BORE DIAGRAM AND COST ESTIMATE



Notes:
Actual depths to be determined by on site hydrogeologist

Not to scale

RPS Aquaterra

Notional 10" Production Bore
Drawing 1

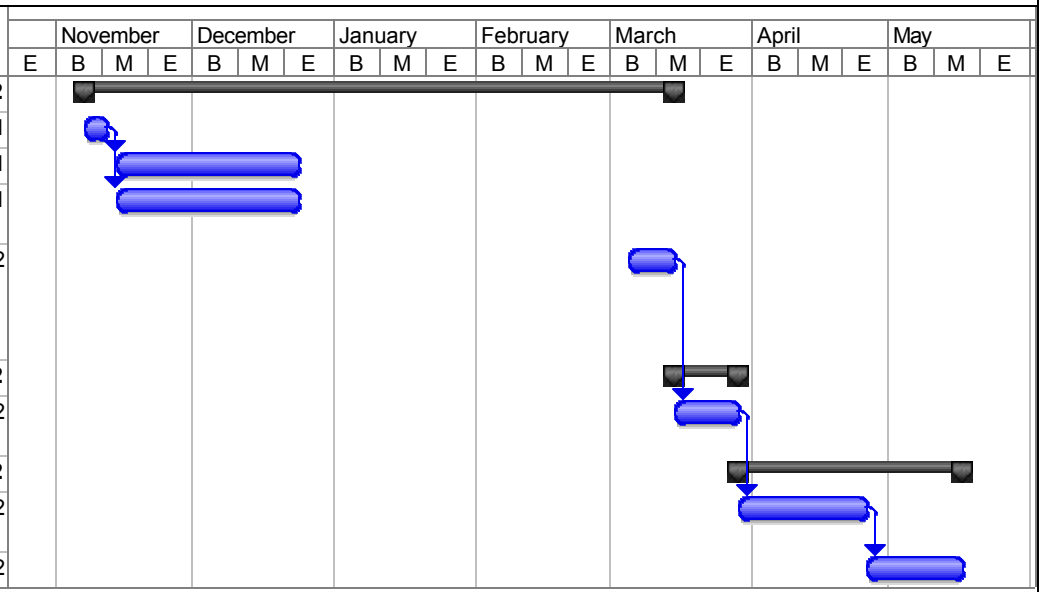
West Erregulla Water Supply Well - Drilling Cost Estimate

Item	Unit	Rate	Estimated Quantity	Total Cost	Mobilisation	PB1
Preliminaries						
Crew Inductions	hr		0	$0.00		
Safety initiatives as required by client	hr		0	$0.00		
Movement/ Travel						
Mobilisation - Production (All time to mast up on first hole)	item	$20,000.00	1	$20,000.00	1	
Demobilisation - Production (All time from mast down on last hole)	item	$20,000.00	1	$20,000.00	1	
Time Rates						
Worktime	hr	$897.81	20	$17,956.20		20
Worktime rig running	hr		0	$0.00		
Worktime rig idle	hr		0	$0.00		
Carting casing/gravel pack from lay down area to site	hr	$809.98	4	$3,239.92		4
Standby - Production	hr	$639.98	8	$5,119.84		8
Condition Hole	hr		4	$0.00		4
Water Carting (chargeable only where water shortage prevents the continuation of drilling)	hr	$706.94	8	$5,655.52		8
Slow penetration	hr	$884.93	0	$0.00		
Airlift development of production bores	hr	$856.07	8	$6,848.56		8
Airlift development	hr		0	$0.00		
Development (including recovery testing)	hr	$856.07	0	$0.00		
Casing time	hr	$849.37	16	$13,589.92		16
Gravel pack time	hr	$849.37	8	$6,794.96		8
Setting up for mud drilling	hr	$849.37	8	$6,794.96		8
Mixing mud	hr	$849.37	8	$6,794.96		8
Hire Costs/Extra Machinery						
Water Truck Hire	day		0	$0.00		
Backhoe hire with certified ROCP	day		0	$0.00		
Provision of submersible pump, riser and Gen. set	day		0	$0.00		
Water Truck hire - 10,000 ltr plus capacity	day	$500.00	10	$5,000.00		10
Mud Pump	day	$1,000.00	4	$4,000.00		4
Drilling						
Drilling for Surface Casing						
Drilling collar hole for production bore surface casing	mtr	$300.00	6	$1,800.00		6
Rotary Mud Drilling						
Drilling 305mm (12")	mtr	225	244	$54,900.00		244
Other Costs/ Consumables						
Freight	allowance	$8,000.00	1	$8,000.00		1
Shur-seal	10kg		0	$0.00		
Aus-plug	8kg		0	$0.00		
Aus-trol	15kg		0	$0.00		
Cement	20kg bag	$20.48	10	$204.80		10
AB foam	500ml can	$32.45	0	$0.00		
Liqui-Pol	25L	$141.08	0	$0.00		
Aus-Gel/Quik-Gel	20L drum		0	$0.00		
Lost circulation material (ie; Kwik-seal)	20L drum		0	$0.00		
Biopolymer	15kg drum	$120.00	10	$1,200.00		10
Pac R	25kg bag	$247.88	10	$2,478.80		10
Quickmud	20L drum	$160.00	10	$1,600.00		10
Pac L	25kg	$236.10	0	$0.00		
Supa Foam	25L	$97.68	0	$0.00		
Dextrid/Aus-Dex	item		0	$0.00		
Quick-Set	each		0	$0.00		
Cement Premix (Quikset cement)	each		0	$0.00		
Bentonite Powder	each		0	$0.00		
Bentonite Pellets	20L drum		0	$0.00		
Test Pumping						
Mobilisation/Demobilisation Production (Test Pumping)	item	$10,508.41	0	$0.00		
Install and remove the pump	item	$2,122.35	0	$0.00		
Test pumping (step and Constant Rate Test)	hr	$215.65	0	$0.00		
Recover	hr	$172.32	0	$0.00		
Standby Time (Test Pumping)	hr	$172.32	0	$0.00		
Other	unit		0	$0.00		
Other	unit		0	$0.00		
Materials						
Surface casing for 356mm (14") drilling	mtr	230	6	$1,380.00		6
Surface casing for 406mm (16") drilling	mtr		0	$0.00		
203mm (8") ND Steel Casing (Slotted)	mtr		0	$0.00		
203mm (8") ND Steel Casing (blank)	mtr		0	$0.00		
203mm (8") ND Steel screens (Johnson)	mtr		0	$0.00		
254mm (10") ND steel casing (blank)	mtr	$142.00	150	$21,300.00		150
254mm (10") ND steel casing (slotted)	mtr	$198.00	100	$19,800.00		100
324 mild steel casing welded retainer rings	mtr		0	$0.00		
400-350NB Lockable caps and concrete surrounds	item		0	$0.00		
400NB Lockable caps and concrete surrounds	item		0	$0.00		
508 OD x 9.5 WT mild steel casing	mtr	$230.00	0	$0.00		
Stainless steel base plate	item		0	$0.00		
Centralisers	item	$50.00	20	$1,000.00		20
Gravel Pack 1.6mm - 3.2mm	m3		0	$0.00		
Gravel Pack 3.2mm - 6.4mm (Production)	m3		12	$0.00		12
mild steel to stainless di-electric coupling	item		0	$0.00		
Gravel Pack 3.2mm - 6.4mm (Exploration)	m3	$459.62	12	$5,515.44		12
Total Initial Cost				$240,973.88		

APPENDIX C:
SCHEDULE

West Erregulla Groundwater Study - Schedule

ID	Task Name	Duration	Start	Finish
1	**Preliminaries**	**93 days**	**Mon 7/11/11**	**Thu 15/03/12**
2	Confirmation to Proceed	5 days	Mon 7/11/11	Fri 11/11/11
3	26D Licence Application	30 days	Mon 14/11/11	Fri 23/12/11
4	Drilling SOWs and liason with suitable contractors	30 days	Mon 14/11/11	Fri 23/12/11
5	General Mobilisation to Site (drilling contractor) - this assumes client has access and drill pads prepared	10 edays	Mon 5/03/12	Thu 15/03/12
6	**Drilling and Testing**	**10 days**	**Thu 15/03/12**	**Thu 29/03/12**
7	Drilling - pilot and production bore	14 edays	Thu 15/03/12	Thu 29/03/12
8	**Project Conclusion**	**35 days**	**Thu 29/03/12**	**Wed 16/05/12**
9	Submit completion report and 5C Licence application	20 days	Thu 29/03/12	Wed 25/04/12
10	5C Licence Granted	15 days	Thu 26/04/12	Wed 16/05/12



Project: West Erregulla Groundwater Study - Schedule
Date: Thu 28/07/11

Task
Split
Progress
Milestone
Summary
Project Summary
External Tasks
External Milestone
Deadline

RPS Aquaterra

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APPENDIX D:
RPS AQUATERRA COST ESTIMATE

RPS Aquaterra

Client	**Warrego Energy**
Project Title	**West Erregulla Water Supply Bore**
Job No	**1329C**
Date Created	**28-Jul-2011**
Last Updated	**28-Jul-2011**

PROFESSIONAL FEES			Tasks	B1 Budget		B2 Budget		B3 Budget		B4 Budget		Budget Totals	Total Budget Hours
				Project Management and Licensing		Drilling Scope of Work, Contractor Liaison		Drilling Supervision		Bore Completion Report			
Staff	**Role**	**Rate $/day**	**Rate $/hr**	**hr/d**	**fees ($)**	**hr/d**	**fees ($)**	**hr/d**	**fees ($)**	**hr/d**	**fees ($)**		
Greg Sheppard	Principal Hydrogeologist		242	8	$1,936	4	$968	4	$968	4	$968	$4,840	20
Fiona Dixon	Senior Hydrogeologist		210	16	$3,360	8	$1,680	16	$3,360	16	$3,360	$11,760	56
Nick Taylor	Project Hydrogeologist		176			16	$2,816			40	$7,040	$9,856	56
Martin Rocks	GIS Officer		138										
Daily Rates													
Greg Sheppard	Principal Hydrogeologist	2420						2	$4,840.00			$4,840.00	20.00
Nick Taylor	Project Hydrogeologist	1760						10	$17,600.00			$17,600.00	100.00
Total Professional Services (Hours/Cost)				24	$5,296	28	$5,464	140	$26,768	60	$11,368	**$48,896**	
Office Support		5%	5%		$265		$273		$1,338		$568	$2,445	
Task totals					**$5,561**		**$5,737**		**$28,106**		**$11,936**	**$51,341**	**252**

EXPENSES			B1 Project Management		B2 Drilling Scope of		B3 Drilling Supervision		B4 Bore Completion		Budget Totals	
Item	**Remarks**	**Final Rate $**	**No.**	**Cost $**	**No.**	**Cost $**	**No.**	**Cost $**	**No.**	**Cost $**		
Aquaterra Expenses												
Equipment Hire/Supply	daily allowance	$25					10	$250			$250	
Field Communications (mob phone)	daily allowance	$13					10	$130			$130	
Field Computer	per day	$30					10	$300			$300	
		SUB TOTAL						$680			$680	
Expenses												
Vehicle Hire	daily allowance	$165					10	$1,650			$1,650	
Accommodation+meals	daily allowance	$177					10	$1,770			$1,770	
Laboratory Costs	per sample	$165					1	$165			$165	
Misc field costs (freight etc)	allowance	$550					1	$550			$550	
Misc office costs	allowance	$220										
		SUB TOTAL						$4,135.00			$4,135	
Total Expenses								$4,815			**$4,815**	
Total Project Fees and Expenses				**$5,561**		**$5,737**		**$32,921**		**$11,936**	**$56,156**	

Notes
RPS Aquaterra reserves the right to review rates applicable to any work occurring after 31 December 2011.
Rates are valid for all work undertaken until 31 December 2011.
Communication charges are estimates only.
Actual costs will include all call charges.

All prices are exclusive of GST; this will
be added as a 10% surcharge on invoices.

F:\Jobs\1329B\600\Appendices\[1329C_Project Cost Tracking1.xls]Budget

Prepared by:____FD_____ Checked by:_____GMS_____

RPS AQUATERRA PTY LTD
TERMS OF CONTRACT
Standard Terms and Conditions for
Supply of Professional Services

1. Standard Application

These terms and conditions set out the basis upon which RPS Aquaterra Pty Ltd A.C.N 082 286 708 (herein "RPS Aquaterra") will contract to supply professional services to the Client (which party shall be and be deemed hereby to be the person with whom a particular contract is formed and to whom these standard terms and conditions have been published for the purposes of forming legal relations) AND publication of these standard terms and conditions by RPS Aquaterra to the Client by endorsing same upon the reverse of a quotation or estimate for provision of professional services or as an addendum or annexure to same or to a contract shall be deemed to constitute adequate publication to and acceptance by the Client for the purposes of formation of legal relations between RPS Aquaterra and the Client.

2. Rates of Remuneration

2.1 Rates

RPS Aquaterra shall invoice to the Client and the Client shall pay to RPS Aquaterra remuneration for services provided by RPS Aquaterra to the Client rated in accordance with the rates detailed in the cost estimate or cost quotation to the Client and accepted by the Client (the contract), for the services to be provided by RPS Aquaterra to the Client, subject to sub-clause 2.5 and clause 10 of these conditions and/or express agreement in variation hereof between RPS Aquaterra and the Client.

2.2 Daily Rate Computation:

The daily rate for the purposes of computing the remuneration due to RPS Aquaterra from the Client shall mean a shift period (or aggregate of periods) not exceeding 10 hours in any 24 hour period (midnight - midnight) for personnel engaged in on-shore work and any shift period (or periods aggregating) 12 hours in any 24 hour period (midnight - midnight) for personnel engaged in off-shore work.

2.3 Day Rate Charge Period:

Where RPS Aquaterra personnel are to be engaged in the provision of services at the Client's site, the daily rate of remuneration commences with effect from the day upon which the RPS Aquaterra personnel leave Perth to travel to the Client's site. The daily rate of remuneration shall terminate upon the day of return of the RPS Aquaterra personnel to Perth.

2.4 Expert Evidence:

In the event that RPS Aquaterra personnel are required by the Client to attend any Court, Tribunal or other deliberative body at the request of the Client and for the purpose of providing Expert Evidence on behalf of the Client then in that event the Client shall pay to RPS Aquaterra upon invoice the day rate of remuneration agreed between RPS Aquaterra and the Client for the provision of the service in respect of the particular personnel required for the provision of Expert Evidence **plus a margin** of 50% of that rate pro rata for every hour or part thereof that the RPS Aquaterra personnel is in attendance upon the Client (or the Client's Solicitor) or at the Court, Tribunal or other place for the purpose of the preparation of and providing or being available to provide the Expert Evidence sought.

2.5 GST

Standard rates and services exclude GST. This will be levied as a surcharge from July 2000.

3. Payment for Service

The Client shall pay to RPS Aquaterra all invoices rendered by RPS Aquaterra in accordance herewith without deduction not later than the last day of the calendar month next following the date of the invoice (or 30 days whichever is the greater) AND in the event that the Client shall default in the payment of invoice (or any part thereof) as aforesaid and such default shall continue for more than seven (7) days regardless of whether or not formal demand has been made by RPS Aquaterra then the Client shall be liable to pay to RPS Aquaterra as agreed liquidated damages in respect of default in due payment of the invoice that sum equal to 1.5% of the invoice for each full calendar month (or part pro rata thereof) that default in payment shall continue AND FURTHER all payments in arrears by the Client to RPS Aquaterra shall be applied first in discharge of the said liquidated damages for default payment and the balance thereover (as applicable) shall be applied in payment of the invoice.

4. Place for Payment

All payments to RPS Aquaterra shall be paid to RPS Aquaterra at its address herein or to an account nominated in writing by RPS Aquaterra to the Client.

5. Invoice Period

RPS Aquaterra shall invoice the Client at the end of each calendar month on an interim basis and at the conclusion of the service (or as otherwise mutually agreed).

6. Transport and Services

Where RPS Aquaterra incurs a cost associated with the transport of its personnel from Perth to the Client's site or return to Perth (or vehicular transport on site or incidental as required), meals or accommodation, or other actual disbursement cost associated with the provision of the service then the same shall be and constitute a charge payable by the Client to RPS Aquaterra at cost to RPS Aquaterra plus a margin of 7.5% of the cost incurred PROVIDED where agreed between RPS Aquaterra and the Client in variation hereof the Client may provide part or all of the said transport and services in which event no claim shall be made by RPS Aquaterra upon the Client in respect of those transport facilities and/or services provided at the cost of the Client.

7. Currency

All rates of remuneration quoted and invoices rendered by RPS Aquaterra are in Australia dollars (A$) and shall be payable to RPS Aquaterra in A$ unless otherwise expressly agreed in variation hereof.

8. Insurances

RPS Aquaterra shall maintain current at all times all proper insurances required by law and sufficient for the reasonable requirements of the service provided to the Client (or as specified and agreed with the Client) AND the Client shall maintain current during the term of the provision of the service by RPS Aquaterra all insurances required by law for the indemnification of the Client's employees injured in the work place AND FURTHER the Client indemnifies RPS Aquaterra absolutely in respect of any work place injury occasioned by any of the Client's employees working with or in association with RPS Aquaterra's personnel.

9. Regulations

RPS Aquaterra and the Client shall each conduct their respective operations and activities in compliance with all laws and regulations made pursuant to those laws applicable at the location where the service is undertaken including without limitation compliance with all health, safety and environmental regulations.

10. Validity Period

RPS Aquaterra reserves the right to withdraw any offer to provide services if the offer is not accepted by the Client and/or the services to be provided are not commenced within sixty (60) days of the date of the offer. Where the service envisages a performance term greater than one hundred and twenty (120) days from the date of commencement until the actual date of completion of the service RPS Aquaterra reserves the right to revise and increase the rates of remuneration agreed between RPS Aquaterra and the Client at the outset of the contract for provision of services AND the said rates shall be subject to review at the conclusion of each period of 365 days PROVIDED it is agreed that no increase in the rates of remuneration during the term of any on-going contract shall exceed five percentum (5%) at any review.

11. Legal Relations

11.1 Independent Contractor

RPS Aquaterra is and shall remain at all times an independent contractor to the Client and shall remain responsible in all things for all its separate costs and liabilities. No partnership, joint venture or other association or agency shall be or be deemed to be constituted by any agreement made between RPS Aquaterra and the Client.

11.2 Contract

Until such time as an offer to provide service by RPS Aquaterra to the Client is accepted by the Client the same shall constitute an offer by RPS Aquaterra to provide the service detailed upon the terms hereof. Subject to the reservation provided in clause 10 & 11.7, the Client may accept an offer made by RPS Aquaterra by execution of the same or execution of an authorisation to proceed and return of the executed copy to RPS Aquaterra and upon receipt of the executed copy by RPS Aquaterra a binding contract will be deemed hereby to have been made between RPS Aquaterra and the Client for the provision of the service upon the terms and conditions herein provided.

11.3 Good Faith

RPS Aquaterra undertakes to act in absolute good faith in the provision of service to the benefit of the Client including without limitation the preservation of the Client's confidential information and/or intellectual property as applicable PROVIDED ALWAYS that the Client shall put RPS Aquaterra on notice by written memorandum or other adequate means of notice of any information or knowledge disclosed to RPS Aquaterra (or its personnel) which is of a confidential nature or which comprises or contains intellectual property of the Client AND any information (including documents) supplied by the Client to RPS Aquaterra not so specified may be treated by RPS Aquaterra as being within the public domain.

11.4 Client's Covenant

The Client shall in absolute good faith provide to RPS Aquaterra and its personnel all logistic supports, services, personnel and facilities (including those referred to in clause 6) together with such technical or other information or documents as may be required to enable RPS Aquaterra and its personnel to professionally address and perform the service contemplated AND the failure of the Client to provide support and facilities to RPS Aquaterra as herein provided shall be and be deemed to constitute fundamental breach of contract by the Client and in the event that such failure shall continue for more than 72 hours following notice of default by RPS Aquaterra to the Client then RPS Aquaterra may elect to terminate the contract and withdraw its personnel and invoice the Client for the full value of the contract which shall be and be deemed hereby to constitute liquidated damages due to RPS Aquaterra incident upon the default by the Client as aforesaid.

11.5 Governing Law

RPS Aquaterra and the Client agree that the contract shall be governed by the laws applicable in the State of Western Australia and in the event of any dispute incapable of resolution by commercial negotiation the parties agree to submit to the jurisdiction of the Court of appropriate jurisdiction in the said State.

11.6 Entire Agreement

A contract made between RPS Aquaterra and the Client shall constitute the entire agreement between them PROVIDED any contract may be amended or varied by written memorandum of agreement to vary or amend exchanged between RPS Aquaterra and the Client.

11.7 Availability

The provision of services in respect to which these standard terms and conditions are published by RPS Aquaterra to the Client is subject to the availability of RPS Aquaterra personnel at the time of acceptance by the Client of the offer for provision of services AND RPS Aquaterra reserves the right to decline to provide the services sought by the Client by a notice in writing to the Client within seven days of acceptance by the Client in the event that personnel required are unavailable.

12. Limitation of Liability

RPS Aquaterra warrants to the Client that it shall employ skilled and experienced personnel in all matters relating to the service provided to the Client in concert with best industry practice AND shall endeavour in all things to provide the service in accordance with the Client's specifications and within the time parameters agreed PROVIDED ALWAYS that the Client acknowledges that in the event of the failure or delay of the provision of the service by RPS Aquaterra to the Client regardless of the cause or circumstance of the failure or delay (including without limitation negligence by any of RPS Aquaterra's personnel), RPS Aquaterra's liability to the Client SHALL BE LIMITED to the balance of any monies owing by the Client to RPS Aquaterra in respect of the service and the Client EXPRESSLY ACKNOWLEDGES AND AGREES that RPS Aquaterra shall not be liable for and the Client shall make no claim upon RPS Aquaterra for any consequential loss suffered by the Client whatsoever.