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DRILLSEARCH ENERGY LIMITED

Underground Water Impact Report – ATP940P

February 2016

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DRILLSEARCH ENERGY LIMITED

Underground Water Impact Report - ATP940P

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Contents

List of Figures

List of Tables

EXECUTIVE SUMMARY

The following is an Underground Water Impact Report (UWIR) completed for the purposes of meeting the requirements of Chapter 3 of the *Water Act 2000* (Qld). The report covers the current and proposed production testing activities on Authority to Prospect 940 (ATP 940P) by Circumpacific Energy (Australia) Pty Limited (a wholly owned subsidiary of Drillsearch Energy Limited). These activities include the drilling of exploration wells, hydraulic fracture stimulation of the wells, and production testing of those wells. Future planned wells and production testing over the forthcoming three (3) years is also considered. Non-associated groundwater take required to provide source water for hydraulic fracture stimulation and other activities is also considered.

The report provides:

- a description of the hydrogeological context of the area including a description of the aquifers present and how they interact;
- an estimate of how much underground water will be required to be taken as a result of the proposed production testing activities (including non-associated water take);
- an estimate of the groundwater level impacts as a result of the proposed production testing activities as determined through a groundwater flow model;
- a description of the predicted small immediately affected areas (IAA) generated by the completed and proposed exercise of Drillsearch's underground water rights;
- a monitoring strategy to verify modelling predictions and quantify impacts; and
- a reporting strategy back to the Department of Environment and Heritage Protection (EHP) should there have been a material change from predictions.

The key findings of the report are that overall, no material impacts to underground water resources are predicted as a result of the production testing activities on ATP940P. While small immediately affected areas are predicted in the Winton and Glendower formations, no immediately affected bores can be identified. As such, no make good obligations for private water bores are triggered under the *Water Act 2000*.

A monitoring strategy has been proposed which will ensure that realised groundwater changes align with predictions. As knowledge of the hydrogeology in the area expands, the model will be re-run with updated information and re-submitted to the department.

A public notice about the proposed underground water impact report will be made and submissions from the public sought in accordance with the requirements of the *Water Act 2000*.

1 INTRODUCTION

ATP940P is located approximately 260km west of Thargomindah in southwest Queensland (**Figure 1**). The nearest populated area is Innamincka, which is located approximately 25 km from the north-western border of the study area. The tenure holders of ATP940P are Circumpacific Energy (Australia) Pty Limited, a wholly owned subsidiary of Drillsearch Energy Limited (DLS) which holds 40% equity in the permit and is also the operator; and QGC Limited which holds 60% equity in the permit.

The *Water Act 2000* (Qld) (Water Act) requires petroleum tenure holders to manage impacts of extraction of underground water from their production testing or production activities. To assist in achieving this, petroleum tenure holders must prepare an UWIR, which is used to proactively predict any possible impacts of the petroleum operations on underground water resources and implement monitoring and mitigation measures if necessary.

The key aspects of an UWIR are:

- information about underground water extractions resulting from the exercise of underground water rights;
- information about aquifers affected, or likely to be affected;
- maps showing the area of the affected aquifer(s) where underground water levels are expected to decline;
- a water monitoring strategy; and
- where required, a spring impact management strategy.

This UWIR provides information about the relevant underground water extractions and the potential impacts on aquifers within ATP940P in relation to the previous and any future production testing of exploration wells. This UWIR covers the entire area of ATP940P, however most attention is focussed on areas which may be subject to groundwater impacts, which are predominantly in the western portion of the permit.

1.1 Objective

The purpose of this document is to satisfy the requirements of section 370 of the Water Act for the existing and proposed future production testing activities within ATP940P in the Cooper Basin in southwest Queensland. The proposed production testing and groundwater extraction requirements are detailed below.

1.2 Purpose

This UWIR has been prepared to describe the hydro-geological context of the project area and predict the impacts on underground water associated with proposed underground water take of both associated water (extracted in the process of production testing) as well as groundwater sourced from other formations to provide source water for hydraulic fracturing activities. Note that water added to the well during the hydraulic fracturing process and removed again in flow back is not classed as associated water for the purposes of this report. A hydro-geological conceptualisation has been prepared to assist in understanding the aquifers in the project area. A model has been prepared to predict groundwater impacts expected as a result of the previous and proposed production testing activities. This UWIR also proposes a monitoring strategy to compliment and verify the groundwater modelling. The monitoring strategy will also be used to quantify any possible impacts and be used to refine future groundwater models.

1.3 Background

Drillsearch is an oil and gas producer and explorer focused on the highly prospective Cooper-Eromanga Basin. The company is Australia's third-largest onshore oil producer, with a clear strategy to become a meaningful supplier of gas and gas liquids. Drillsearch has established a holding of oil and gas exploration permits covering a large area in the Cooper-Eromanga Basin. The Company holds 18 permits and 6 tenements with a net permit interest of ~15,000km². Drillsearch holds at least a 50% interest in 17 of these 24 areas and operates14 permits. The location of ATP940P is illustrated in **Figure 1**.

1.4 Cooper-Eromanga Basin

The Cooper-Eromanga Basin is located in Central Australia and spans the north-eastern region of South Australia and the south-western region of Queensland. The Great Artesian Basin (GAB) is the dominant hydrogeological feature in the region and, within the southwestern area of the GAB there is the Eromanga Basin that superimposes the Cooper Basin. A range of conventional and unconventional oil and gas operations have been ongoing in the Cooper-Eromanga Basin since 1954 and today key operators include Santos, Beach Energy, Drillsearch, Senex Energy, Origin and many others.

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1.5 Project Information – ATP940P

Located in far southwest Queensland and being over 2,500 km^2 in area, ATP940P forms a central part of Drillsearch's Central Unconventional Resources portfolio. Drillsearch's Unconventional Business Strategy is to prove the presence, prevalence, producibility and profitability within the company's acreage. The targets for the ATP940P exploration program are deep shale and tight sandstone gas reserves. Over 1,100km^2 of 3D seismic acquisition testing has been undertaken on the permit, which has been followed by the drilling of four vertical exploration wells up to 4,050m deep. These wells showed indications of elevated gas in the primary intervals and two wells (Anakin and Charal) were subsequently hydraulically stimulated and production tested before being suspended. The remaining two wells, Padme and Amidala were not tested and remain in a cased and suspended state not open to the reservoir (i.e. unperforated and not in communication with the target petroleum. reservoirs of the REM Shales or Toolachee/Patchawarra/Tirrawarra formations).

Over the report period (three years), it is expected that the largest development scenario would be the construction of 10 exploration wells and associated treatments such as hydraulic fracturing. Further detail about the locations of these wells and associated groundwater extraction locations is presented in the “Underground Water Extraction” section. The water extraction profile for such a project is vastly different from a coal seam gas project. The target formations have produced effectively no “associated water” during production testing. Instead, “non-associated” water is extracted up-front for associated activities and later on for drilling and hydraulic fracturing fluid purposes. This results in very a different risk profile for water resource impacts, where groundwater impacts are likely to reduce over time once the wells have been completed, versus CSG where significant volumes of water may need to be extracted for years after wells have been completed. As such, the water monitoring strategy is focussed on pre- and immediately-post completion timeframes as well as verification of groundwater impact modelling.

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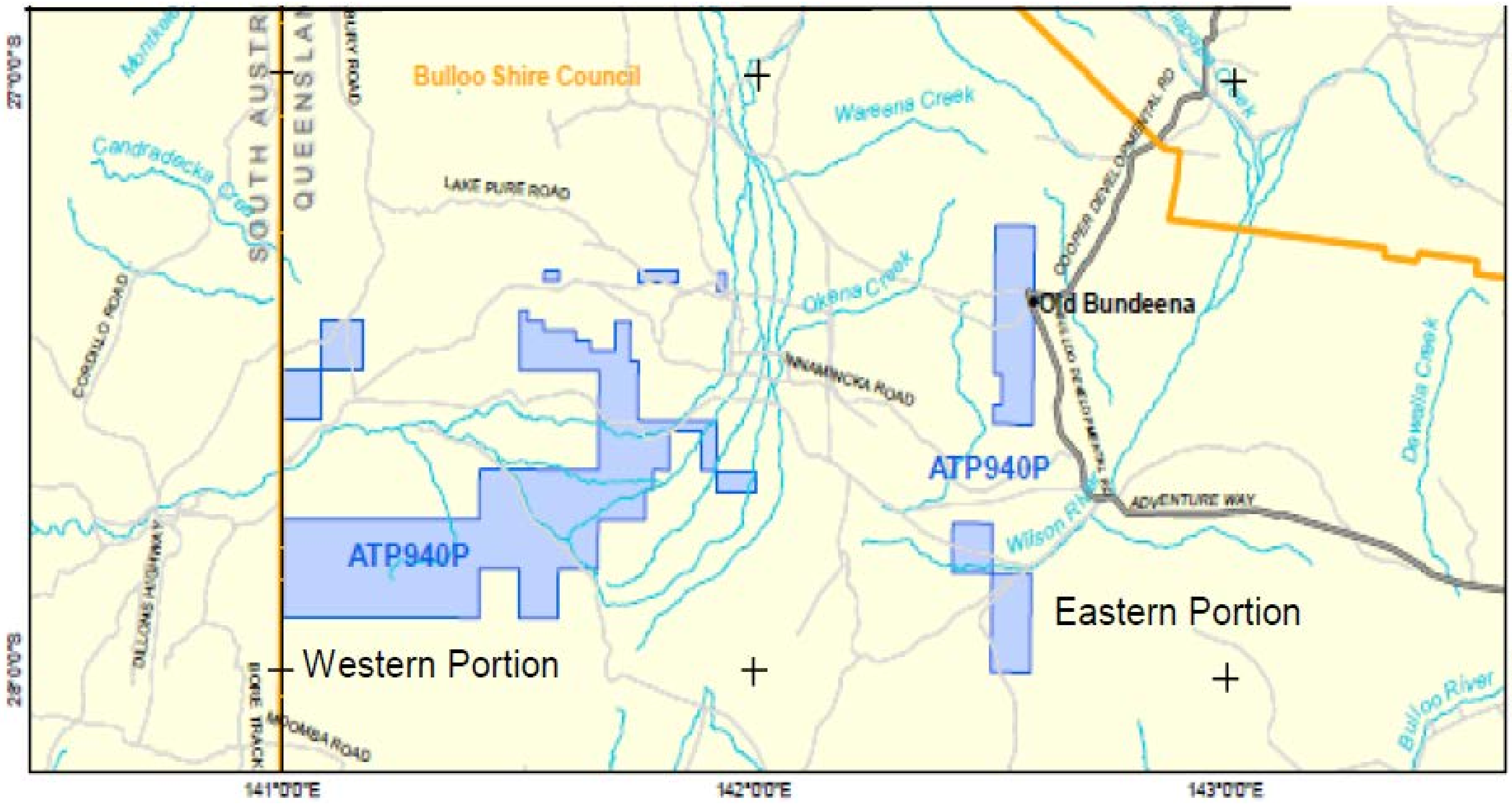


Figure 1: Locality Plan

2 LEGISLATION

2.1 Statutory Requirements

A UWIR is developed to document compliance with sections 370 to 379 of the Water Act. This UWIR has also been developed in consideration of the EHP guideline Preparing an Underground Water Impact Report or Final Report.

The start date for production testing on ATP940P was24 December 2014 at Charal-1, therefore the UWIR is due for submission to EHP by 24 February 2016, or 14 months after the start date.

The report contains:

- An estimate of the volume of water likely to be produced from the production testing activities (including non-associated water take);
- A description of the relevant aquifers of the area;
- An analysis of movement of underground water as a result of the production testing activities;
- An analysis of likely corresponding water level changes;
- A map showing the Immediately Affected Areas (IAA);
- A description of the modelling techniques used to make the predictions;
- A description of how the modelling was used to produce a map of the IAAs; and
- A groundwater monitoring strategy.

2.2 Water Act 2000

In terms of the management of impacts on underground water caused by the exercising of underground water rights by petroleum tenure holders, the requirements of the Water Act are achieved by:

- requiring petroleum tenure holders to monitor and assess the impact of the exercise of underground water rights on water bores and to enter into 'make good' agreements with the owners of the bores
- the preparation of UWIRs that establish underground water obligations, including obligations to monitor and manage impacts on aquifers and springs;
- establishing a management framework overseen by the Office of Groundwater Impact Assessment (OGIA) which addresses cumulative underground water impacts from multiple tenure holders in an area (e.g. the Surat Cumulative Management Area).

The Water Act gives OGIA other functions and powers for managing underground water. If a water bore has an impaired capacity as a result of petroleum activities, an agreement will be negotiated with the owner of the bore about the following:

- the reason for the bore's impaired capacity;
- the measures the holder will take to ensure the bore owner has access to a reasonable quantity and quality of water for the authorised use and purpose of the bore; and
- any monetary or non-monetary compensation payable to the bore owner for impact on the bore. If an agreement relating to a water bore is made the agreement is taken to be a 'make good' agreement for the bore.

The UWIR is required to define the IAA expected to result from petroleum activities. An IAA is defined as an area where the predicted drawdown within 3 years is at least:

- 5 m for a consolidated aquifer;
- 2 m for an unconsolidated aquifer; or
- 0.2 m for a spring.

UWIRs are published to enable comments from bore owners within the area. Submissions made by bore owners will be summarised by Drillsearch, addressed as appropriate and provided to EHP. UWIRs are submitted for approval by EHP. OGIA may also advise EHP about the adequacy of these reports.

OGIA will maintain a database of information collected under monitoring plans carried out by petroleum tenure holders in accordance with approved UWIRs. The database will also incorporate baseline assessment data collected by petroleum tenure holders.

2.3 Consultation Summary

Public consultation was carried out via publication of a public notice in the Charleville Western Times on 21 January 2016. Individual notices were also sent to relevant land owners on the same day. The notices contained the following information:

- a description of the area to which the report relates;
- where copies of the report may be obtained
- how the copies may be obtained;
- how written submissions on the report may be given;
- that submission must be given to the responsible entity;
- that a copy of submissions must be given to the chief executive;
- the day by which submissions may be made, that is at least 20 business days after the notice is published; and
- where the submissions may be given.

The UWIR was also provided on Drillsearch Energy Limited's website from the 21 January 2016. Consultation was undertaken for a minimum of 20 business days. No comments or submissions were received from land owners or the general public. A copy of the public notice is contained in Appendix 2.

2.4 Petroleum and Gas (Production and Safety) Act 2004

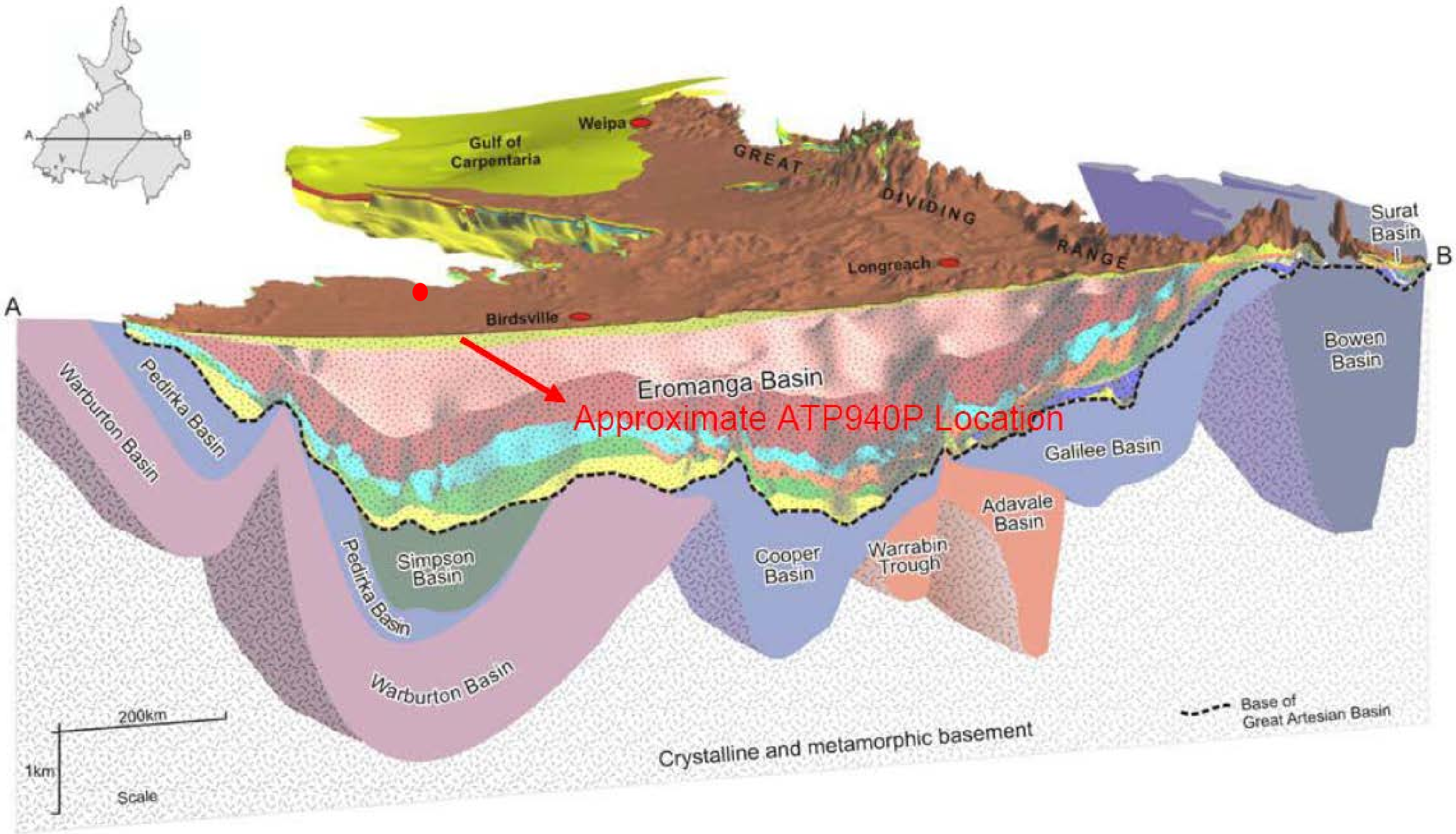
Under the *Petroleum and Gas (Production and Safety) Act 2004* the petroleum tenure holder may take or interfere with groundwater to the extent that it is necessary and unavoidable during the course of an activity authorised for the petroleum tenure. The *Petroleum and Gas (Production and Safety) Act 2004* requires tenure holders to comply with underground water obligations specified in the Water Act.

3 GEOLOGICAL SUMMARY

3.1 Geological Setting

The study area is situated within the Eromanga Basin and the Cooper Basin, a part of the GAB, comprising sequences of sedimentary strata that extend to a depth of around 4,000 m. The Eromanga and Cooper Basins are formed within a large syncline uplifted and exposed along its eastern margin and that tilts generally to the southwest. An overview of the regional geological setting is presented in **Figure 2**.

The Winton Formation is the uppermost of the GAB formations within the Eromanga Basin, although it is not artesian in the study area. It consists of interbedded sandstone, shale, siltstone and coal deposits and directly underlies the Quaternary and Tertiary sediments. Other major GAB formations below the Winton Formation include the Wallumbilla Formation, Cana-Owie Formation, Hooray Sandstone, Westbourne Formation, Birkhead Formation, Hutton Sandstone and the Poolowanna Formation.



(Excerpt taken from CSIRO GAB Water Resource Assessment, 2012)

Figure 2: Regional geological setting.

3.2 ATP940P Geology

A summary of key components of the geology and hydrogeology associated with the study area is presented. Information derived from detailed desk studies previously undertaken by Drillsearch (e.g. Golder, February 2013) has been summarised in this report along with other key findings as required.

3.3 Surface geology

The surface geology within the study area (Australia 1:125,000 Geological Map Series, 1969) shows low-lying flood plain areas that typically comprise unconsolidated Quaternary alluvium and upland areas comprised of consolidated sandstone, siltstone and mudstone sediments of the Glendower Formation (Tertiary) and Winton Formation (Cretaceous) (Figure 3). The Quaternary deposits consist of fluvial and aeolian sand deposits and are typically overlain by thick floodplain and channel mud deposits.

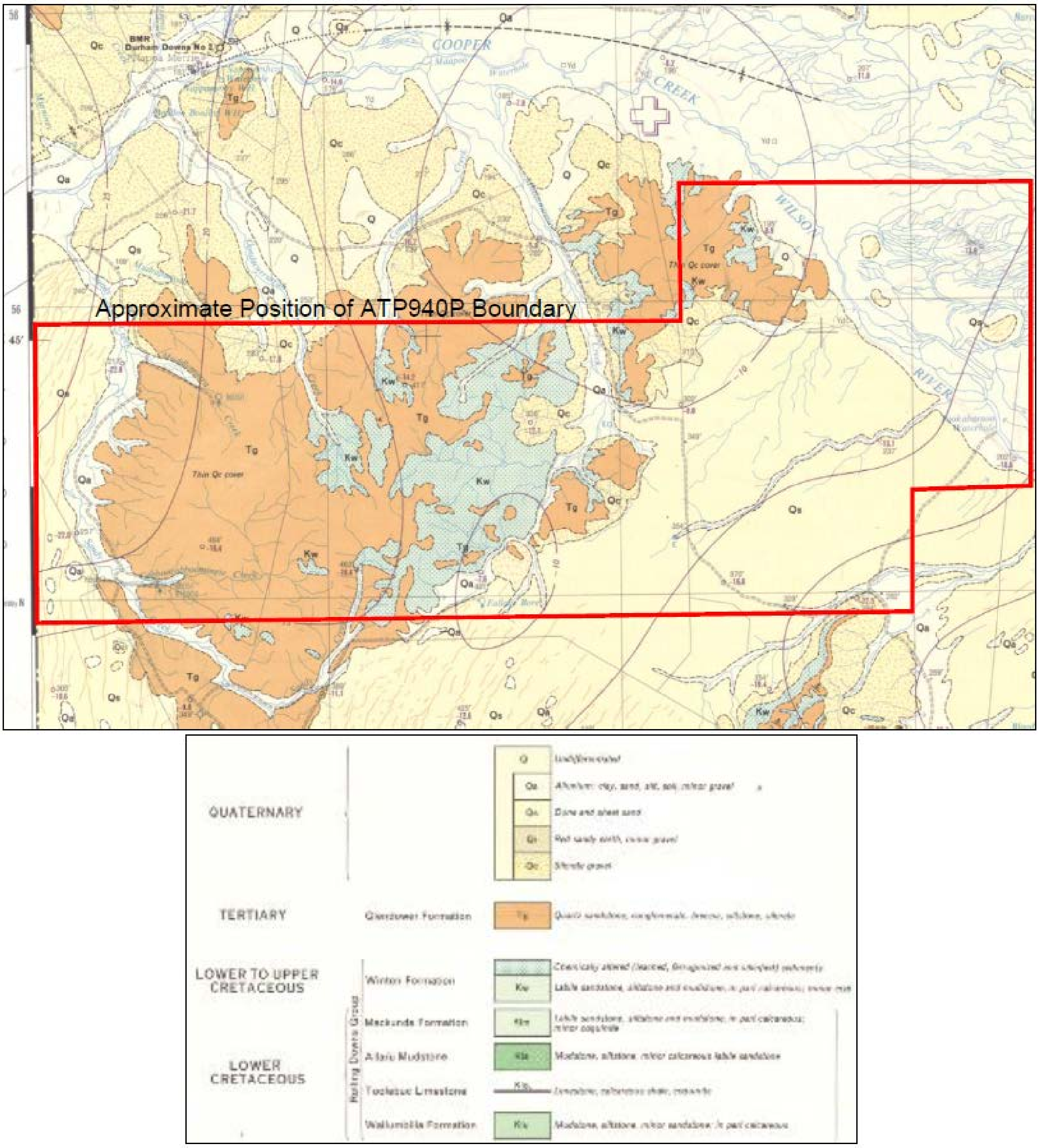


Figure 3: Surface geology map of ATP940P (Western Area)

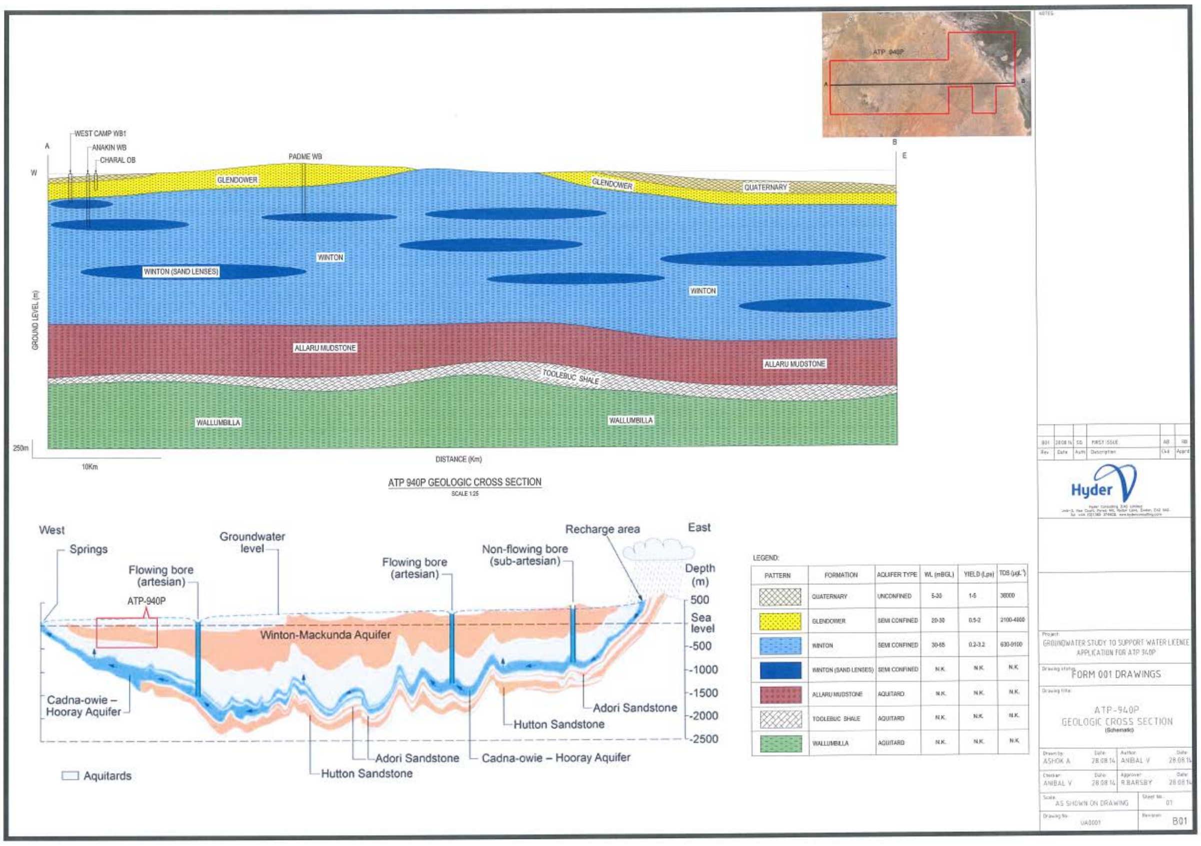


Figure 4: Regional Schematic geological cross-section from west to east across ATP940P

3.4 Subsurface geology

In order to fully understand the present and future use of groundwater resources, a brief overview of the stratigraphical formations beneath ATP940P, and their water-bearing capabilities, is required as presented in Figure 5.

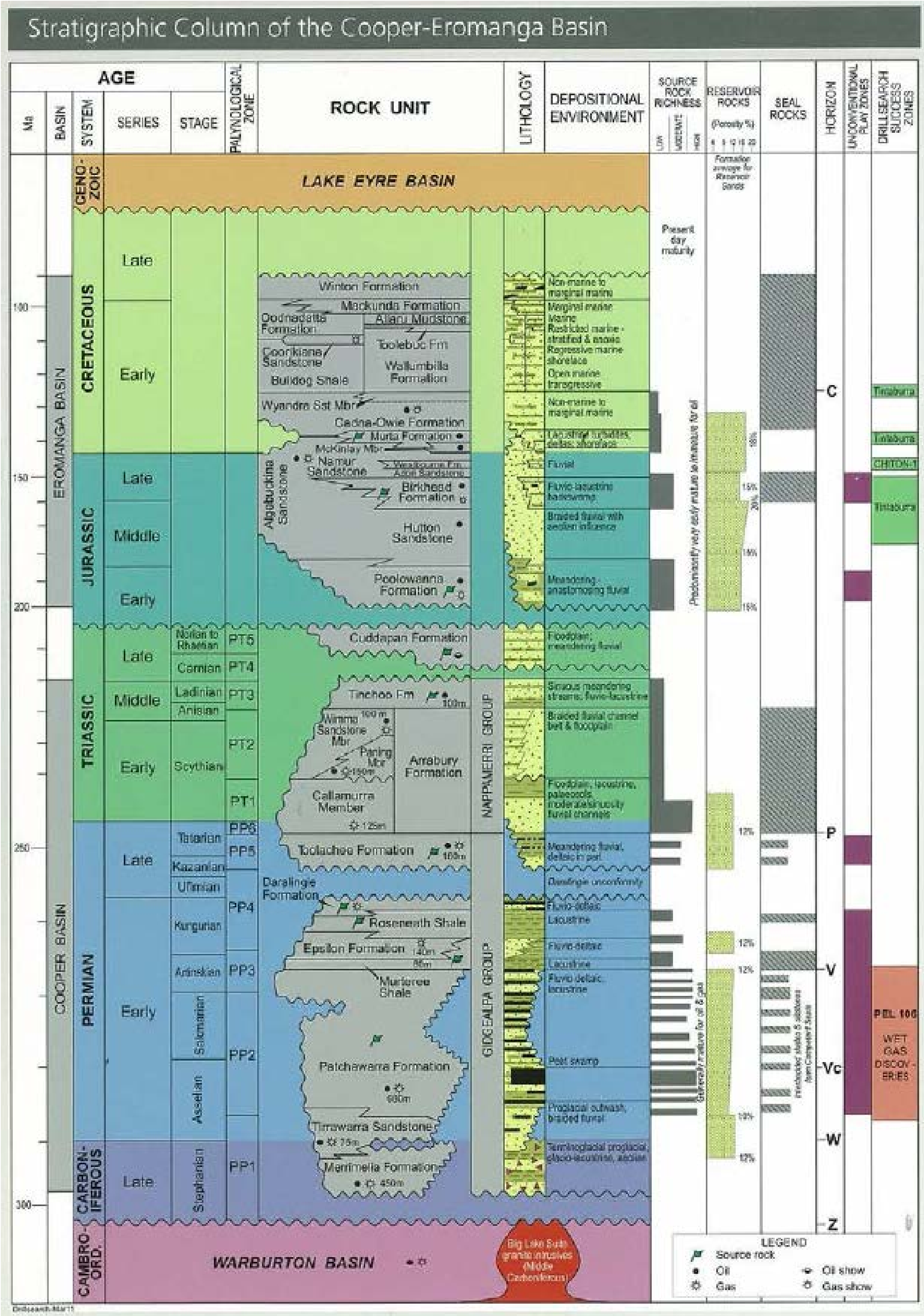


Figure 5: Cooper-Eromanga Basin Stratigraphy

The GAB is the dominant hydrogeological feature in the region and, within the GAB there is the overlying Eromanga Basin and underlying Cooper Basin. The major Eromanga formations are, from upper to lower:

Winton Formation: the Winton Formation consists of interbedded fine to coarse sandstone, shale, siltstone and coal. Within ATP940P, the top of the Winton Formation is typically 50-150 metres below ground level and 450-850 metres in thickness. The Winton Formation is the upper unit of the Rolling Downs Group which is generally associated with aquitards; although according to the EHP database there are water-bearing regions in this formation that service a number of stock and domestic water supply bores.

Wallumbilla Formation: consisting of predominantly interbedded mudstone, siltstone, sandy mudstone, sandstone and limestone. The fined-grained sediments in the Wallumbilla Formation have low porosity and permeability. The Wallumbilla Formation ranges from 300-1000 Metres in thickness.

Cadna-Owie Formation: interbedded sandstone, siltstone, silty mudstone and marine mudstone. Within ATP940P, the Cadna-Owie Formation occurs at depths between 1,300-1,750 metres below ground level, with a thickness of 80-120 metres. In Queensland, it is restricted to subsurface (i.e. does not outcrop). The lower portion of the Cadna-Owie has very low porosity and is widely accepted to be an aquitard.

Hooray Sandstone/Namur Sandstone: the upper Hooray Sandstone is commonly referred to as the "Murta Member"; the lower portion the "Numur Sandstone." The Hooray is found at depths between 1,400-1,800 metres below ground level, with a thickness ranging between 140-220 metres. The upper Murta Member comprises of a siltstone bed that forms an aquitard throughout ATP940P. The lower Namur Sandstone is a major water bearing unit with some oil also present.

Westbourne Formation and Adori Sandstone: the Westbourne Formation consists of fine to very fine-grained sandstone imbedded with siltstone and shale. Although widely considered to be an aquitard, the Department of Natural Resources and Mines Groundwater Database indicates that a number of private bores have been completed in the Westbourne Formation. The Westbourne is found at 1,500-1,950 metres below ground level, with a thickness of 8-150 metres across the basin. The Adori is predominantly fluvial sandstone with minor siltstone and conglomerate, ranging in thickness between 20-60 metres, and is often difficult to distinguish from the Westbourne.

Birkhead Formation: consisting of interbedded sandstone and siltstone, with minor mudstone and shale. Within ATP940P, the top of the Birkhead Formation ranges from 1,650-1,215 metres below ground level, with a thickness ranging between 40-100 metres. Regionally, the Birkhead is considered an aquitard between the overlying Adori Sandstone and the underlying Hutton Sandstone aquifers.

Hutton Sandstone: a significant sandstone aquifer in the GAB, the Hutton is located at depths of 1,700-2,000 metres below ground level, and ranging in thickness from 30-200 metres.

Poolowanna Formation: the Poolowanna Formation consists of an upper dominant mudstone subunit and a lower dominant sandstone unit, at depths of between 1,800-2,500 metres below ground level.

The formations of the Cooper Basin are divided into two groups; the overlying Triassic Nappamerri Group, and the underlying Permian Gidgealpa Group.

Toolachee Formation: unconformably overlies the Patchawarra Formation in this area, and is a lithologically similar unit to the Patchawarra Formation. In Queensland, the Toolachee ranges in thickness between 25-130 metres.

Roseneath Shale: a confining bed that consists of Lacustrine deposits of siltstone, mudstone and minor sandstone and, in Queensland, is between 50-200 metres in thickness.

Epsilon Formation: is defined as series of sandstone and siltstones and shales with minor coals. The Epsilon is approximately 100-150 metres thick in the Nappamerri Trough.

Murteree Shale: a confining bed siltstone and fine-grained sandstone, the Murteree target formation is generally less than 80 metres in thickness.

Patchawarra Formation: is a sequence of stacked sands, silts and coals, laid down in a former meandering fluvial to swamp environment. The Patchawarra sands are fine-grained and have relatively poor reservoir characteristics. In south western Queensland, the Patchawarra can be as much as 500 metres in thickness, and is the second-most widespread Permian unit, extending to the limits of the Cooper Basin.

Tirrawarra Formation: is a massive sandstone section deposited in a high energy braided stream environment related to glacial outwash and generally has good reservoir characteristics. The Tirrawarra Sandstone is 30-100 metres thick in south-western Queensland and considered to be an aquifer.

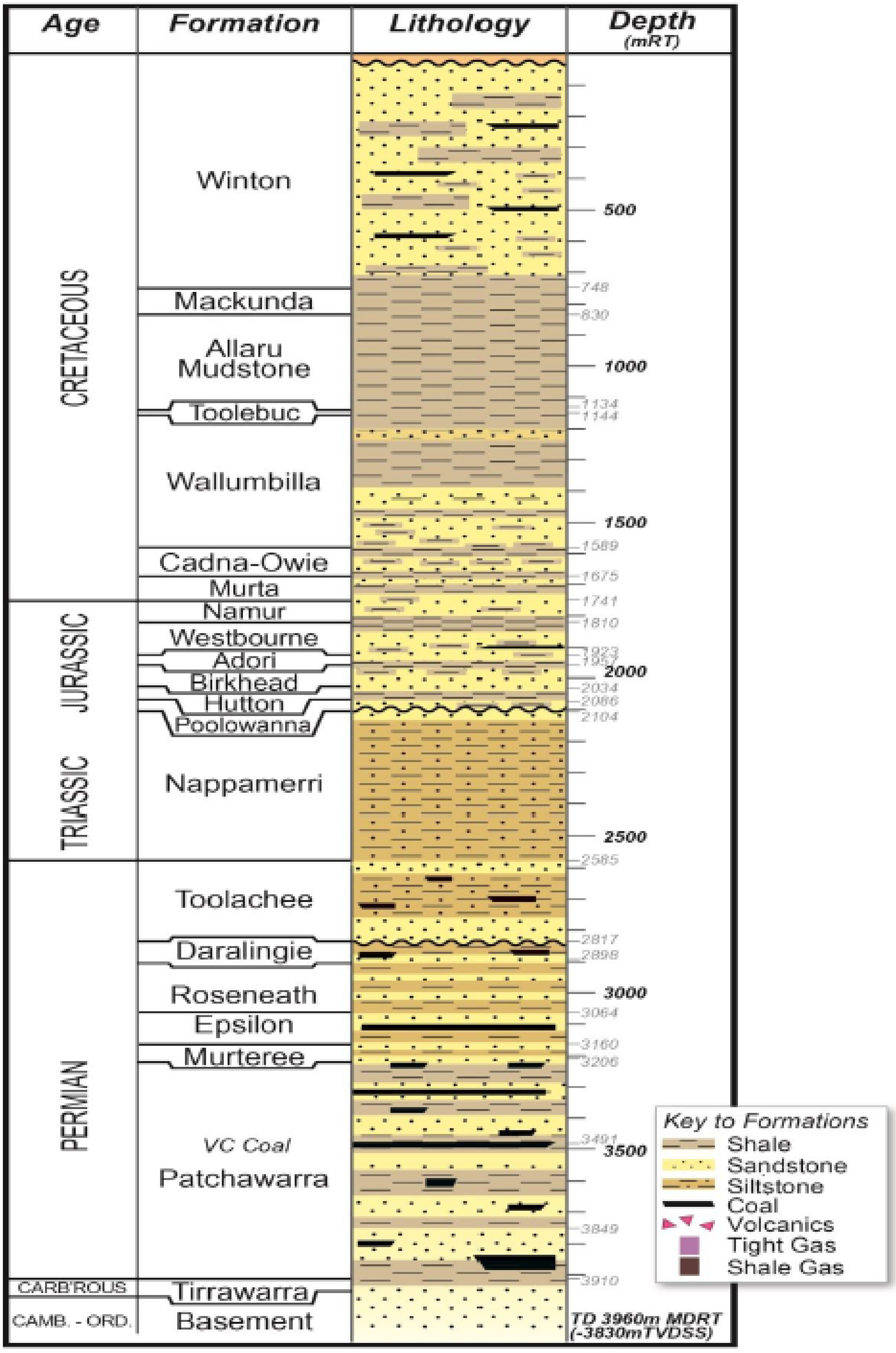


Figure 6: ATP940P region-specific stratigraphy

4 PETROLEUM WELL DESIGN

Well design and construction provides the mechanical integrity of the well bore for the operational conditions and life of the well. The design and construction process ensures that the casing, well head equipment are designed to meet the stresses and loads associated with the high temperature and pressures that are anticipated with the target formations, and ensure that any impacts to the surrounding environment are avoided or minimised to the greatest possible extent.

Casing design has been modelled as a high pressure, high temperature well ("HPHT") in accordance with the "*BG Well Engineering Minimum Standard Casing Design*" (document reference, BG-ST-WE-WE-004).

Critical casing loads and safety factors have been calculated for each casing string, utilising LandmarkTM Wellcat analysis software. Real-time mud-logging services will provide 24 hour advanced surveillance of drilling activities to confirm pressure and temperature effects for the ensuing hydraulic stimulation activities. Mud cooler systems will be installed for the drilling stage to moderate drilling fluid temperature and ensure physical integrity of the well prior to the installation of the well casing.

Specialised HPHT cement that contains a high silica content to maintain well integrity at the expected high temperatures will be utilised for well construction. Well integrity is managed through a range of tests and monitoring measures, such as:

- recording string pressures (tubing and all annuli) to confirm no communication between casing strings (i.e.; maintain isolation from outer strings);
- testing of wellhead voids and cavity pressures to ensure no communication between casing strings;
- valve functionality;
- top up of annuli with inhibited fluid and pressure test
- monitoring maximum Allowable Annular Surface Pressure;
- pressure test or inflow test all valves
- re-energise/pressure test wellhead seals.
- calliper/sonic log casing or tubing to check integrity for corrosion and wall failure; and
- corrosion analysis studies.

Monitoring will be undertaken during well construction to ensure that fluids and that the high temperatures do not cause the rapid expansion of fluids that may be trapped in the annuli between surface casings. Appropriate monitoring to check and bleed off any trapped pressure will ensure the casing does not collapse.

5 UNDERGROUND WATER EXTRACTION

5.1 Water Requirements

Shale gas projects differ vastly from coal seam gas projects in terms of water requirements.

5.2 Source water for hydraulic fracture stimulation – quantity of water already produced

To date, water has been extracted from a range of bores installed by the operator to provide water for authorised activities. Water has also been extracted for construction, dust suppression and other associated activities. The volumes of water taken from each bore in the 2014 and 2015 financial years is detailed in Table 1 below.

Table 1: Water extracted to date.

Bore Name*	Latitude (GDA94)	Longitude (GDA94)	FY2014 Water Usage (ML)	FY2015 Water Usage (ML)
Anakin OB	27.47.39	141.01.43	5.68	0.00
Anakin Deep	27.47.41.5	141.01.46.8	16.36	0.00
WCamp WB2	27.50.45	141.00.55	1.69	0.55
West Camp	27.50.35	141.00.57	28.36	33.68
Anakin WB3	27.47.41	141.01.42	0.47	10.00
Padme 1	27.46.42.5	141.12.14.1	0.08	0.64
Padme WB3	27.47.442.2	141.01.43.3	4.77	9.54
Anakin WB4	27.47.45	141.14.44	0.02	28.99
		Total ML	**57.43**	**83.40**

5.3 Quantity of water estimated to be produced over the next three years.

It is anticipated that the only significant ongoing underground water extraction will be in sourcing water for further drilling, hydraulic fracture stimulation and associated activities. Table 2 details predicted requirements per bore.

The quantity of water required by Drillsearch for fracture stimulations has not been fully determined or a programme defined at this stage. Drillsearch provided the following maximum groundwater abstraction estimates:

- 25 ML abstracted over a one month period and stored (e.g. within containment ponds) for use at each site (i.e. an average abstraction rate of about 5 L/s over 60 days);
- Water take will be undertaken at only one site at any time (i.e. no concurrent sites will be in operation);
- There will be a one month stand down period between water take (i.e. 25 ML in month one at site one, no abstraction in month two, 25 ML in month three at site two, no abstraction in month four, and so on).

A groundwater take will therefore only be required for up to a maximum of 24 months and for a total volume of 250 ML.

Table 2: Estimated quantity of water to be produced in the next three years.

Water Requirement	Volume (ML)	Period	Abstraction Rate (m^3/day)	Abstraction Rate (Lps)
Well construction (per well)	10ML	1 month	333.33	3.9
Well development (per well)	15ML (10 stages requiring 1.5Ml each)	1 month	500	5.8
Total Requirement (assuming 10 wells)	250ML	20 months	416.67 (average)	4.8 (average)

6 AQUIFER AND UNDERGROUND WATER FLOW AND LEVELS

6.1 Hydrogeology of ATP940P

The target hydrocarbon producing formations for ATP940P are not considered to be aquifers, and do not have the potential to produce meaningful volumes of associated water.

Drillsearch have identified through pumping testing undertaken to date that the Glendower and Winton Formations can provide suitable quality and volumes of water for fracture stimulation requirements. The following hydrogeological description therefore focuses on these units. Other potential but less suitable aquifers are greater than 1,000 m below ground level, confined beneath extensively thick low permeability units, and therefore outside of the scope of this report.

A summary of aquifers units relevant to this study are summarised in Table 3.

The sedimentary sequence of the uppermost Eromanga Basin deposits (within the Rolling Downs Group) and overlying Tertiary deposits comprise an alternating sequence of sandstones, siltstones, mudstones, and shales. The porous water-bearing sandstone intervals are bounded by low permeability mudstones, siltstones and shales that act as aquitards, and restrict/prevent vertical groundwater movement providing confined conditions for the establishment of deeper artesian aquifers.

Aquifers within the Quaternary alluvial deposits consist predominantly of sand units overlain by low permeability mud deposits and are expected to be unconfined. Their thickness ranges from hundreds of metres in low lying areas (for example adjacent to present day drainage of the Cooper River) to absent in numerous upland areas.

Table 3: Summary of Regional Hydrogeological Units

Stratigraphic Unit		Lithology	Top (m bGL)	Bottom (m bGL)	Thickness (m)	General Hydraulic Properties	Water Quality
Quaternary		Alluvium, dune, gravel, silcrete gravel deposits depending on location	0	50-100	No presence in upland areas to 100	Water-bearing	Saline to brackish
Tertiary (Glendower Formation)		Quartz, sandstone, conglomerate, breccia, siltstone, silcrete	0-100	300	No presence where eroded to 200	Water-bearing	Saline to brackish
Cretaceous (Winton Formation)	Rolling Downs Group	(top weathered – leached, ferruginized and silicified) Sandstone, siltstone and mudstone, in part calcareous, minor coal	Typically 50-150	500-1000	400-850	Water-bearing sand lenses	Brackish to fresh
Cretaceous (Makunda Formation)		Sandstone, siltstone, and mudstone, in parts calcareous, minor coquinite (fossil rich rock)	n.d.	n.d.	n.d.	n.d.	n.d.
Cretaceous (Allaru Mudstone)		Mudstone, siltstone, minor calcareous sandstone	Typically 800	1100	300	Confining beds (aquitard)	-
Cretaceous (Toolebuc Formation)		Limestone, calcareous shale, coquinite	1100	1110-1150	Typically 60	Confining bed (aquitard)	-

Note: Rolling Downs Group extends below the Toolebuc Limestone Formation to a mudstone (Wallumbilla Formation).
n.d. - no data

A regional hydrogeological cross section of these and the deeper artesian aquifer system is shown in Figure 5. In the Habermehl conceptualisation, the sandstones of the Winton and Mackunda Formations are shown as one shallow aquifer, grey coloured strata show aquitards (such as the lower Rolling Down Group), whilst the Quaternary-Tertiary deposits are not shown. An interpretation of near surface geological conditions (based on the Australia 1:250,000 Geological Map Series) for shallow aquifer and aquitard units has been included.

6.2 Underground water flows and aquifer interactions

In general, groundwater flow in shallow sub-artesian aquifers is likely to be spatially highly variable and influenced by local topographical conditions. By comparison, groundwater flow through the deeper artesian aquifers is consistent and flows towards the south to southwest (Habermehl and Lau, 1997). Given the scarcity of water level data in this area, meaningful groundwater level contour plans have not been produced for this assessment. Available data (taken from the EHP database) though suggests groundwater levels in sub-artesian aquifers trend from high to low in an east-southeast to west-northwest direction across the study area (Figure 7). By interpretation, it is possible that groundwater levels are controlled to some degree by the Winton Formation outcrop in the centre of the study area where there is higher potential for direct recharge. Given the nature of the stratigraphic sequence (i.e. sandstone, siltstone, mudstone and shale layering) it is also likely that the Glendower Formation and Winton Formation combine to create a multilayered leaky aquifer system

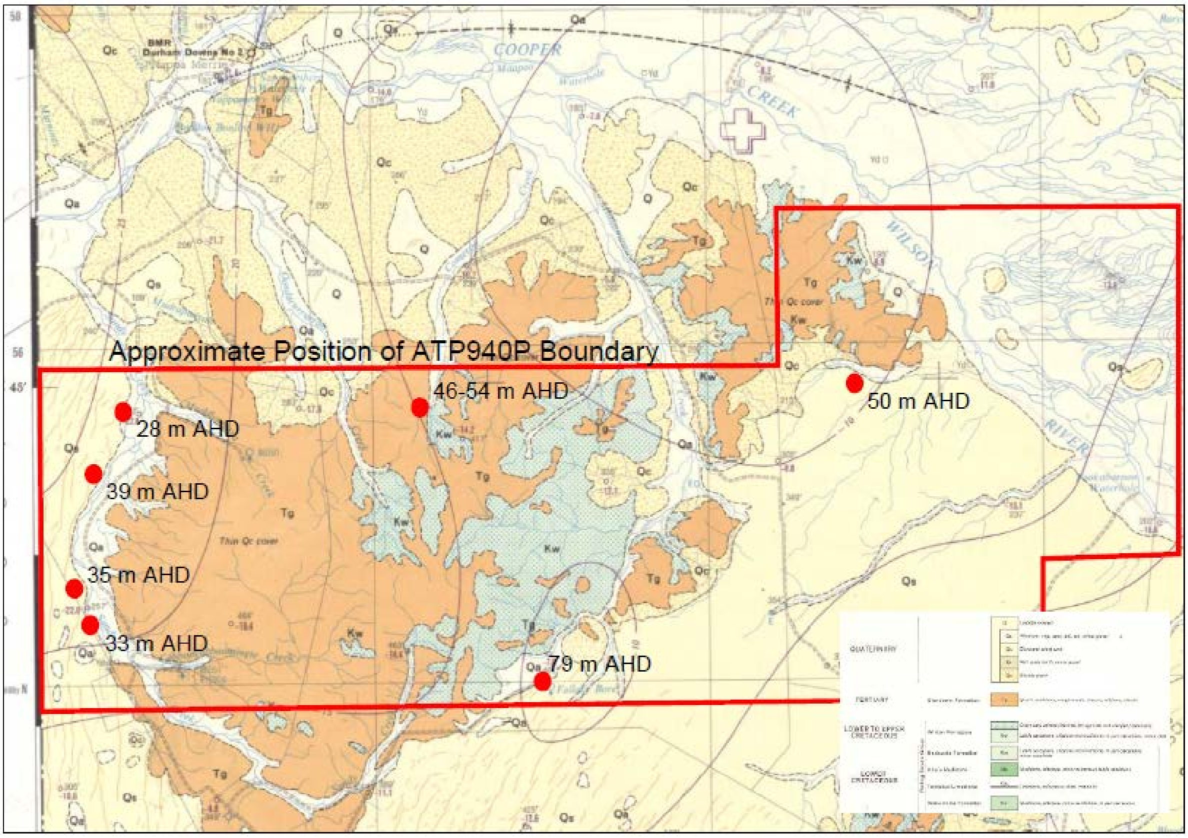
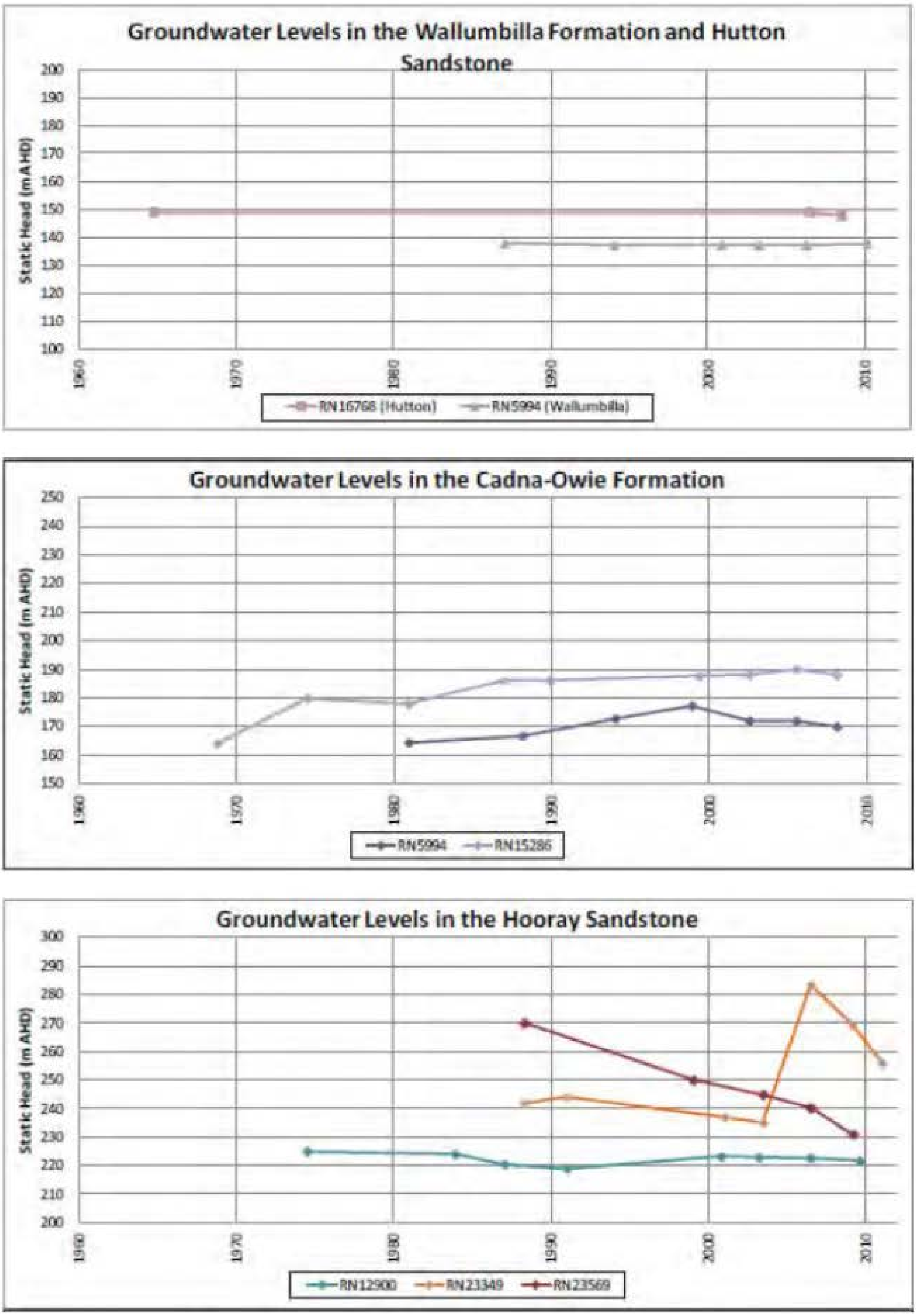


Figure 7: Groundwater Level (Spot Readings) (m AHD)

Groundwater levels for several monitoring bores completed in the deeper artesian aquifers (including the Wallumbilla Formation, Cadna-Owie Formation, Hutton Sandstone, and Hooray Sandstone) were also obtained from the EHP database (notably some of these are over 50 km from the study area). The data has been plotted (Figure 8) and with the exception of the Hutton Sandstone Formation would imply an upwards hydraulic gradient between the various formations, where a connection between them exists. The strength of the artesian conditions compared to shallow groundwater levels would imply that sub-artesian aquifer interaction does not occur.

6.3 Location of any significant faults that intersect aquifer

Major faults within the Eromanga and Cooper Basins are typically deep seated and do not displace units above the Eromanga Basin stratigraphy (Gravestock et. al. 1998). This is supported by the Australia 1:250,000 Geological Map Series (Figure 2-3) which shows no faults within the study area. It is unlikely that groundwater in the study area is fault controlled.



Taken from Golder, February 2013.

Figure 8: Groundwater Level Data from Selected EHP Monitoring Bores (Major GAB Aquifers)

6.4 Groundwater Bores

A Water Bore Baseline Assessment of existing water takes within the study area has been undertaken under separate study by Drillsearch and is presented in Appendix 3 (Golder, July 2013). The study identified that stock water supply developments typically target the shallow Winton Formation and the Glendower Formations. Twelve bores were identified and visited during the assessment (Figure 9). Bore locations were identified from the Queensland DNRM groundwater bore database and from enquiries made during the field reconnaissance. Bores do not generally exceed 30 m depth.

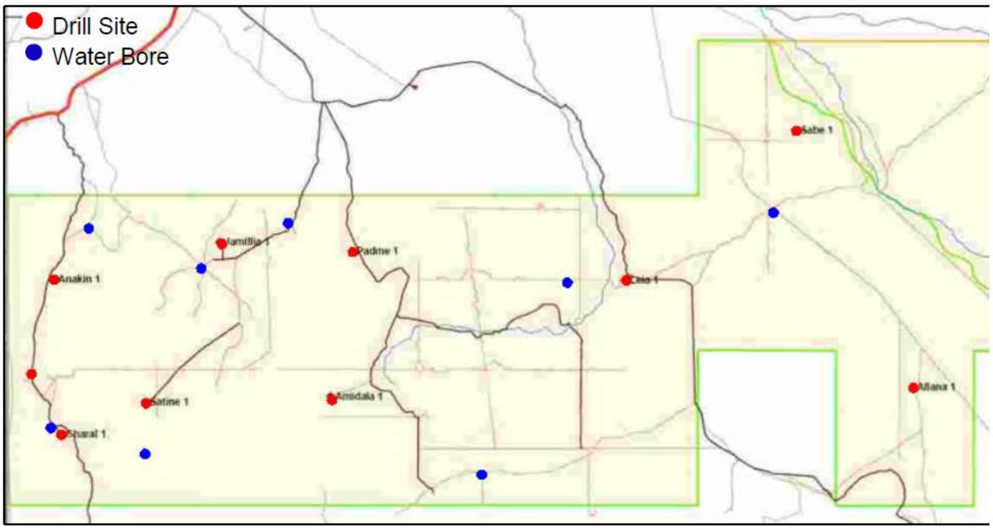


Figure 9: Borehole Locations

The baseline assessment established that all of the identified bores were (or are) intended to be used for stock watering and that all bores are currently unserviceable and unused (i.e. all pumping systems are decommissioned).

Based on the finding of the baseline assessment we therefore consider that no impact to existing water bores could currently occur as a result of the proposed groundwater take.

6.4.1 Groundwater Quality

Available groundwater quality information for the relevant aquifers is presented as follows:

Glendower Formation: Water quality from the Glendower Formation in the Cooper Basin region is of fair quality and useful for domestic, livestock watering and irrigation purposes. However, the groundwater quality data collected from the DNRM Groundwater Database and from extant bores located within ATP940P indicates that the sodium, chloride, TDS and sulphate concentrations in the Glendower Formation significantly exceed the drinking water limits. Additionally, the sulphate concentrations are marginal for livestock watering purposes. Nonetheless, the Glendower Formation is the principal water source for the townships of Thargomindah and Eromanga (most likely due to its stratigraphical proximity). Where groundwater is successfully located in the Glendower, typical flow rates are approximately 1.2 litres per second. The relatively shallow nature and flow rate from the Glendower suggests that groundwater has medium to high accessibility from this formation. Despite the general unsuitability of water quality for drinking and domestic use and its ongoing use for such purposes, the relevant environmental values relate to drinking, domestic and industrial uses.

Winton/Mackunda Formation: The Winton Formation provides fair quality water that is used for domestic, livestock watering and irrigation purposes. However, as with the Glendower Formation, the sodium, chloride, TDS and sulphate concentrations in this formation significantly exceed the drinking water limits, and the sulphate concentrations are marginal for livestock watering purposes (Appendix I). Nevertheless, the relatively shallow depth of the Winton Formation makes it a likely candidate for ongoing potential groundwater use.

Drillsearch was unable to locate flow for the Winton Formation at the time of this application. However, given the relatively shallow nature of this formation and relative abundance of groundwater bores in this formation, it is assumed that groundwater from the Winton has a medium to high accessibility. As with the Glendower Formation, the ongoing use of groundwater from the Winton/Muckunda Formations for domestic and drinking purposes (despite the relatively poor quality) means that the environmental values to be preserved should also relate to drinking, domestic and industrial uses.

Allaru Mudstone, Toolebuc Shale and Wallumbilla Formation: No groundwater data was available for the Allaru Mudstone, Toolebuc Shale or Wallumbilla Formation which is likely due to the fact that each of these formations are major confining beds (aquitard) with low or very low porosity and permeability.

Cadna-Owie Formation: No groundwater data could be located during the preparation of this amendment application. However, there is scientific literature that indicates that the upper Cadna-Owie Formation is considered to be a major aquifer, with water varying from 285 to 1490 mg/L TDS. For the purposes of this amendment application, Drillsearch has assumed that the groundwater in the Cadna-Owie Formation is of sufficient quality to be useful for drinking and domestic purposes, and livestock watering and irrigation. The Cadna-Owie Formation is located at depths between 1,300-1,750 metres below ground level. No flow/volume data could be located for the Cadna-Owie Formation and so Drillsearch has assumed medium flow rates from this formation. However, the depth of the Cadna-Owie Formation can only be described as poor to very poor in respect to overall accessibility. The current water usage is industrial only (oil/gas production) and therefore the environmental values for preservation shall extend to other industrial uses.

Hooray Sandstone: According to the DNRM Hydrogeological Framework Report for the GAB WRP Area – Version 1.0, the Hooray Sandstone produces reasonable yields of groundwater, with salinities between 187 to 3750 mg/L TDS. This would appear to be consistent with the data collected from the DNRM groundwater database for this formation (Appendix I) and suggests that the water is unsuitable for drinking but can be utilised for livestock and irrigation purposes. The current water usage is industrial only (oil/gas production) and therefore the environmental values for preservation shall extend to other industrial uses.

Murta Formation: Although water quality data from the Murta Formation is very limited, the data that is available indicates the water has a pH range of between 7.55-8.0, conductivity 2140-53330 µs/cm and TDS ranging from 1390 to 34131 mg/L. The groundwater qualitative data for the Murta was obtained from produced water that had been separated from the hydrocarbon component prior to analysis, and there is a reasonable risk that any groundwater that is sourced from the Murta within the Cooper Basin could contain low to moderate concentrations of hydrocarbons.

The extreme variability in water quality may be attributable to the low permeability of the lower portion of the formation, therein preventing stratigraphical mixing and groundwater homogeneity. In any case, the elevated salinity in some areas of this formation would preclude its use from drinking water supply, stock watering and irrigation (although there may be limited circumstances where groundwater could be utilised). Additionally, the omnipresent risk of hydrocarbon concentrations in the Murta would significantly reduce the useability of water sourced from this formation (Appendix I).

Although there is no flow data available for the Murta, its heterogeneous water quality is indicative of discrete and isolated pockets within this formation, and is therefore unlikely to contain useful water volumes. Additionally, the considerable depth of the Murta (over 1800 metres below ground level) would make accessing water in this formation extremely difficult. Groundwater accessibility is considered to be very low from this formation. The current water usage is industrial only (oil/gas production) and therefore the environmental values for preservation shall extend to other industrial uses.

Namur Sandstone: Water quality data for the Namur Sandstone ranged in pH 7.1-7.8, Sodium 2540-3570 mg/L, Chloride 14889mg/L, Bicarbonate 1443 mg/L, Sulphate 1140 mg/L, Conductivity 10860-45700 µs/cm, and TDS 6950-29248 mg/L.37 It should be noted that the quality data was obtained from produced oil field water that had been separated from the hydrocarbon component prior to analysis. Under normal domestic and commercial groundwater extraction methodology, the user could expect the presence of hydrocarbons (including benzene, toluene, ethylene and toluene) in the groundwater. The physiochemical attributes of groundwater sourced from the Namur in the Cooper Basin region would make it unsuitable quality for drinking, livestock or irrigation purposes.

There is limited groundwater flow data from the Namur Sandstone, and the single source of information available to Drillsearch suggests only limited groundwater flows (approximately 1L/hr) that would be of little or no domestic or commercial use. In addition to relatively poor flows, the depth of the Namur (1750-1900 metres) means that the cost of drilling water bores into this formation is extremely prohibitive and extremely difficult to access by future water users (see Appendix H). Groundwater accessibility is considered to be extremely low from this formation. The current water usage is industrial only (oil/gas production) and therefore the environmental values for preservation shall extend to other industrial uses.

Hutton Sandstone: Water quality data obtained for the Hutton Formation ranged in pH 4.7-7.1, Sodium 2540-4640mg/L, Chloride 3400-14889 mg/L, Bicarbonate 1443-1268 mg/L, Sulphate 110-1140 mg/L, Conductivity 5880-55600 µs/cm, TDS 3712-35584 mg/L. As with the Namur, groundwater quality data was obtained from produced water that had been separated from the hydrocarbon component and groundwater users could expect low to moderate concentrations of hydrocarbons.

Based on the limited data available, it would appear that the groundwater quality in the Hutton Sandstone in the Cooper Basin can be highly variable, with slightly acidic and highly saline water in some areas, as well as the likelihood of low to moderate hydrocarbon concentrations and generally unsuitable for drinking water supply, stock watering and irrigation.

The Hutton Sandstone is located at depths of between 2030-2200 metres below ground level. Bridgeport Energy reports relatively poor flow rates of groundwater flow between 0.0008-0.08ML/day (Appendix H). In contrast, Santos reports an average rate of water extraction of approximately 13.7ML/day across its oil fields targeting the Hutton. Regardless of flow, the depth of the Hutton Formation in the Cooper Basin region and the overall variability in flow indicates extremely inaccessible groundwater from this formation. The current water usage is industrial only (oil/gas production) and therefore the environmental values for preservation shall extend to other industrial uses.

Roseneath and Murteree Formations: For completeness, the Roseneath and Murteree Formations are mentioned here. Both formations are recognised confining layers (aquitards) and do not hold any groundwater. There is no potential for groundwater usage from water sourced from these formations within the Cooper Basin.

Epsilon Formation: No groundwater data could be located however it is considered it would likely have similar properties to the Patchawarra Formation. This may be because the Epsilon Formation is generally associated with natural gas production (as opposed to oil production) – a process that generally does not produce appreciable quantities of groundwater. For the purposes of this amendment application, Drillsearch has assumed that the groundwater in the Epsilon Formation would be of insufficient quality to be useful for drinking and domestic purposes, and livestock watering and irrigation. There is no flow or volume data available for the Epsilon Formation. However, according to Santos document, “Underground Water Impact Report for Santos Cooper Basin Oil & Gas Fields, SW QLD”, the Epsilon is historically a conventional gas target and there is generally little or no liquid that is associated with gas production other than hydrocarbon condensate. Santos makes reference to the fact that the water required for gas processing facilities (Ballera) must be sourced from local groundwater bores, which suggests that insufficient water is “produced” by the conventional gas process (in contrast to CSG production). Given Santos’ long-established expertise and understanding of the conventional gas industry in the Cooper Basin, Drillsearch considers it prudent to adopt that same position and conclude that the volume of groundwater within the Epsilon Formation is potentially limited. Furthermore, given that the Epsilon is located at depths of between 3064-3100 metres below ground level, the accessibility of groundwater from this formation would be extremely poor. The current water usage is industrial only (oil/gas production) and therefore the environmental values for preservation shall extend to other industrial uses.

Patchawarra/Tirrawarra: According to some sources, the salinity of the Patchawarra Formation is in the vicinity of 14000 ppm. Drillsearch water quality data from both the Patchawarra and Tirrawarra Formations suggest a TDS range between 4600-11820 mg/L, conductivity of 7200-10000 µS/cm, Sodium 2800-3690 mg/L, Chloride 2900-4350 mg/L, Sulphate as high as 1310 mg/L and Bicarbonate 1700-1820 mg/L; as well as containing a significant hydrocarbon component.

A typical analysis of hydrocarbons extracted from the Patchawarra and Tirrawarra may comprise approximately 10% (by weight) of hexanes, 12% heptanes, 13% octanes and 9% nonanes. It would be reasonable to conclude that groundwater extracted from the Patchawarra and Tirrawarra may contain at least low to moderate concentrations of these short-chain petroleum hydrocarbons. Popular scientific opinion suggests that these hydrocarbon compounds may have deleterious effects on human and livestock health. Based on the threshold limits in the ADWG, ANZECC and QWQG, groundwater from the upper Tirrawarra and Patchawarra is unsuitable drinking and general domestic use, and only marginal for livestock watering and irrigation.

The Patchawarra/ Tirrawarra Formations are located at depths of between 3200-4200 metres below ground level. In terms of flow rate from each formation, the Drillsearch Flax Field produced 0.677-0.8 ML/day of produced water from the Tirrawarra (Flax-1) during 2011-2012. During that same period, water production from the Patchawarra (Flax-5) was approximately 5.99-12.4 ML/day. By all accounts, the water flow rate from the Patchawarra and Tirrawarra Formations is relatively good;

however the overall accessibility of that water can only be described as extremely poor due to the extreme depth of these formations and the spatial variability reservoir quality. The current water usage is industrial only (oil/gas production) and therefore the environmental values for preservation shall extend to other industrial uses.

6.5 Springs

According to the GAB Spring Register, there are no Discharge Springs, Recharge Springs, or Watercourse Springs located within the vicinity of ATP940P (Figure 10). The nearest discharge spring is located approximately 240 kilometres southeast of ATP940P, and is the sole registered groundwater dependant ecosystem for the entire south-west Queensland region.

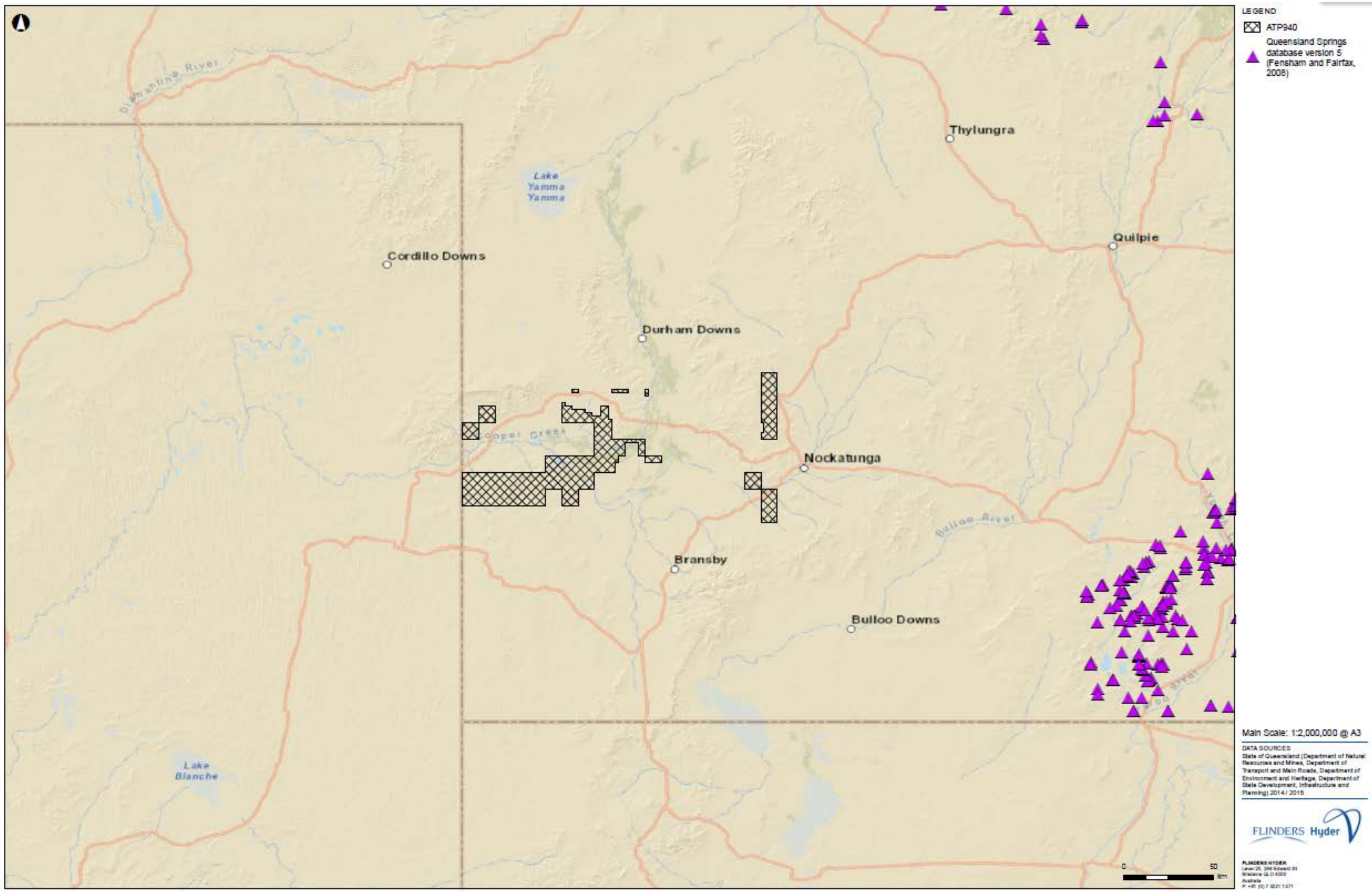


Figure 10: Springs

7 GROUNDWATER MODELLING

7.1 Modelling approach

An approach using three-dimensional (3D) numerical modelling has been undertaken to provide an indication of the ‘drawdown magnitude potential’, caused by groundwater abstraction required at each of the ten drill sites. The predictions of drawdown response have been used to assess the effect on neighbouring wells within the radius of influence of abstraction, the results of which are presented.

A 3D model approach was considered appropriate for the purposes of the UWIR after consideration of:

- The depth of proposed Drillsearch groundwater abstractions compared to the depth of abstraction in private water bores. i.e. Drillsearch are proposing to target the Winton and Glendower formation, which is also being used solely by private wells in the area;
- The large spread of Drillsearch production activities resulting in a significant geographical distribution of the volumes of water produced.

In addition to these considerations, the data (density and quality) and resources available for this assessment were insufficient for the preparation of a detailed numerical model. As a result, the numerical model approach adopted can only be used as an indicative tool akin to an analytical assessment, subject to obtaining more detailed information.

7.2 Visual ModFlow

The groundwater impact assessment was conducted using the three-dimensional numerical model software package Visual ModFlow (Version 4.6.0.164). Visual Modflow is a user interface for the 3D finite difference model ‘ModFlow 2000’ developed by the United States Geological Survey (Harbaugh et. al., 2000).

The groundwater flow equation is solved using the finite-difference approximation. The flow region is subdivided into blocks in which the material properties are assumed to be uniform. In plan view the blocks are made from a grid of mutually perpendicular lines that may be variably spaced, and the water level in each block calculated.

For the purposes of this project the Preconditioned Conjugate-Gradient Package (PCG) was used, whereby convergence of the solver is determined using both head change and residual criteria. The PCG package is described in detail in Hill (1990).

7.3 Assumptions and limitations

The following assumptions and limitations are inherent to the modelling undertaken:

- Sufficient groundwater is available for abstraction;
- The aquifer is unconfined, uniform, isotropic and groundwater flows in all directions.
- A single shallow aquifer system has been assumed (representing the Winton Formation and Glendower Formation).
- Although the model domain covers a significant area and includes a large number of wells, the wider areas where limited geological information and no water level observations are available contain a degree of interpolation.
- The model is a simplification of reality and is based on information available at the time of this study. A sensitivity analysis has been undertaken to consider variability in aquifer parameters used.

- The model results give an indication of abstraction effects on aquifer water levels and not absolute levels that will be encountered in each abstraction well due to (non-linear) well loss effects.

7.4 Justification for single layer adopted in model

Given the scarcity of information currently available, it was not possible to determine from available data whether the Winton Formation and Glendower Formation are hydraulically separated. What is evident is that the two formations are likely to combine to create a multi-layered leaky aquifer system. A single layer was therefore modelled. The limitation of this approach is that predictions of drawdown will be greatest closer to the abstraction, but the effects becoming less pronounced with distance away from it.

In addition, these shallower formations are hydraulically isolated from the deeper artesian aquifers (including the Wallumbilla formation, Cadna-Owie Formation, Hutton Sandstone and Hooray Sandstone) by the confining beds of the Alluru and Toolebuc Formations. Modelling of the deeper aquifer units is therefore not necessary.

7.5 Groundwater impact calculation parameters

Input parameters considered for the groundwater impact calculation are given in Table 4. The values shown have been taken from pumping test results conducted by Drillsearch at already developed sites, i.e. Anakin, Charal, and Padme.

Table 4: Model Input Parameters

Parameter	Units	Minimum	Maximum	Likely
Hydraulic Conductivity	m/s	$2.7x10^{-7}$	$2.7 x10^{-6}$	$6.7 x10^{-7}$
Storage coefficient	m/m	0.01	0.13	0.04

It should be noted that the values of storage presented are not derived from observation well data, but were derived from pumping well data, and are therefore likely to be unreliable without further in-situ testing. If the aquifer is confined rather than unconfined the storage coefficient is likely to be in the order of 0.0004 m/m. A sensitivity analysis has therefore been undertaken to consider variability caused by storage effects (see below).

7.6 Extent of calculation and boundary conditions

The extent of the ATP940P project boundary was used to form the extent of the calculation domain and covers an area of 69.5 km by 30.6 km. This includes a nominal 1km minimal buffer where abstraction wells are sited close to the boundary, i.e. to limit the influence of the boundary conditions on the solution. The cell dimensions assigned to abstraction well sites (and requiring most detail) are 1 m by 1 m, increasing in steps to the edges of the model (requiring least detail) where the cells are 500 m by 500 m.

The model comprises a single layer assigned a unit topographical elevation of 75 mAHD and a basal elevation of -400 mAHD, giving a total aquifer thickness of 475 m. This is in general agreement with the geological conditions encountered.

Boundary conditions have been set as lines of head dependent flux (i.e. general head boundaries) and set at sufficient distance from the area of interest to limit their influence on the solution. To produce representative groundwater levels across the model domain, values assigned to the head dependent flux were 32 m AHD (1 km west of the western model boundary) and 58 m AHD (1 km east of the eastern model boundary).

Available groundwater level data indicate that direct recharge to the Winton Formation outcrop (occurring around the centre of ATP940P study area) may be partly controlling groundwater levels in this area. Recharge was therefore assigned in the model to calibrate against actual groundwater level results. Rainfall data obtained from the Bureau of Meteorology website (www.bom.gov.au) for the nearest rain gauge at Nappa Merrie (station number 045012) has recorded an average annual rainfall of 175 mm. Given the dry conditions and prevalence for high runoff potential in this area, a recharge rate of 2% was adapted for initial model setup, equivalent to 3.5 mm /annum. This was based on obtaining a good fit during calibration and is in keeping with estimates of recharge rates (0.2 mm/year) for unconfined Great Artesian Basin (GAB) aquifers that outcrop some 400 km west of ATP940P (Love et al, 2000), and given that these estimates did not include any flood out zones associated with ephemeral streams, where it is possible that higher rates of recharge may occur.

The base of the model includes a no flow boundary condition and simulates the confining nature of the Allaru Mudstone and Toolebuc Formation that confines the Great Artesian Basin aquifers at depth.

7.7 Water production volumes used for the calculation

As described in the water production estimates section, water abstraction rates used in the model were defined on projected usage forecasts provided by Drillsearch. This assumes each drill site requires 25 ML of groundwater for well site construction and stimulation purposes, as follows:

- **Total consumption per well – 25 ML**
- Site construction and drilling – 10 ML
- 10 stage well stimulation – 15ML

Drillsearch has advised that site construction and drilling would proceed during month one with well stimulation in month two. The model therefore assumes a continuous but variable rate abstraction lasting two months at each of the well sites. It is proposed that abstraction water will be pumped to a storage lagoon for use on site.

As a conservative estimate the model assumes all water is abstracted from a single well, with a one month stand down period between each of the unconventional well sites. Screen lengths adopted were partially penetrating and based on recommendations from pumping testing, i.e. in the order of 50 m in length and screened between -100 mAHD and -150 mAHD. Existing wells were assigned screen positions in accordance with well log details.

7.8 Observed groundwater levels and calibration targets

Groundwater levels considered in the model domain (i.e. those obtained from wells used for groundwater abstraction or monitored by DNRM) were obtained from the DNRM groundwater database and Drillsearch well search records. Representative groundwater levels are given in Table 5 and summarised in Figure 11. It should be noted that the levels presented do not reflect a single point in time and only provide a generalisation of conditions encountered.

Table 5: Summary groundwater levels within ATP940P study area

Bore ID	Formation	Bore Depth (m)	Water Level (m bGL)	Water Elevation (m AHD)
RN50087	Quaternary/Tertiary Glendower	18.8	27.0	28.0
RN50086	Quaternary/Tertiary Glendower	18.7	14.9	49.8
RN50355	Quaternary/Tertiary Glendower	29.7	23.4	34.7
Anakin OB1	Quaternary/Tertiary Glendower	54.0	32.7	39.3
RN16627	Winton	103.1	59.7	79.3
Charal OB1	Winton	84.0	49.0	33.0
West Camp WB1	Winton	140.5	43.5	35.5
Padme WB1	Winton	155.0	75.0	46.0
Padme WB2	Winton	282	67.0	54.0
Anakin WB1	Winton	272.0	33.0	39.0
Anakin WB4	Winton	282.0	34.0	38.0

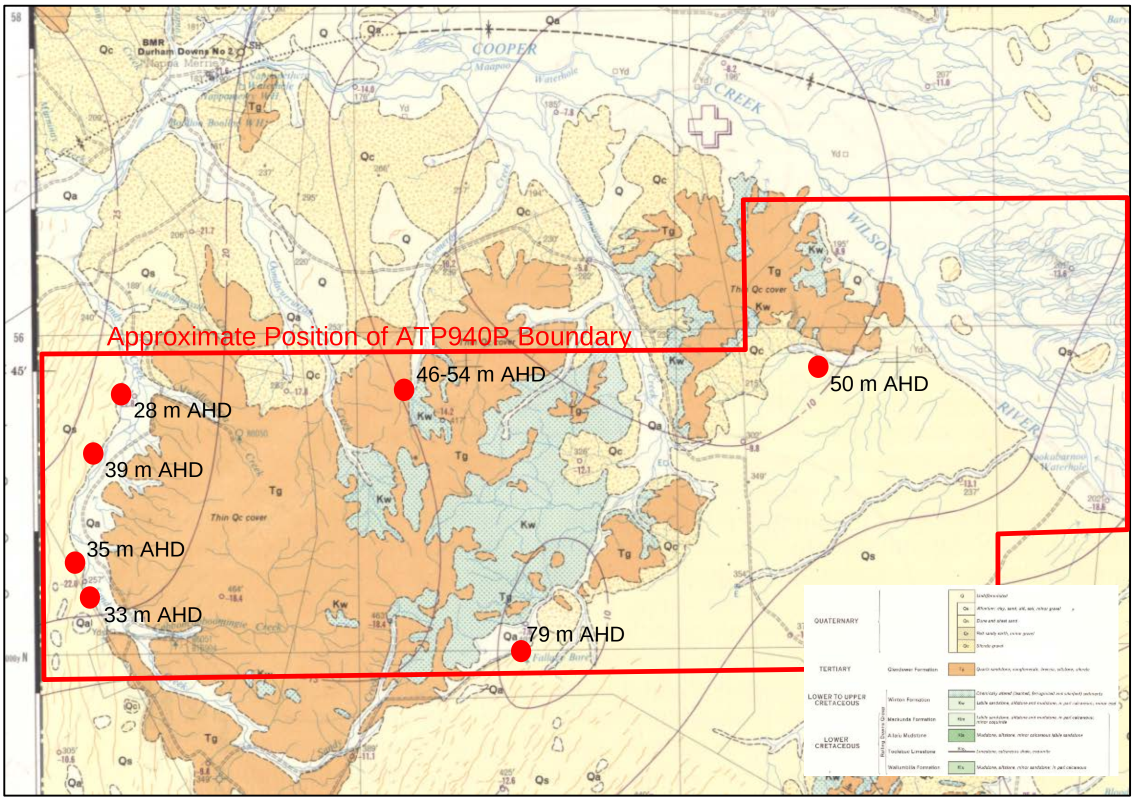


Figure 11: Groundwater Level (Spot Readings) (m AHD)

Calibration was established by visually comparing observed groundwater levels to calculated groundwater levels for unpumped conditions, with the aim to obtain a general fit. The general head boundary flux and recharge conditions were adjusted until a satisfactory fit was achieved. The model was best calibrated with recharge applied to the Winton Formation outcrop (3.5 mm/annum) in the centre of the model domain, representing 2% of average annual rainfall (175 mm/annum). The application of recharge to this area is consistent with the conceptual model presented above. The percentage of recharge used is also consistent with that expected in a dryland environment.

A plot of modelled versus observed groundwater level is given in Figure 12. A reasonable fit between modelled and observed groundwater head is achieved.

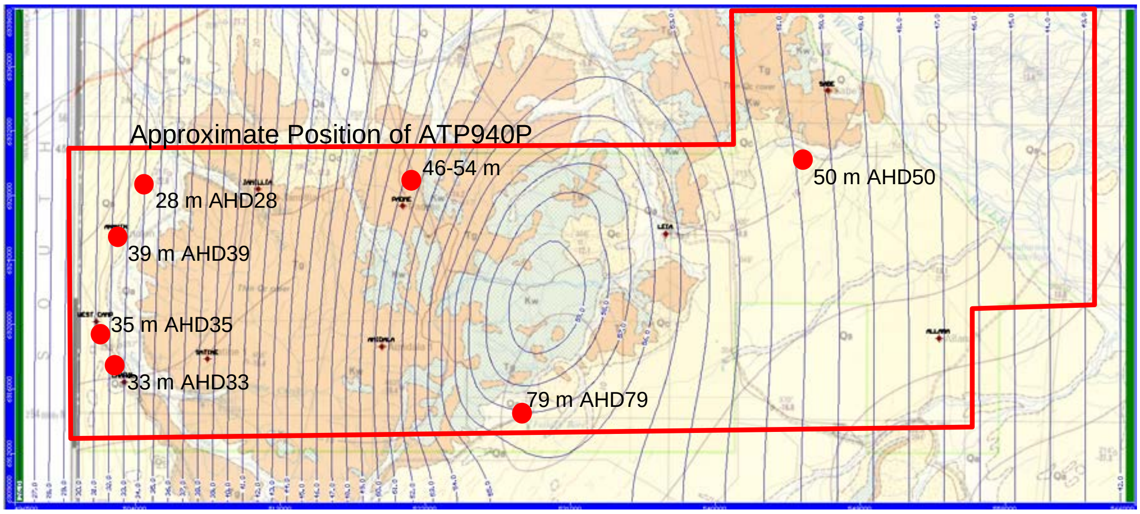


Figure 12: Steady state calibrated groundwater levels (showing modelled contours and spot readings) – m AHD

7.9 Calculated impact

The calculated drawdown based on the proposed development scenario is given in Figure 13. Representative modelled drawdown contours are given in Appendix 1. The maximum calculated drawdown at each of the well and water bore sites is provided in Table 6.

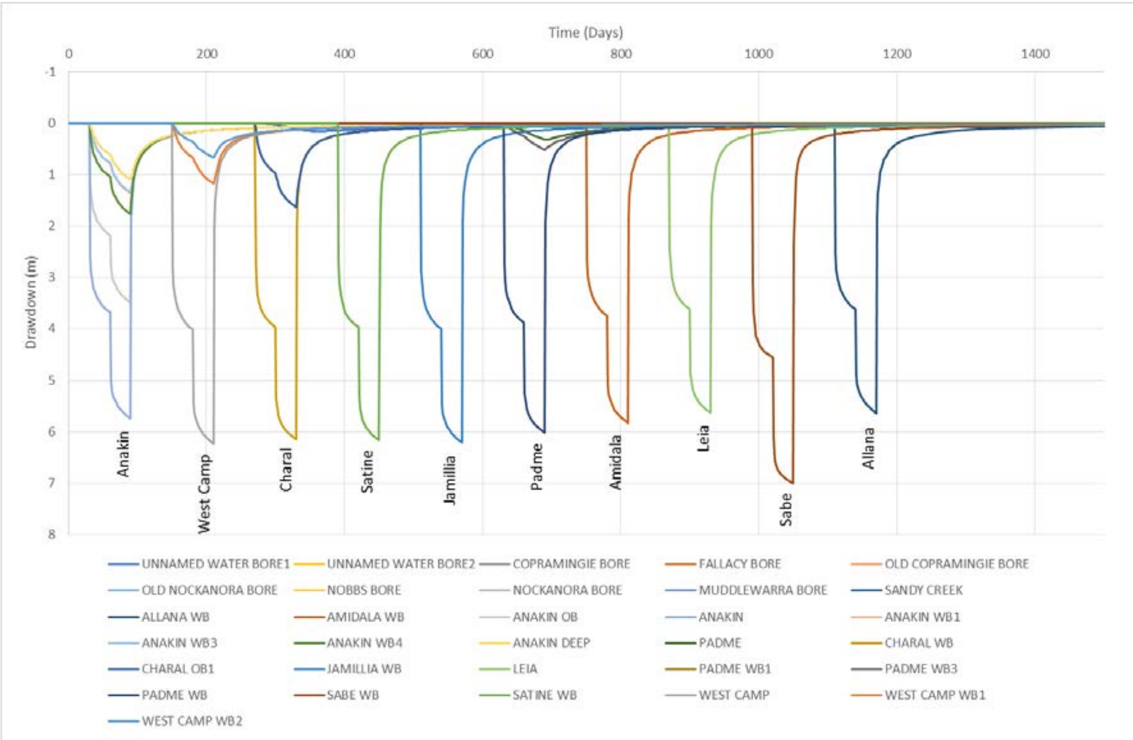


Figure 13: Predicted drawdown at unconventional gas production well sites and identified private water wells

Table 6: Maximum predicted drawdown (aquifer response)

Site ID	Maximum Drawdown (m)	Water Bore ID	Maximum Drawdown (m)	DEHP Registration Number	Geographic Location (GDA94)	
					Latitude	Longitude
Allana	5.7	Unnamed Water Bore (1)	0.2	n/a		
Amidala	6.0	Unnamed Water Bore (2)	0	n/a		
Anakin	5.8	Sandy Creek	0	50087	-27.76665	141.05034
Charal	6.2	Old Nockanora Bore	0	none	-27.75742	141.4672
Jamillia	6.4	Old Copramingie Bore	0	16904	-27.88738	141.08427
Leia	5.8	Copramingie Bore	0	50695	-27.88746	141.0843
Padme	6.2	Nockanora Bore	0	50086	-27.75747	141.46262
Sabe	7.2	Nobbs Bore	0	12661	-27.79515	141.338735
Satine	6.3	Muddlewara Bore	0	6052	-27.78804	141.11813
West Camp	6.3	Fallacy Bore	0	16627	-27.89823	141.28755

Pumping testing data for wells installed at West Camp, Anakin, Padme and Charal for shorter duration (2 day tests) are summarised in Table 7. Wells are in the main screened in the Winton Formation (one being screened in the Glendower Formation). Although the model results do not predict the same extent of drawdown, the actual drawdown produced during pumping testing represents water levels in pumped wells and so likely includes a high degree of well loss that cannot be replicated by the model. Data from observation wells is not available from these tests and so a direct comparison to aquifer response cannot be undertaken. There is also a lot of uncertainty around vertical hydraulic conductivity (multi-layered aquifer) effects, which cannot be replicated in a single layer model.

Table 7: Summary of pumping test response

Well Site	Discharge Rate (Lps)	Drawdown (m)	Specific Discharge (Lps/m)	Formation
West Camp	4.6 to 5.5	33 to 35	6.4 to 7.2	Winton
Anakin WB1	3.3 to 4.0	47 to 56	14 to 14.2	Winton
Anakin WB4	7.0	56	8	Winton
Anakin OB1	2.7 to 3.1	0.9 to 0.8	0.3	Glendower
Padme WB1	1.3 to 1.7	42 to 46	27 to 32	Glendower
Padme WB3	2.6	46	27	Glendower
Charal OB1	5.0	7.0	3.5	Glendower
		33.6 (Average)	12.7 Average)	

The model results also show that existing extraction wells are generally unaffected by the proposed extractions. The exception is a single extraction well (unnamed water bore) that is in the immediate proximity of the proposed Charal site. The hydrograph for this site (alongside the Charal, West Camp and Copramingie Bore hydrographs) is shown in Figure 23. Of note, is a <0.2 m reduction in groundwater levels at the ‘unnamed water bore’ extraction well. The next closest water bores (Copramingie and Old Copramingie sites) show no effect from proposed extraction.

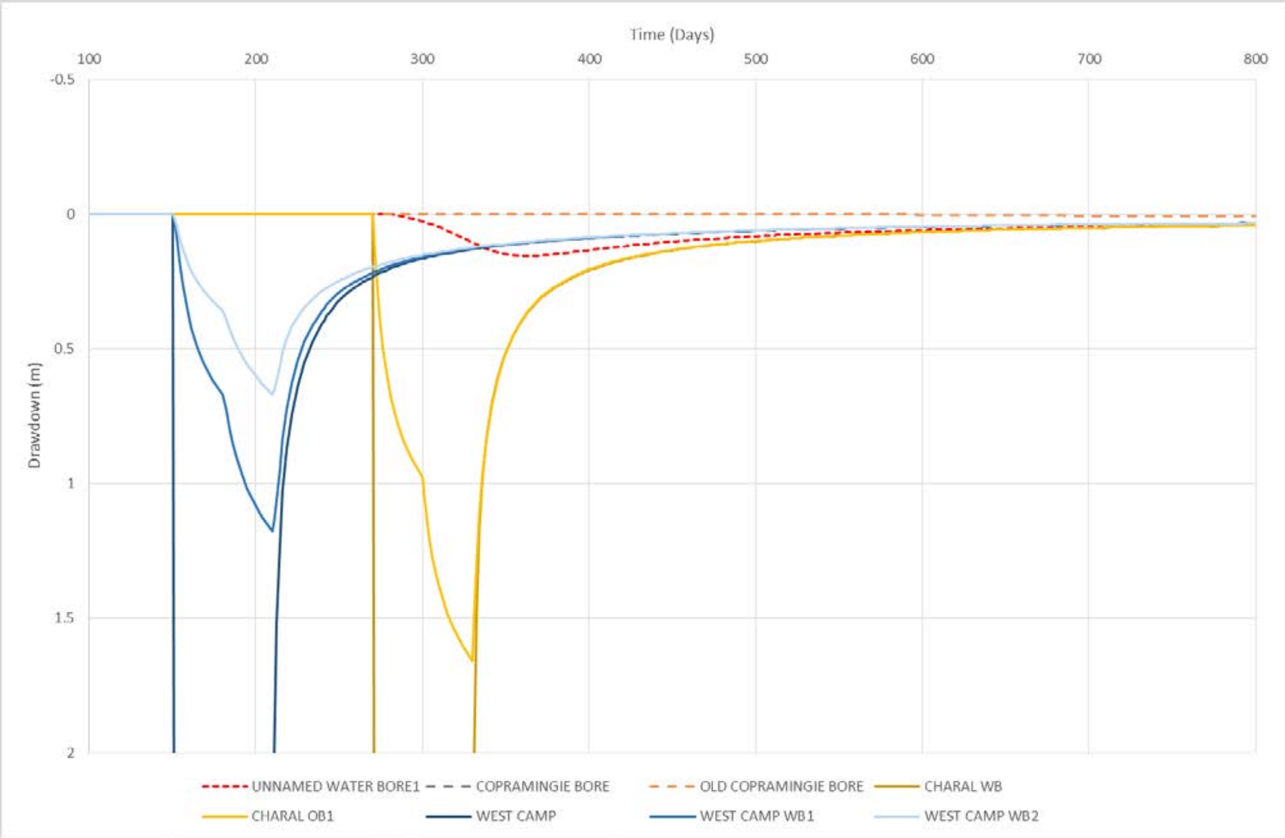


Figure 14: Extraction well response at Charal and neighbouring water bores.

7.10 Sensitivity analysis

The nature of data available has resulted in a 3D numerical model based on a number of underlying assumptions. A sensitivity analysis was therefore undertaken to assess the response of the aquifer to alternative conditions.

Sensitivity analysis has been carried out by systematically changing the calibrated hydraulic conductivity parameters in turn by factors of 0.1, 0.5, 0.75, 1.25, 1.5 and 2 and the storage coefficient by 0.001, 0.01, 0.1 and 2. The sensitivity of the model to these changes is shown in Figure 15.

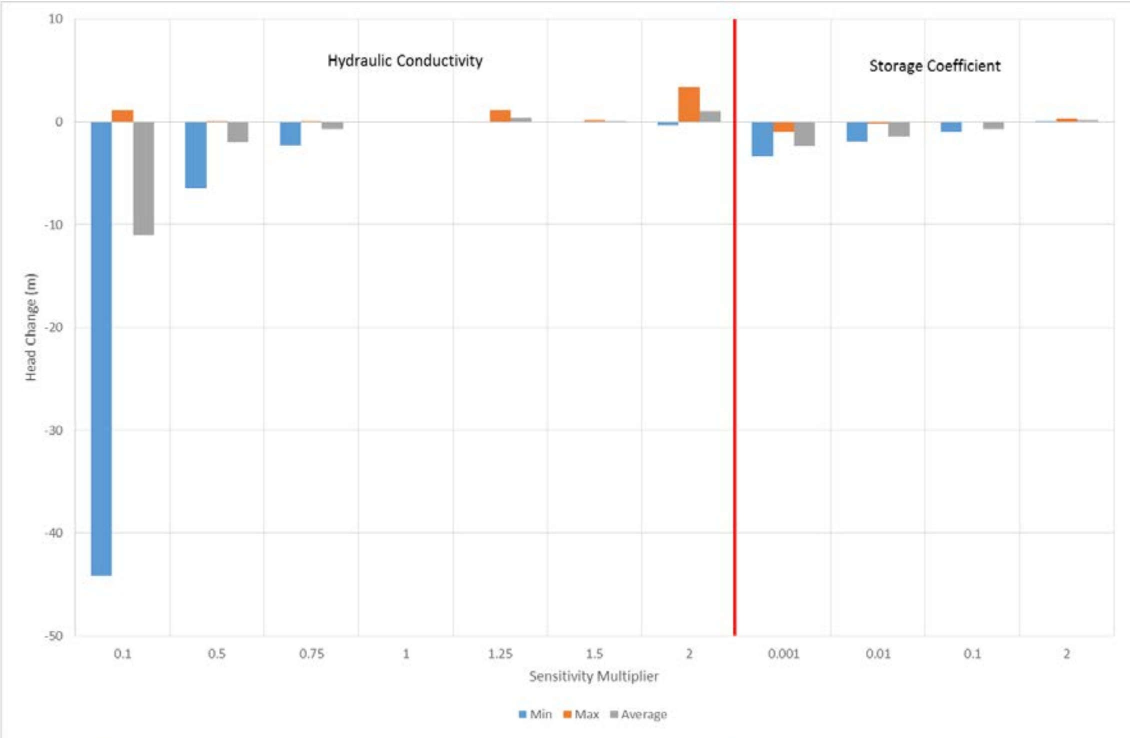


Figure 15: Sensitivity analysis

The analysis shows that the outcome is sensitive to an order of magnitude reduction in hydraulic conductivity. It is noted that a reduction in the hydraulic conductivity would lead to increased drawdown at the abstraction well and a reduced radius of influence.

Adoption of confined aquifer storage properties (i.e. 0.00004 m/m) in the model would result in an increase in drawdown of up to 4.0 m closest to the abstraction well that could radiate away from the well towards neighbouring private wells. Confirmation of aquifer properties would be needed during well construction to confirm actual effects.

7.11 Conclusions

The modelled groundwater level results show there to be limited drawdown across the model domain and that when it occurs drawdown recovers relatively quickly, i.e. to within 0.2m of pre-extraction water levels. Neighbouring wells are generally **unaffected** by the proposed abstraction requirements. The exception is an unnamed water bore (that is not currently used) sited in proximity to the proposed Charal extraction site. The analysis shows that extraction would produce a drawdown of less than 0.2m at the neighbouring water bore site. It is considered that this is insufficient drawdown to derogate any future potential extraction from the unnamed water bore.

A sensitivity analysis has been undertaken due to limitations in the available data set. The analysis shows that drawdown is greatest where the hydraulic conductivity is an order of magnitude less than that assessed. This would lead to a reduction in the radius of influence and less potential to affect water levels in neighbouring private wells. An unconfined storage coefficient was adopted in the model based on pumping testing undertaken to date. Limitations in the data though are noted (i.e. derived from pumping well information). Sensitivity analysis shows that where confined aquifer conditions are present, a degree of drawdown may be evident at neighbouring private wells.

7.12 Summary of key points from model results

Key points from the model results are:

- The impact of abstraction from ATP940P groundwater extraction well sites is limited to a relatively small radius of influence of around 1.5km.
- The maximum predicted drawdown in the unconfined Glendower and Winton Formation strata is up to 7.0 m. This is a worst case scenario due to the assumed programme of development modelled (one month stand down during development of each well site). The impact on the Glendower and Winton Formation strata could therefore be less than 7.0 m.
- The assessment predicts a 0.2 m reduction in water level at a single existing (unused) unnamed water bore. It is highly unlikely that a drawdown of 0.2 m will derogate this supply if brought back into commission. No impacts on other water interests are predicted.
- Sensitivity analysis shows that drawdown may be as much as 45.0 m, but that drawdown will localised to the abstraction well and quickly recover.

7.13 Immediately affected areas

As described in the model results, there will be small areas where drawdown in the aquifers show a temporary decline in water levels by more than the bore trigger threshold (5m as the relevant areas are consolidated aquifers) within three years in both the Winton and Glendower formations. These are known as "immediately affected areas" (IAAs) under the Water Act, and are required to spatially depicted as provided in Appendix X. These outputs assume that the Winton and Glendower Formations behave as a single leaky multi-layered aquifer.

7.14 Make good obligations

There are no "immediately affected bores" (water bores located within the IAA) for either aquifer. As such, no "make good obligations" are triggered under section 409 of the *Water Act 2000*.

8 WATER MONITORING STRATEGY

8.1 Rationale

The underground water monitoring strategy has been developed to address the findings of this UWIR, and to accurately quantify water level and water quality changes caused by the exercise of underground water rights at ATP940P. The information obtained through the monitoring strategy will also be used to confirm and refine future iterations of the groundwater modelling.

The modelling predicts that there will be an IAA within the Winton and Glendower formations, and that there is no “long term affected area” predicted as any potential impact would recover rapidly after extraction ceases. Specifically, the monitoring will verify the scale of drawdown and the speed of impact reduction. Should there be a large discrepancy between monitoring data and the predictions generated through the model, this will provide a trigger and the model will be re-run with updated calibrations and assumptions.

Key elements of the monitoring strategy will involve:

- Implementation of a water production monitoring system at extraction sites within ATP940P.
- Regular measurement of the depth to underground water levels in groundwater bores be undertaken to confirm abstraction effects on groundwater levels and to support on-going assessment of possible impacts.
- Suitable pumping testing be undertaken prior to significant water extractions for future gas well sites to establish accurate figures for hydraulic conductivity and storage coefficient aquifer parameters and aquifer response.

8.2 Monitoring programme

The groundwater monitoring programme is designed to monitor potential impacts from unconventional gas production activities as well as verify the findings of the model used in this report. Drillsearch’s baseline assessment program identified 14 water bores on ATP940P, 5 of which were listed on the DNRM Groundwater Database as “abandoned and destroyed”. Upon carrying out the baseline assessment plan for the remaining 9, it was discovered that they were either abandoned, destroyed or unserviceable and could not be sampled. As such the proposed monitoring programme associated with this UWIR is unable to incorporate any of these bores. However, Drillsearch has recently transferred one water supply bore from its exploration drilling program (Westcamp WB2, S27.50.45; E141.00.55) to the relevant landholder. This bore is considered to be the most appropriate bore for impact monitoring due to its proximity to authorised activities (i.e. the Anakin and Charal exploration wells) and it presently being the only bore used for landholder’s water resource purposes (but noting that make good obligations do not apply as it has been transferred to the landholder following the cessation of petroleum activities within ATP940P). The location of this bore in relation to bores where the water extraction has occurred is presented in Figure 16.

Due to the fact that at least 6 months have passed since the last water extraction within ATP940P, it is considered that there is no value in conducting high frequency monitoring of water bores to verify modelling assumptions regarding water level recovery at that location. However, the locations and frequency of water monitoring would be investigated/defined based on identification of future water extraction events. Where monitoring is identified, minimum requirements would include those presented in Table 8 below:

The groundwater monitoring programme is designed to collect baseline groundwater information and to monitor potential impacts from unconventional gas production activities as well as verify the findings of the model used in this report. Drillsearch's baseline assessment program identified 14 water bore on ATP940, 5 of which were listed on the DNRM Groundwater Database as "abandoned and destroyed". Upon the carrying out of the baseline assessment plan, it was discovered that of the remaining 9, they were either abandoned, destroyed or not in a condition that was able to be sampled.

As such the monitoring programme for this UWIR is unable to incorporate any of these bores. However, Drillsearch has since transferred one of its own water supply bores from its drilling program (Westcamp WB2, S27.50.45; E141.00.55) to the relevant landholder. This bore is considered to be the most appropriate bore for impact monitoring due to its proximity to where water has been extracted as well as it being the only bore which is being used for landholder's water resource purposes (but noting that make good obligations do not apply as it has been transferred to the landholder following the cessation of petroleum activities. The location of this monitoring bore in relation to bores where the water extraction has occurred is presented in Figure 16.

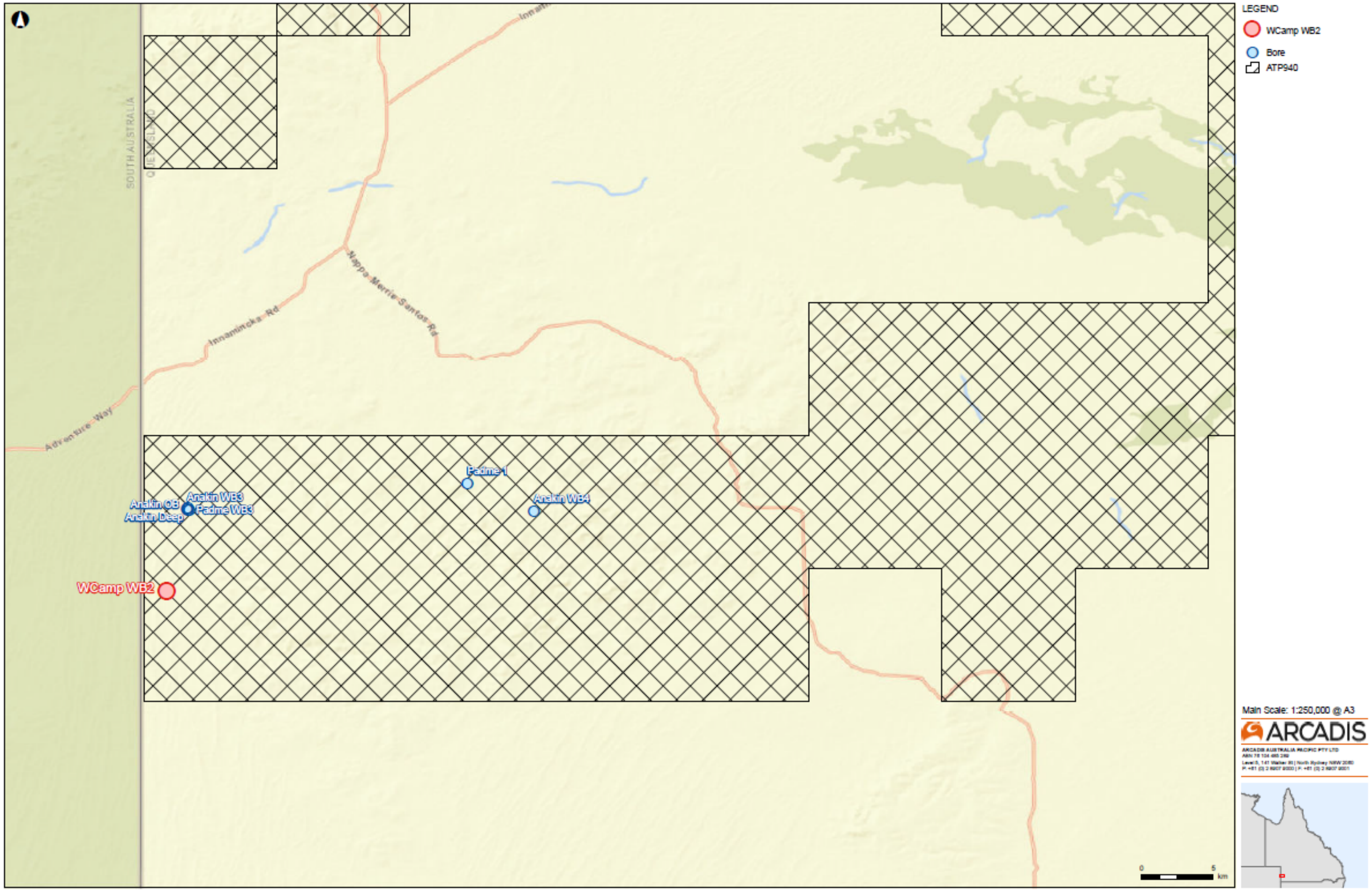


Figure 16: location of proposed monitoring bore

Due to the fact that at least 6 months have passed since the last water extraction, it is considered that there is no value in conducting high frequency monitoring of water bores to verify modelling assumptions regarding water level recovery. However, these would be investigated with future water extraction events.

The parameters to be monitored are listed in Table 8. These parameters are consistent with the requirements of the Department of Environment and Heritage Protection's *Baseline Assessment Guideline*. It should be noted that the full list of parameters will be sampled where it is reasonably practical to obtain representative results in consideration of the logistical difficulties of sample transportation in the extremely remote locations and the holding times of relevant analytes.

Table 8: Parameters to be monitored

Category	Parameters
Pressure	Piezometric pressure measured as depth to water level
Ions	Calcium Chloride Fluoride Potassium Sodium Sulphate Magnesium
Metals	Aluminium Arsenic Barium Beryllium Boron Lead Manganese Mercury Molybdenum Nickel
Alkalinity and hardness	Alkalinity – Total hardness as CaC03
Dissolved Gases	Carbon dioxide Methane Hydrogen sulphide

8.3 Timetable

The gas well development program (and therefore any water extraction) is currently suspended and is likely to not recommence within the report period. As such, the numbers of monitoring locations and type of installations and timing have been based on this (very low risk) situation. However, provision is also made for the circumstance where extraction does recommence as follows:

- Monitor Westcamp WB2 every 6 months for the parameters listed in Table 8 whilst activities are suspended.

- Monitor Westcamp WB2 and any other water bores within 1km of a planned new water extraction for the parameters listed in Table 8 every month for three months prior to recommencement.
- Monitor Westcamp WB2 and any other water bores within 1km of a planned new water extraction for the parameters listed in Table 8 every month for six months after any future water extractions.
- Monitor recovery in all extraction bores after extraction until water levels have stabilised.

It is also expected that groundwater level and water quality will be monitored as a part of the well construction programme to establish the suitability of each site for groundwater supply.

8.4 QA/QC

QA/QC control measures will be implemented during the sampling program. These measures will be consistent with AS/NZ 9000, AS5667 and the 'Department of Environment and Heritage Protection Monitoring and Sampling Manual 2009' (version 2).

Groundwater monitoring and sampling will be conducted by a suitably qualified and experienced professional in accordance with the current edition of the EHP's Monitoring and Sampling Manual 2009 (version 2), or subsequent updated versions; and the AS/NZ 5667.11:1998 Australian/New Zealand Standard for water quality – sampling Part 11; guidance on sampling groundwater.

8.5 Reporting

Monitoring data will be reviewed at least annually. Results of the monitoring will be reported to the Office of Groundwater Impact Assessment annually to coincide with the annual review of the IAA map which is required to be provided to the Chief Executive of the Department of Environment and Heritage Protection. The monitoring strategy may be updated in view of results obtained from monitoring.

9 SPRING IMPACT MANAGEMENT STRATEGY

UWIRs are required to identify springs which could be potentially affected by underground water extraction activities. For these springs where predicted water levels within the source aquifer would decline more than 0.2 metres, a spring impact management strategy is required.

A desktop review of spring inventories has been completed, searching for springs within 20 km of proposed production testing. Springs and watercourses were identified using the following sources of information, and cross-checking against project maps.

- Queensland Government Information Service (Queensland Wetland Data – Springs)
- Wetland Info Website
- Great Artesian Basin Resource Operation Plan Spring Register

Based on these data no springs have been identified within 20 km of the proposed production testing. The closest spring is located greater than 150 km to the east of the tenure area, refer Figure 10. Based on this finding, impact to springs as a result of the proposed production testing has been determined as very unlikely. As such, no spring impact management strategy has been included in this UWIR.

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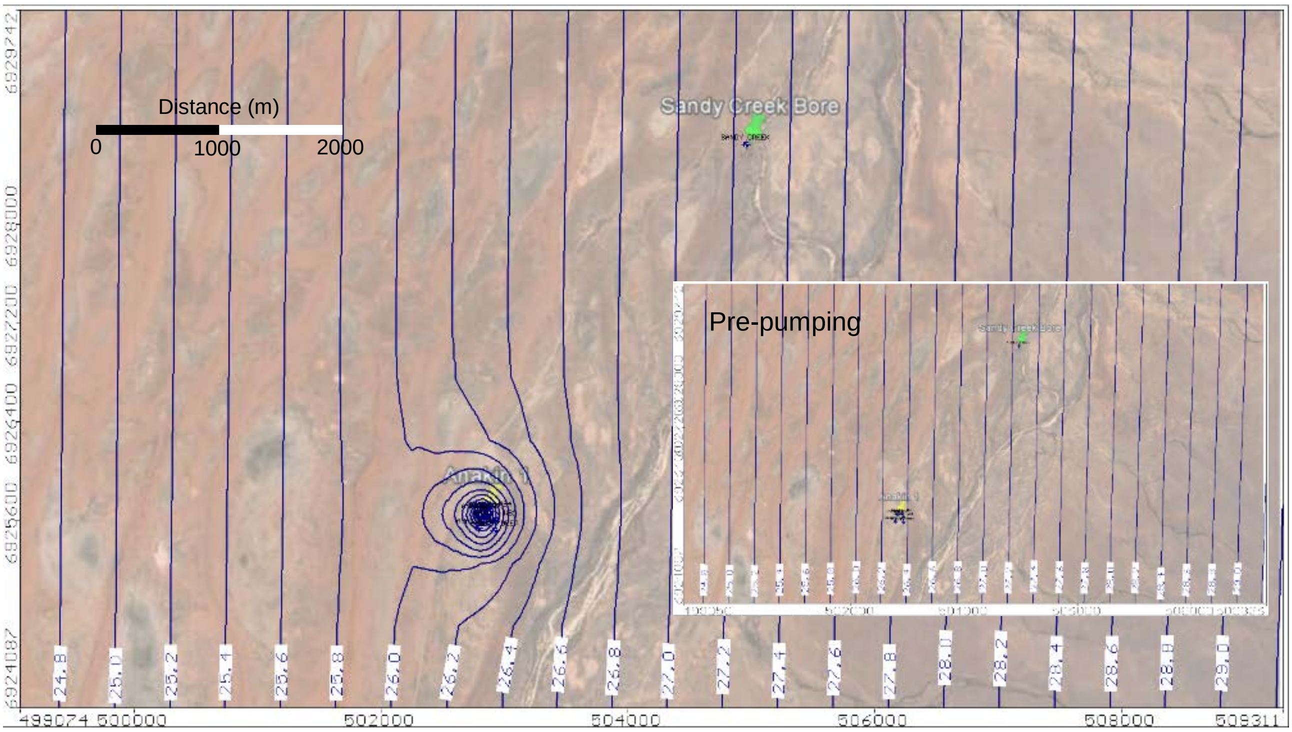
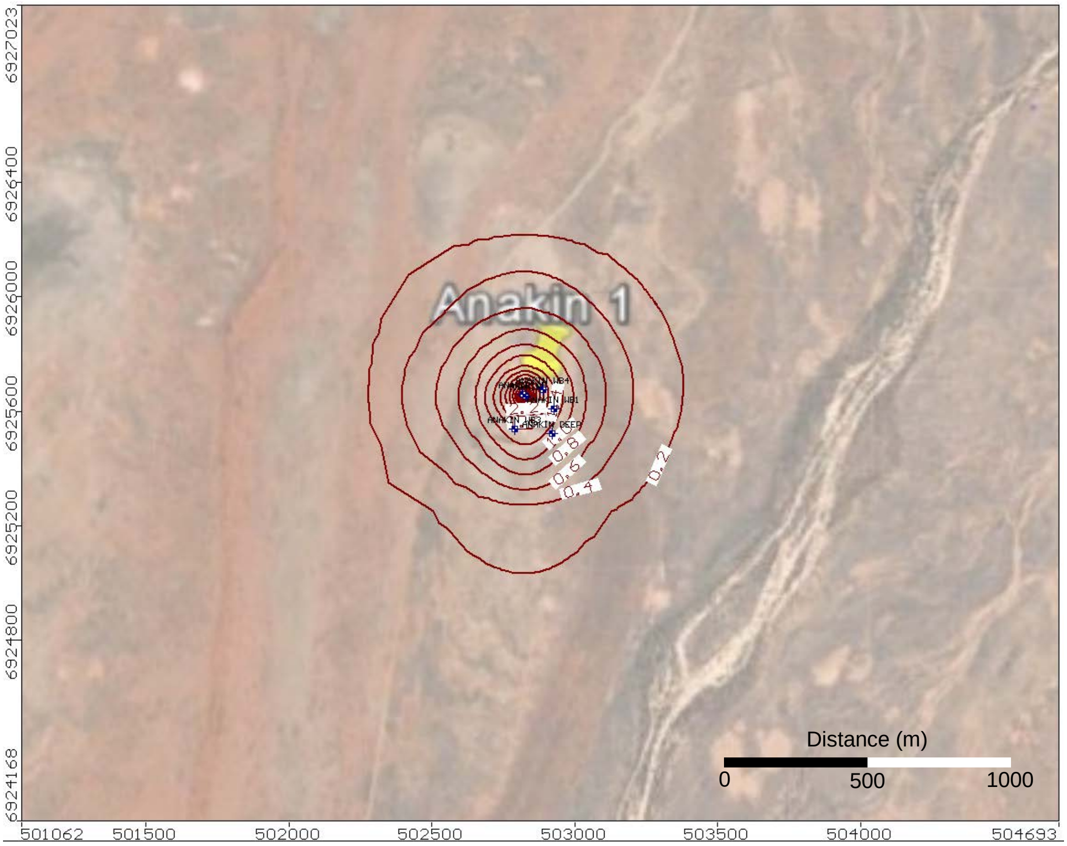
Appendix 1 – Modelling Outputs

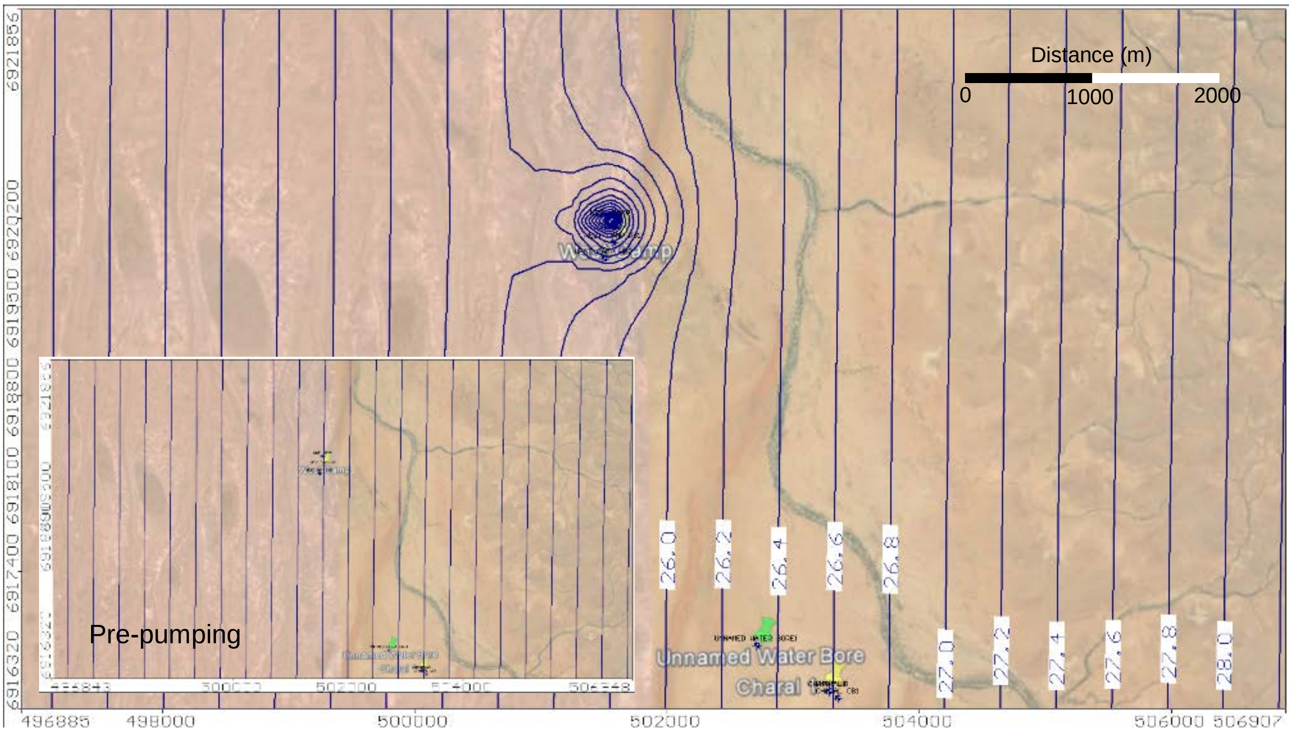
Immediately affected areas



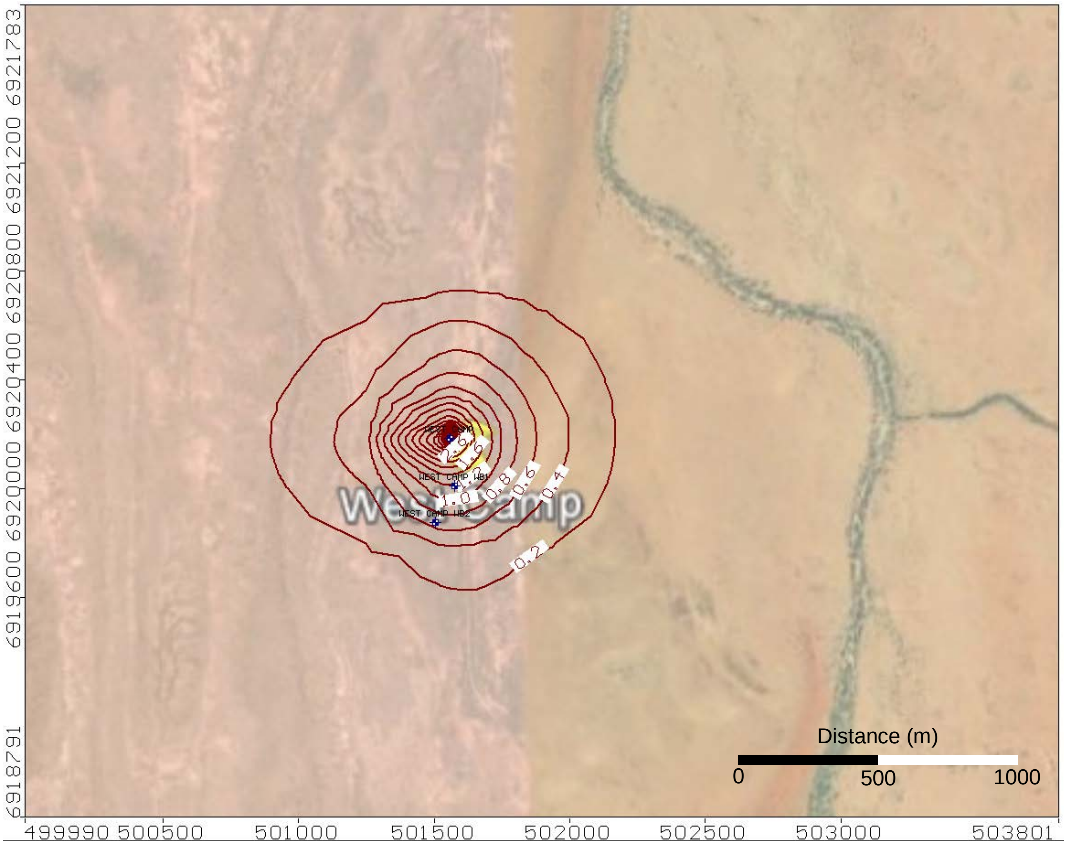
Anakin Pumping Water Levels – m AHD (t = 90 days)



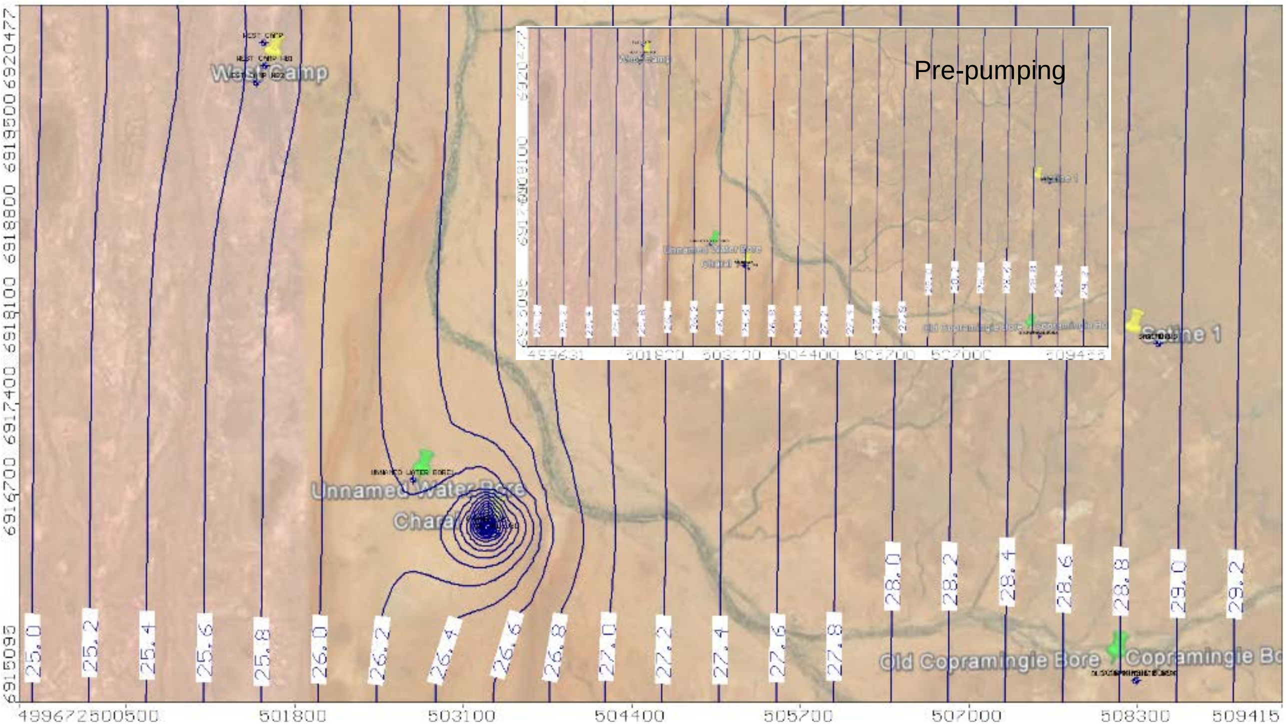
Anakin Pumping Drawdown Levels (t = 60 days) – metres



West Camp Pumping Water Levels – m AHD (t = 210 days)

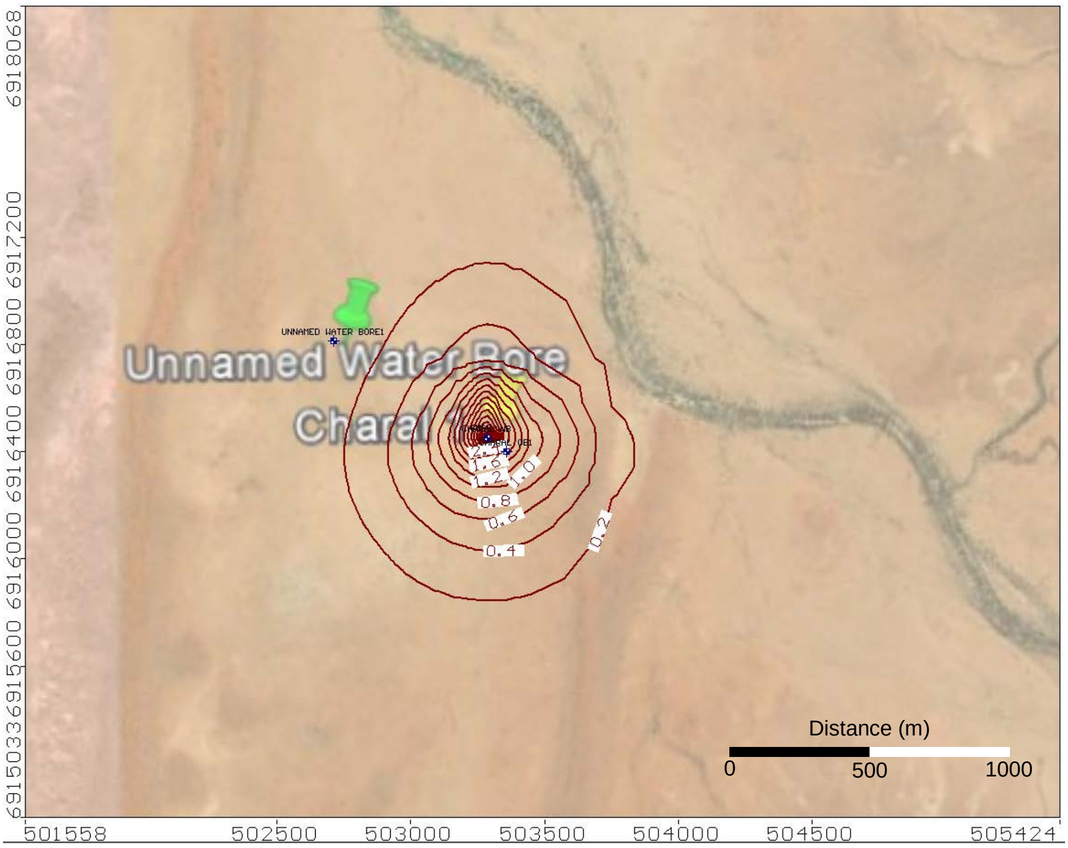


West Camp Pumping Drawdown Levels (t = 210 days) – metres

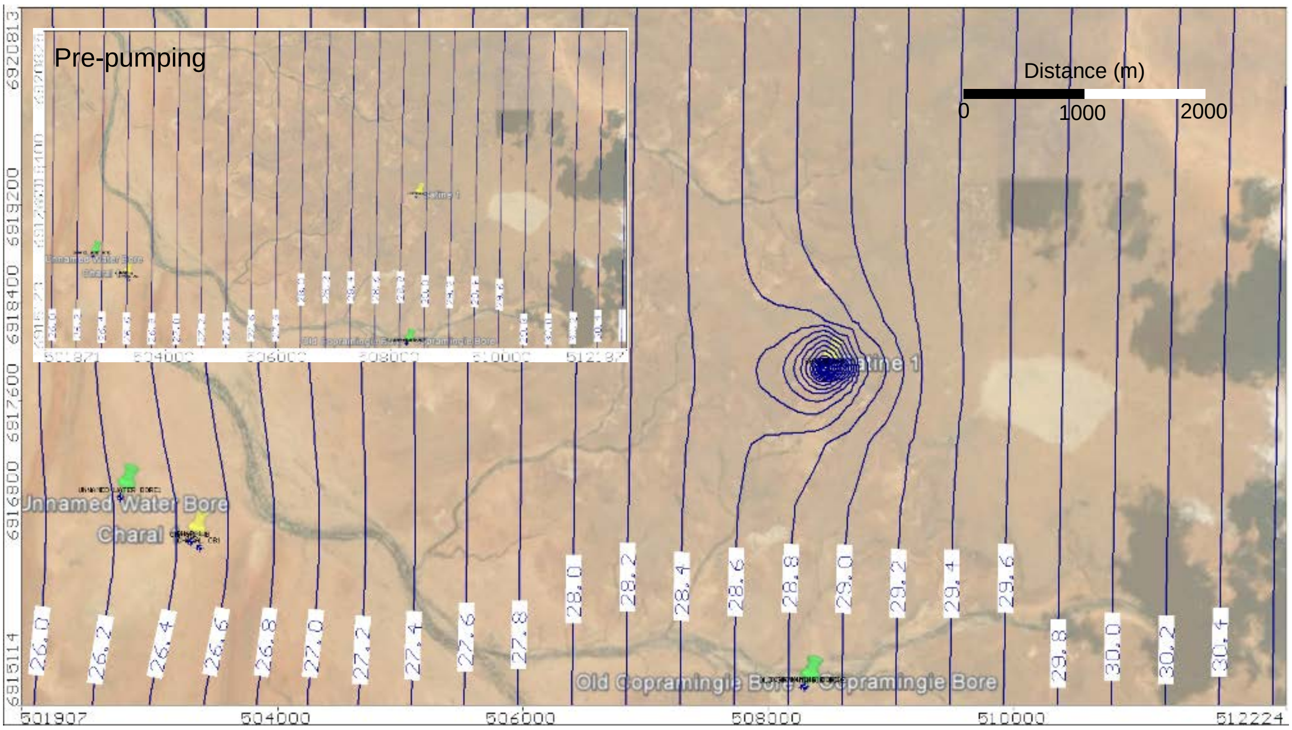


Charal Pumping Water Levels – m AHD (t = 330 days)

Note. West Camp is still in recovery

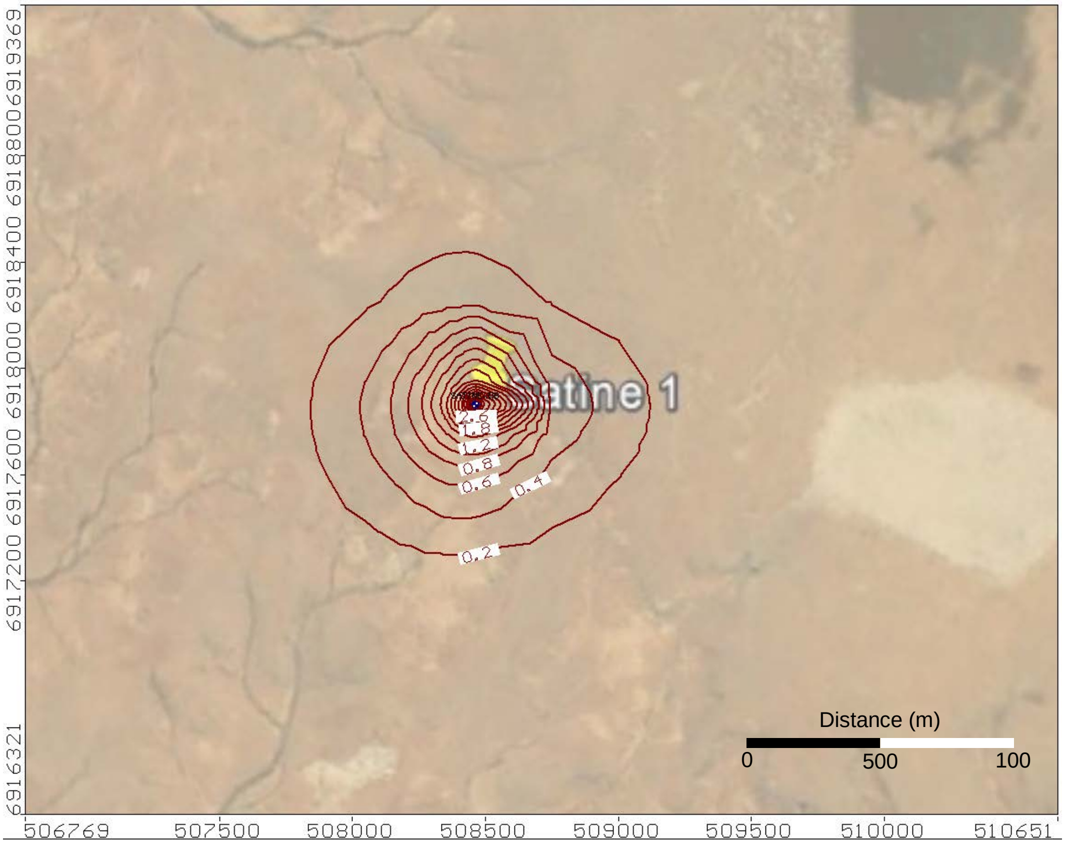


Charal Pumping Drawdown Levels (t = 330 days) – metres

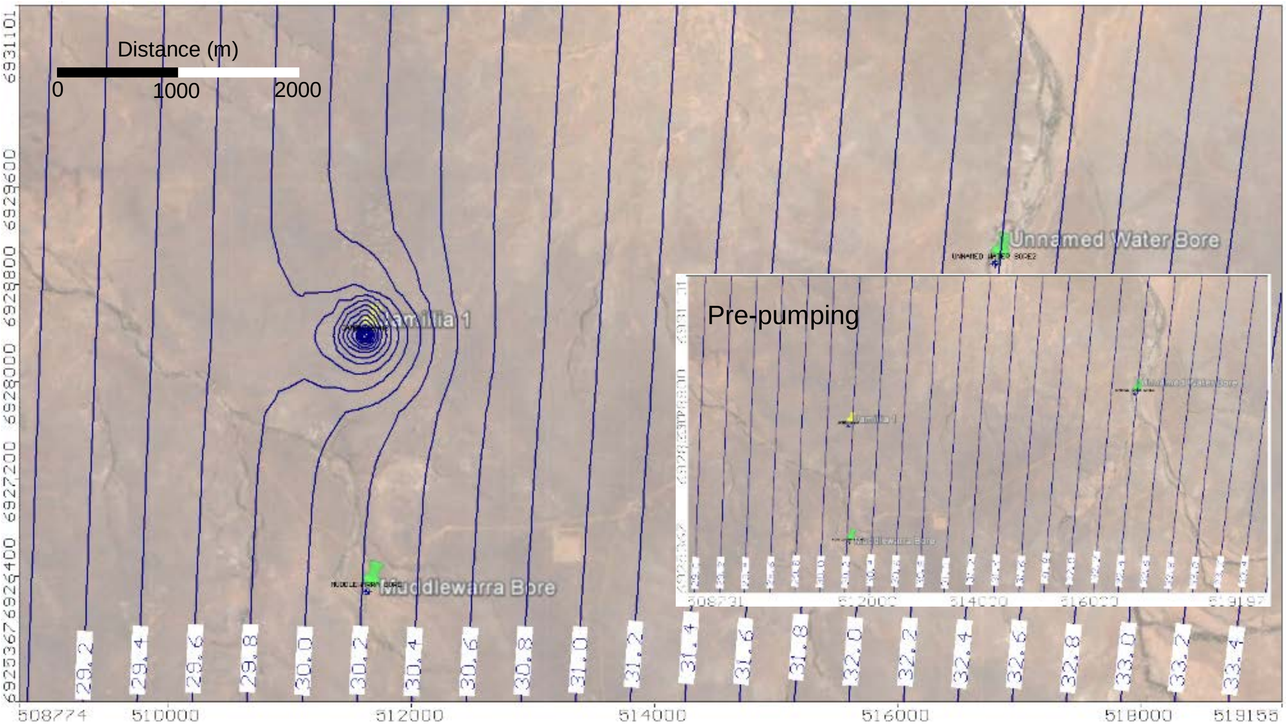


Satine Pumping Water Levels – m AHD (t = 450 days)

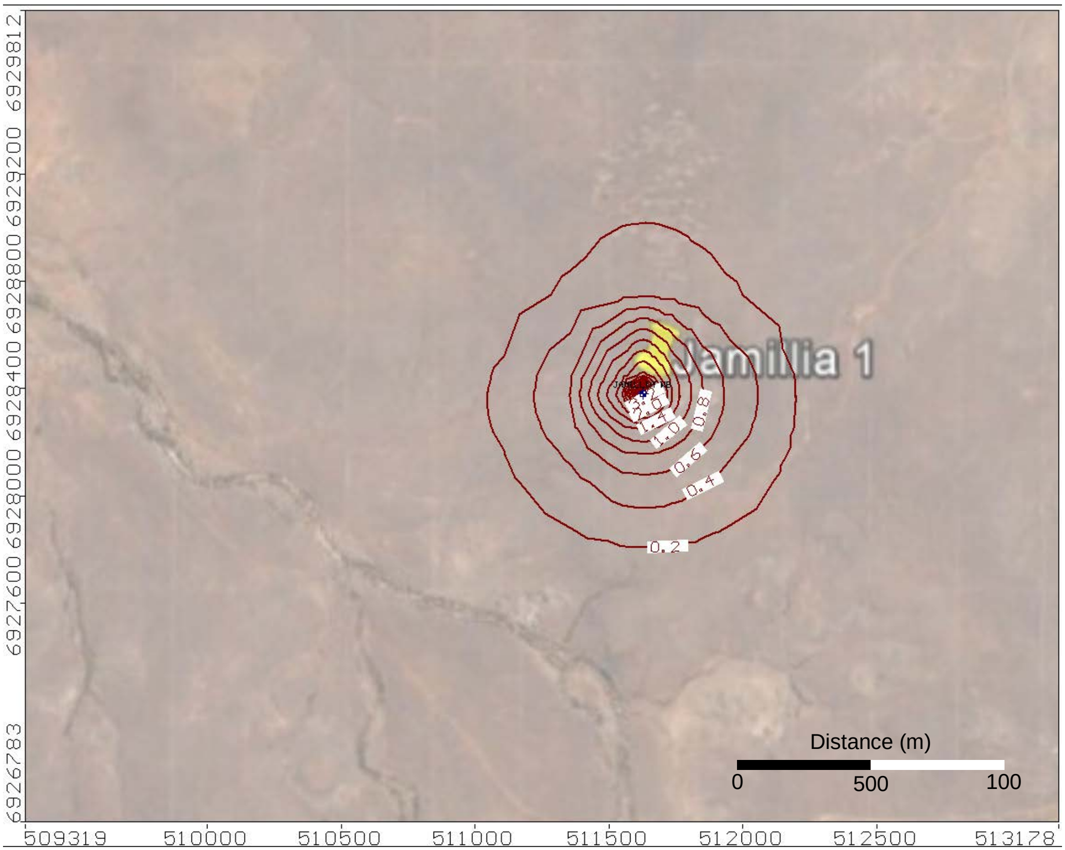
Note. Charal is still in recovery



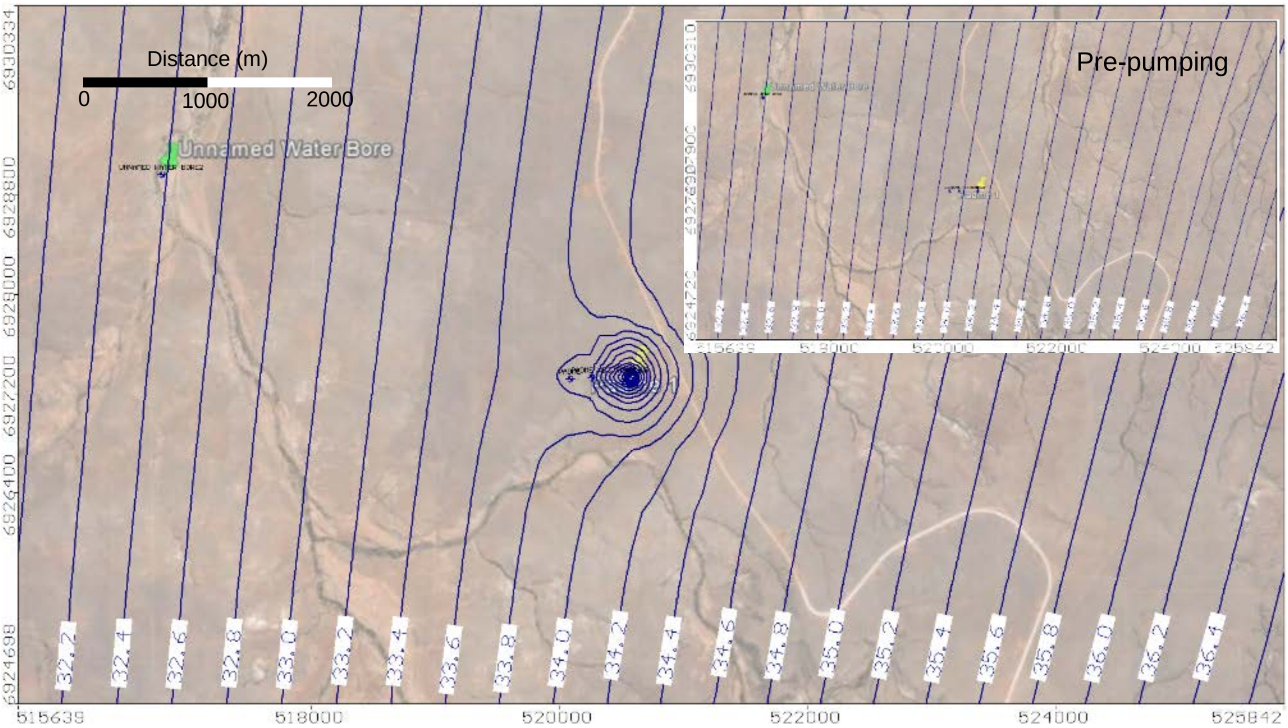
Satine Pumping Drawdown Levels (t = 450 days) – metres



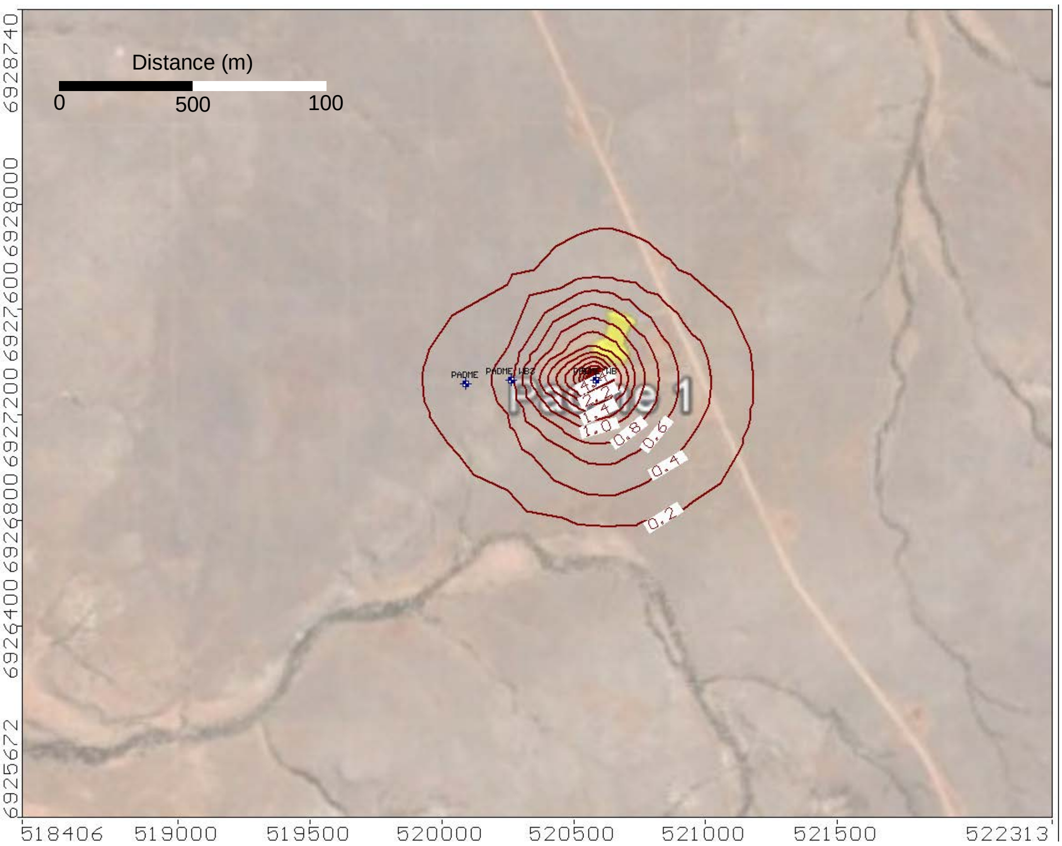
Jamillia Pumping Water Levels – m AHD (t = 570 days)



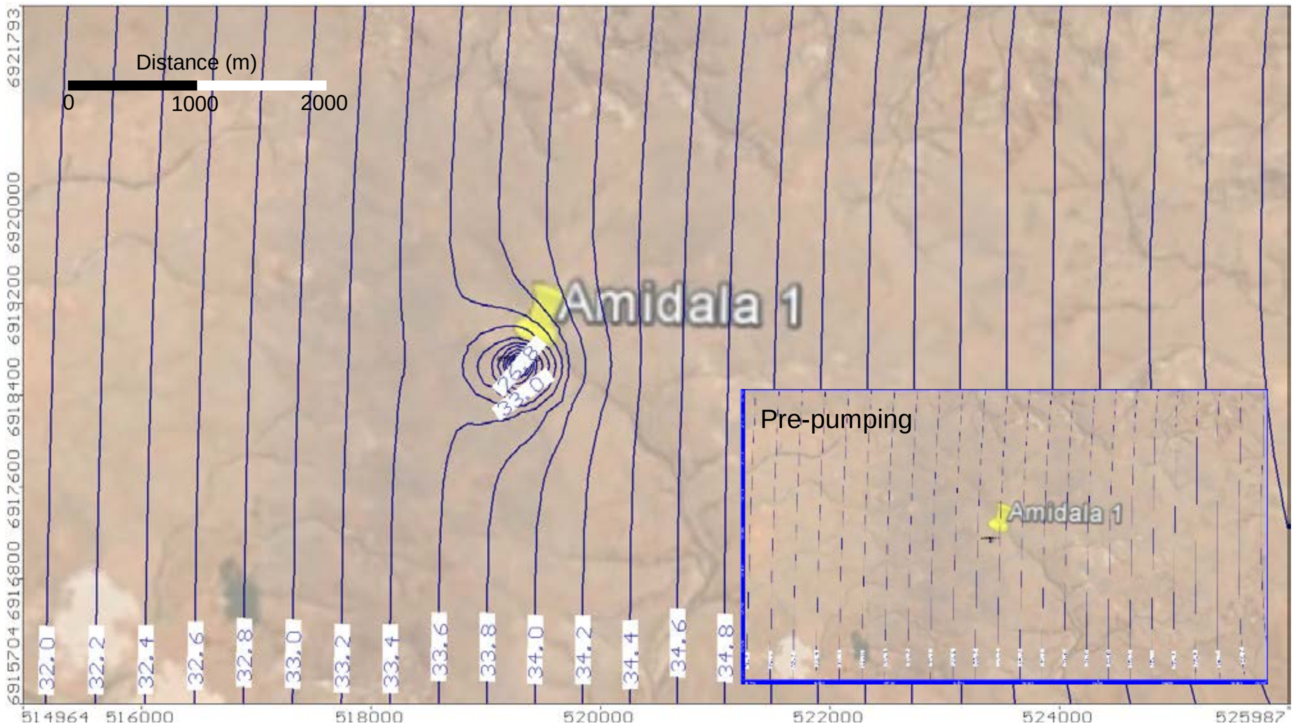
Jamillia Pumping Drawdown Levels (t = 570 days) – metres



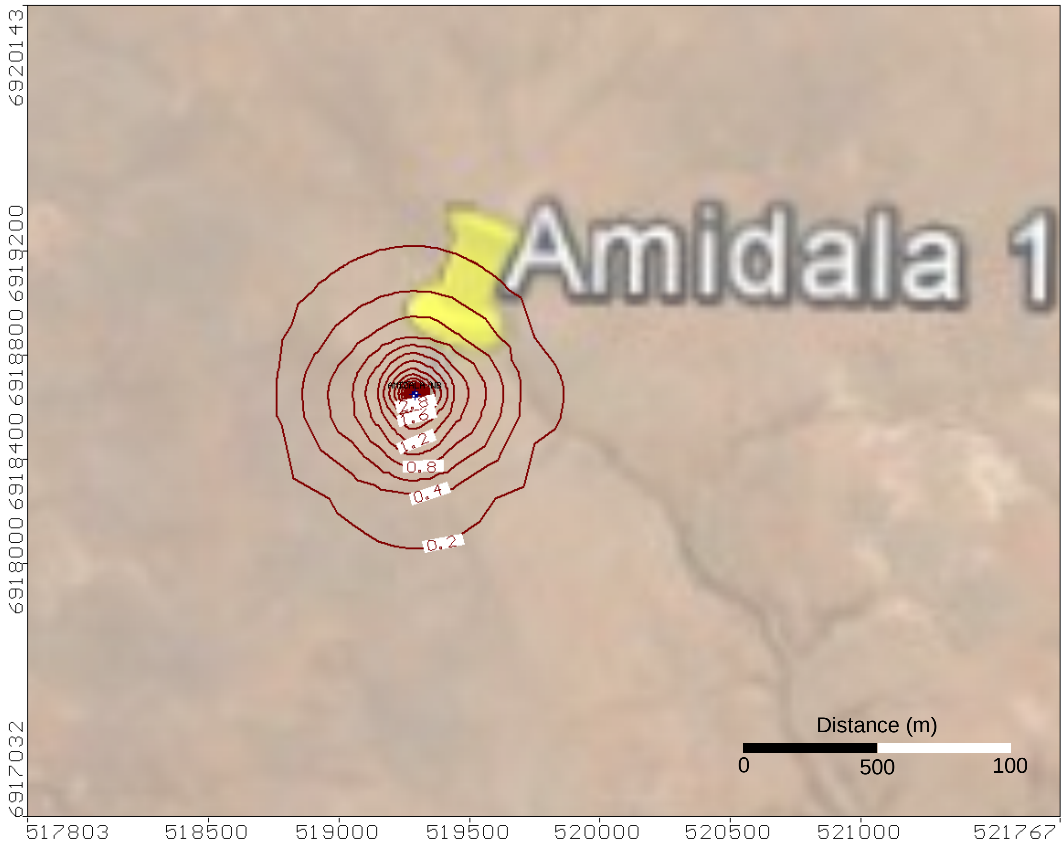
Padme Pumping Water Levels – m AHD (t = 690 days)



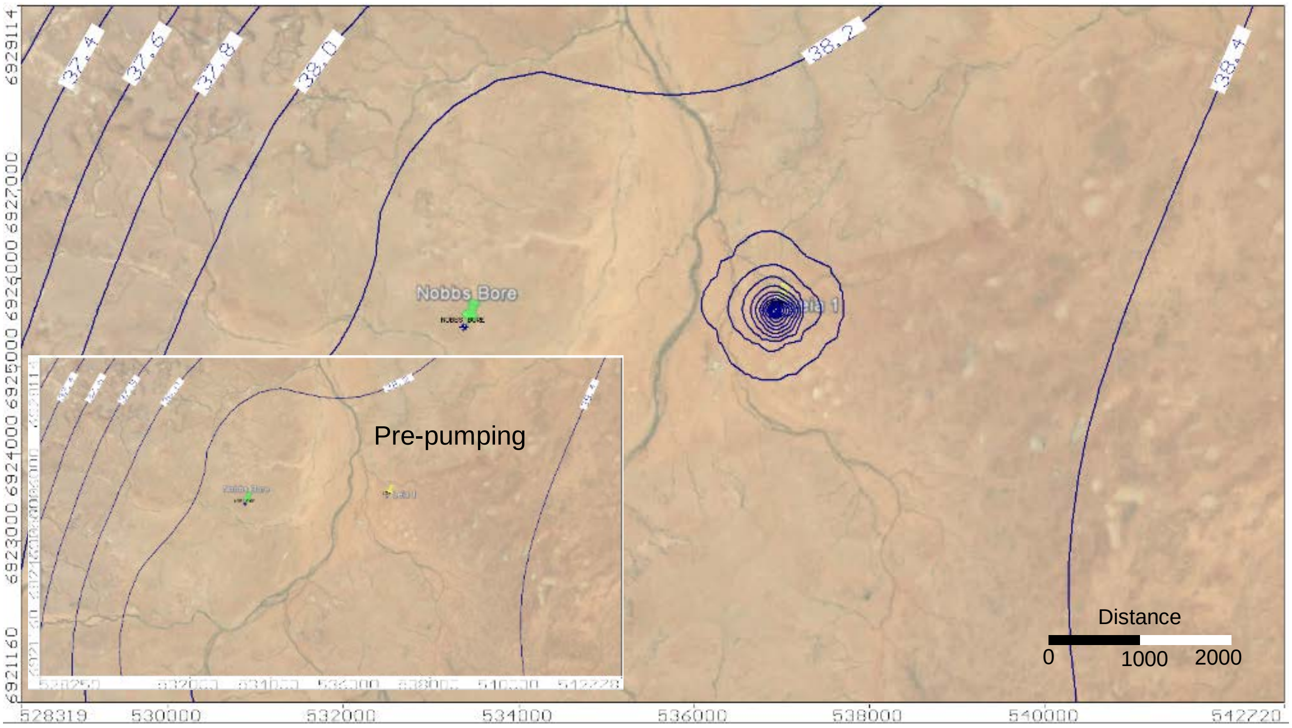
Padme Pumping Drawdown Levels (t = 690 days) – metres



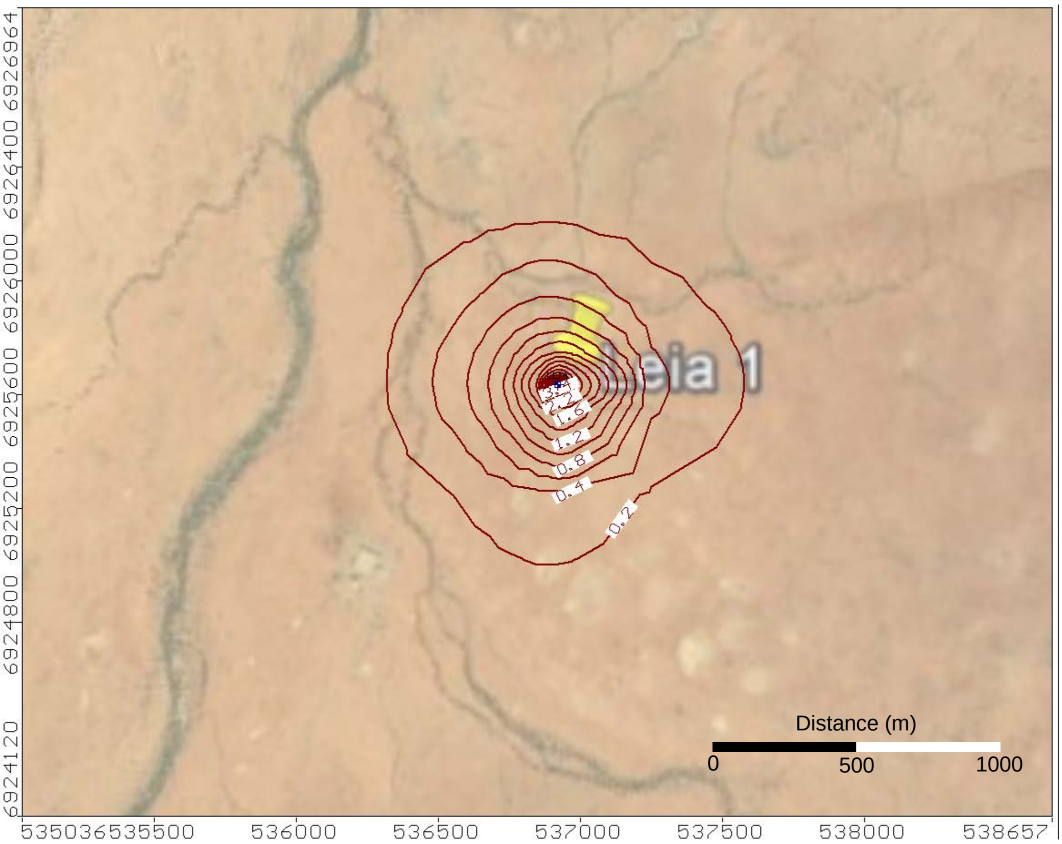
Amidala Pumping Water Levels – m AHD (t = 810 days)



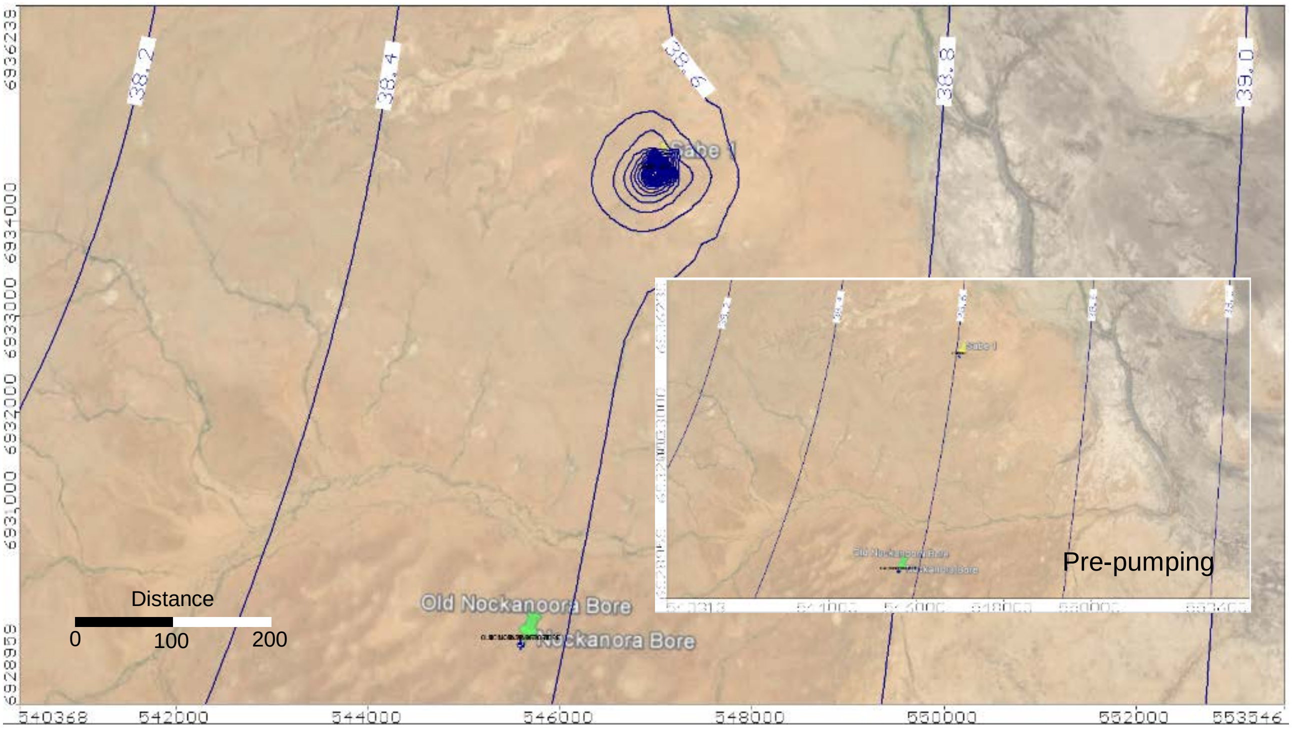
Amidala Pumping Drawdown Levels (t = 810 days) – metres



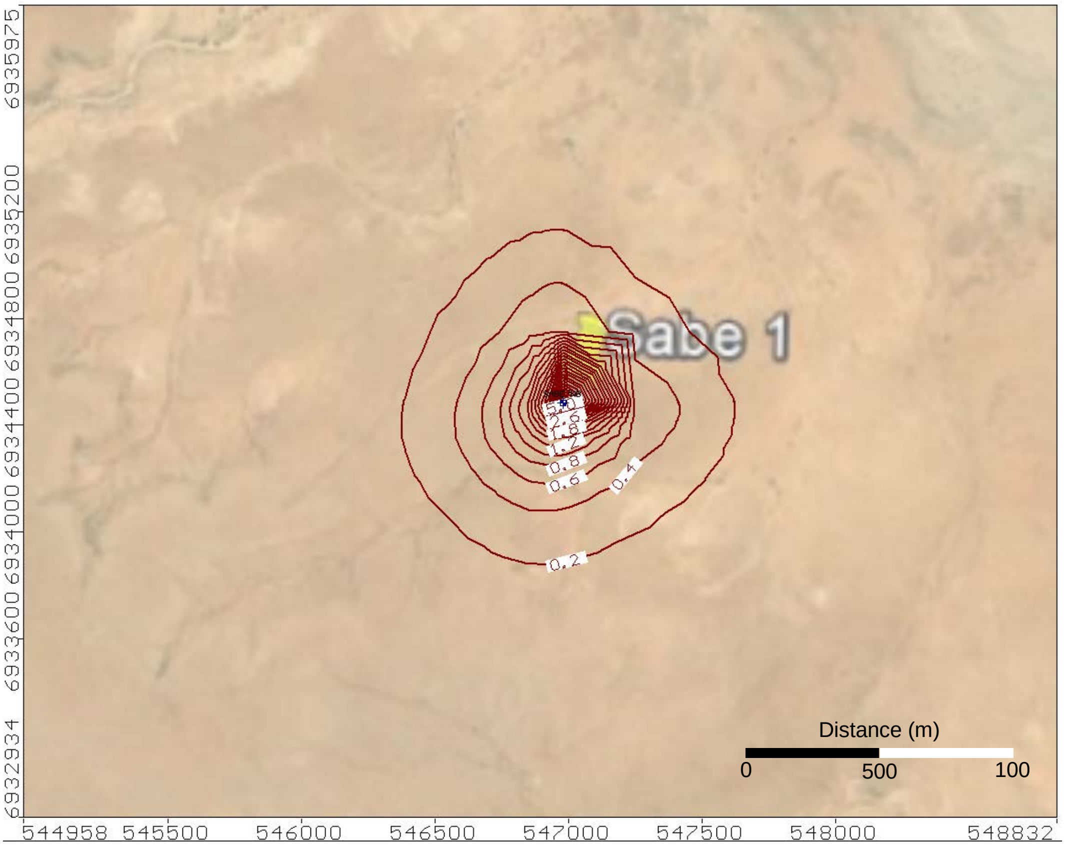
Leia Pumping Water Levels – m AHD (t = 930 days)



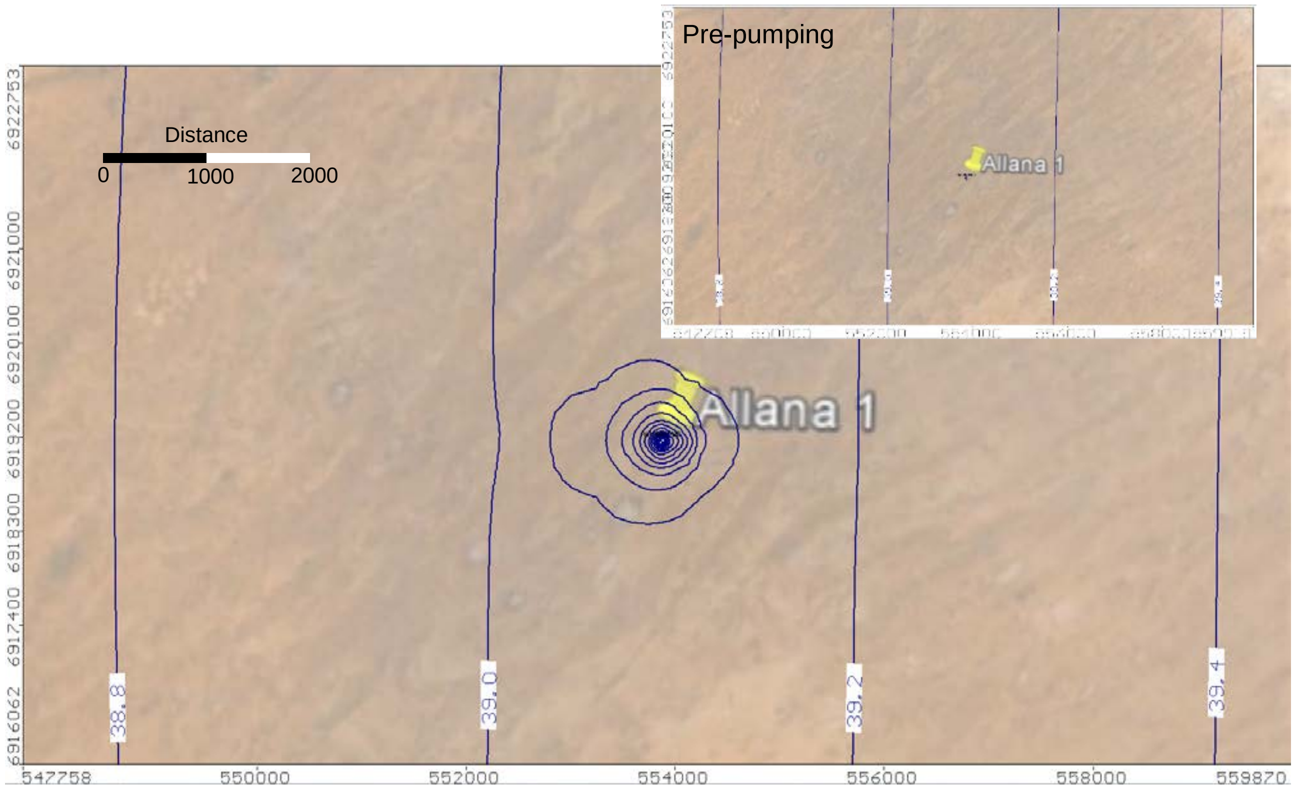
Amidala Pumping Drawdown Levels (t = 930 days) – metres



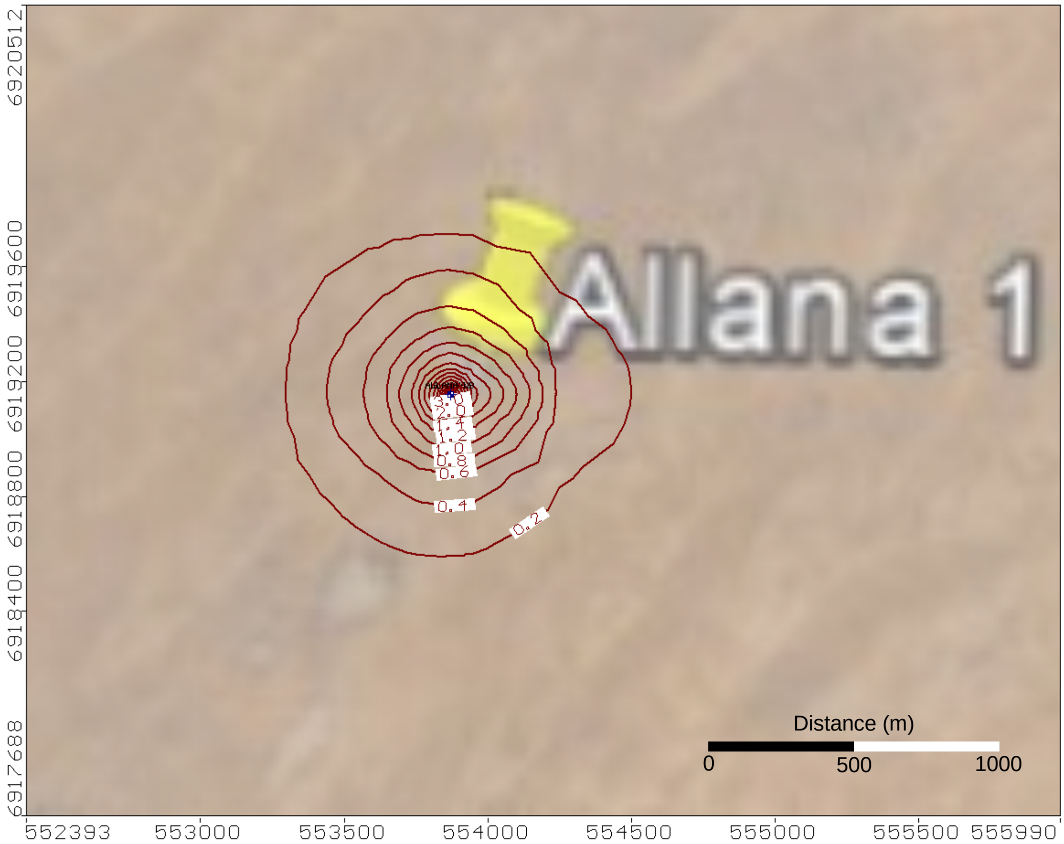
Sabe Pumping Water Levels – m AHD (t = 1050 days)



Sabe Pumping Drawdown Levels (t = 1050 days) – metres



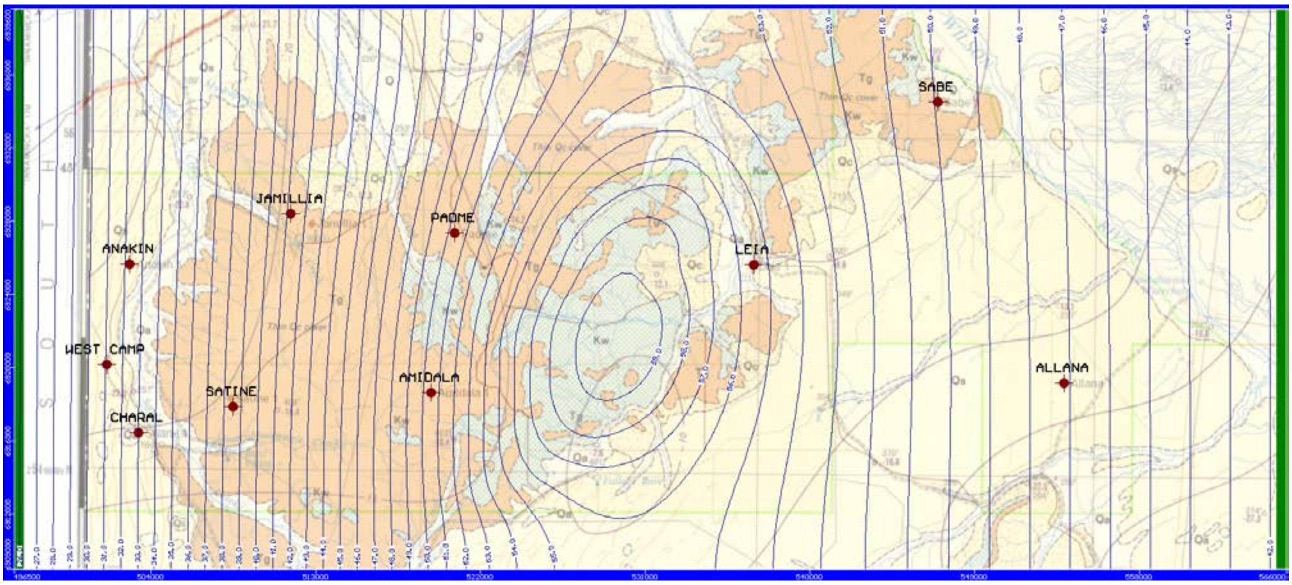
Allana Pumping Water Levels – m AHD (t = 1170 days)



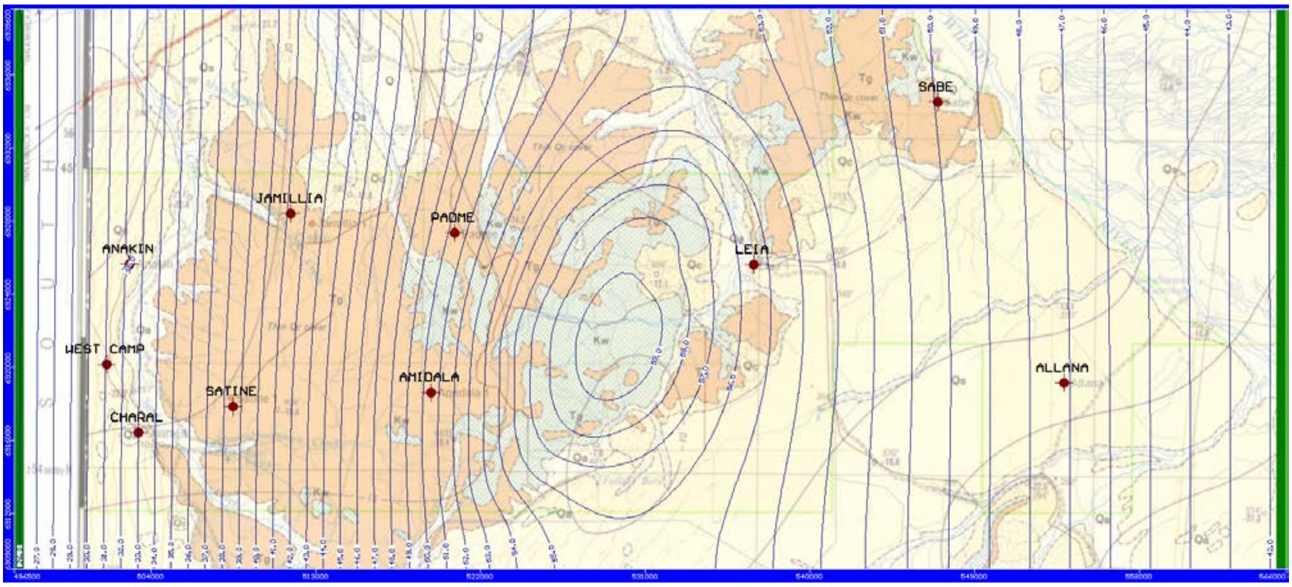
Allana Pumping Drawdown Levels (t = 1170 days) – metre

Sensitivity Analysis

K=2.7e-6 (steady state)



K=2.7e-6 S=0.04 (t=60 days)



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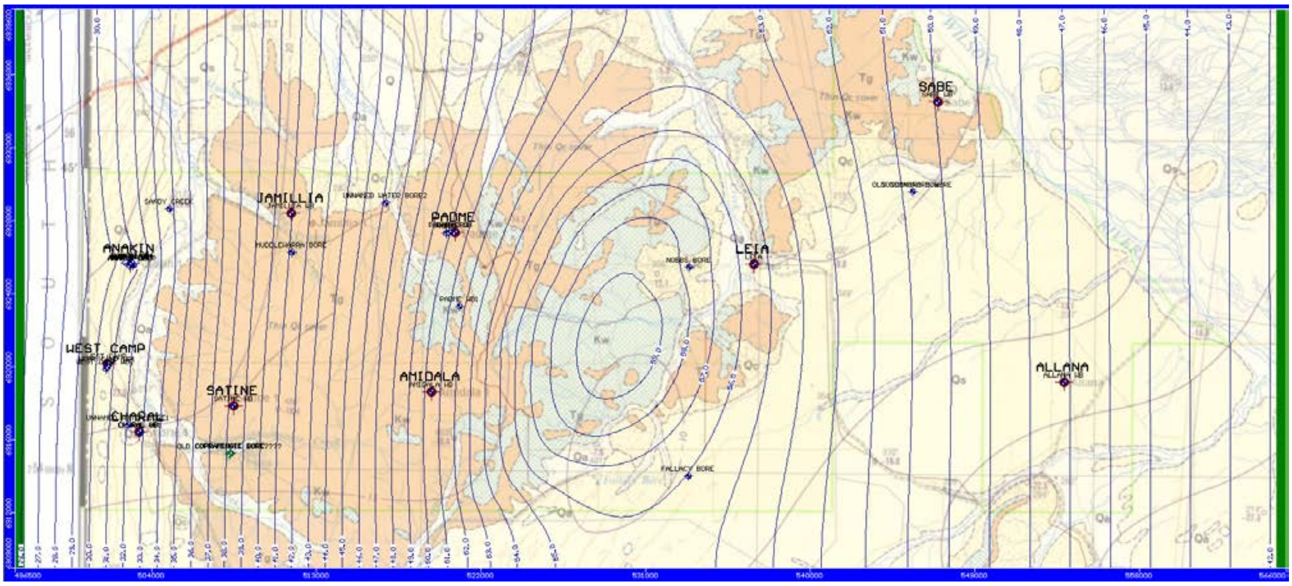
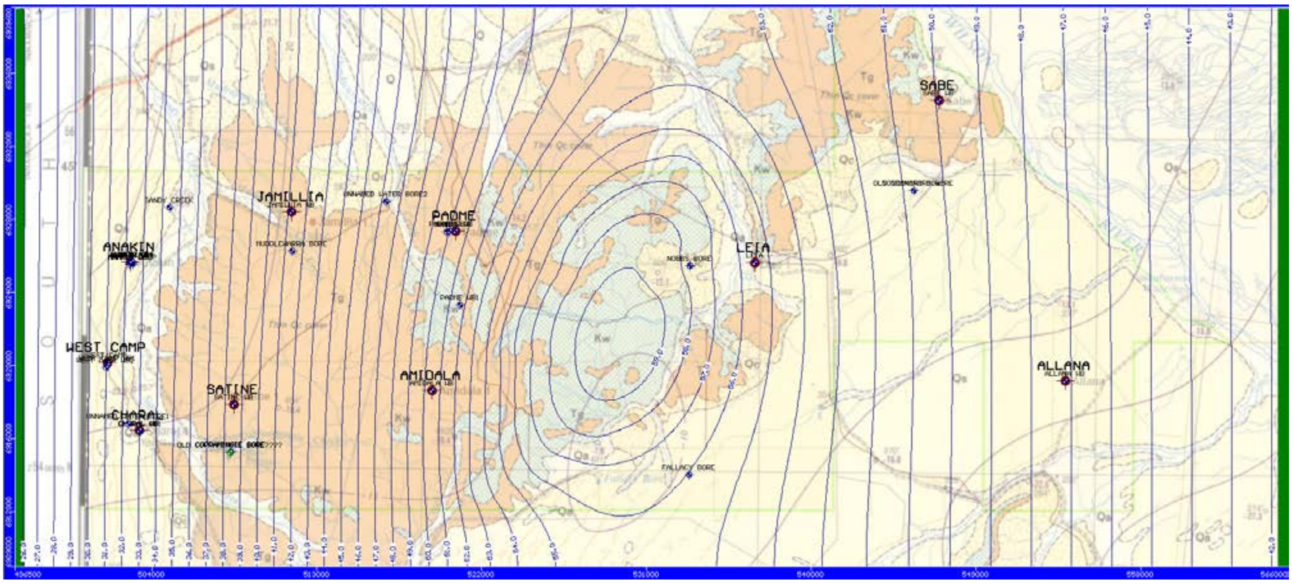
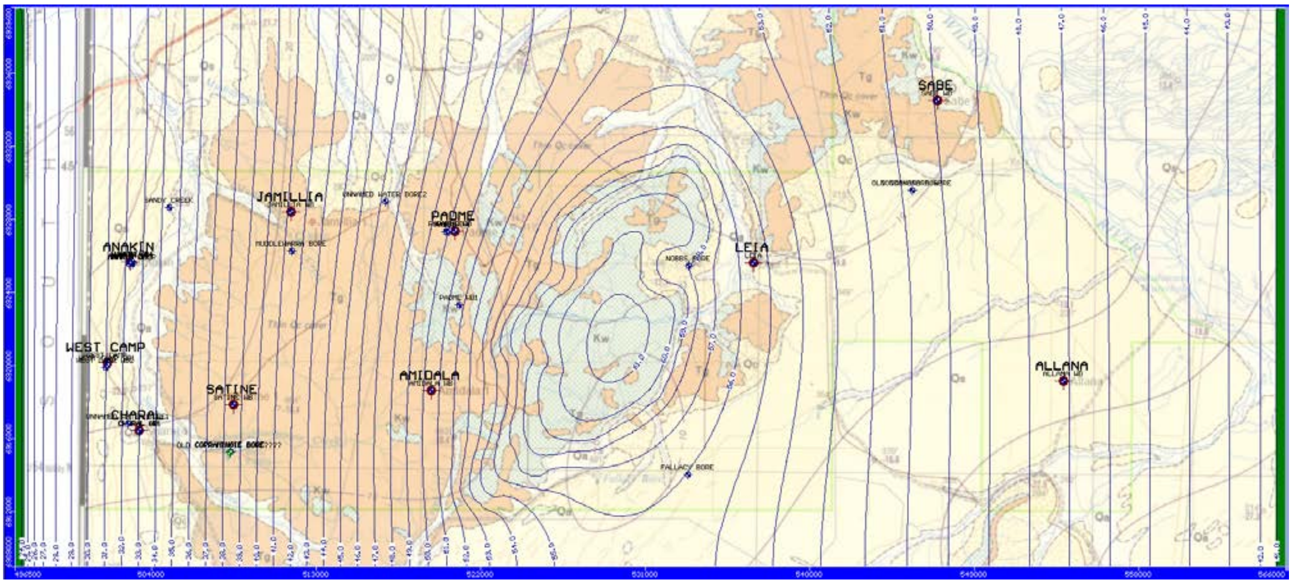


K=2.7E-7 s=0.04 (t=60 days)



K=2.7e-7 S=0.0004 (t=60 days)



Appendix 2 – Public Notice

PUBLIC NOTICE

Pursuant to section 382 of the *Water Act 2000*

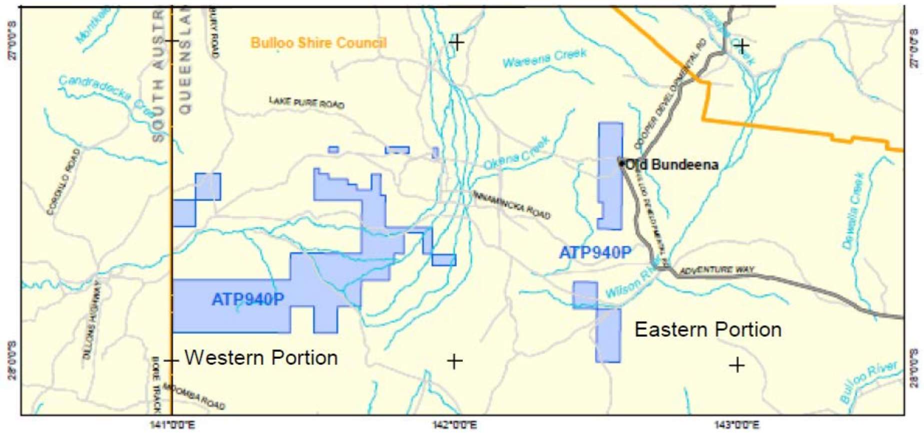
Release of UNDERGROUND WATER IMPACT REPORT

In accordance with the requirements of section 381 and section 382 of the *Water Act 2000* (Water Act), **Drillsearch Energy Limited**, has developed an Underground Water Impact Report (UWIR) for its drilling of exploration wells for gas reserves within ATP940P located within the Cooper-Eromanga Basin of Central Queensland.

You have the opportunity to review and comment on this UWIR.

From: **22 January 2016** you can access the UWIR for **ATP940P** by visiting **Drillsearch Energy Limited's** website at: **www.drillsearch.com.au/sustainability-2/** and following the links to the UWIR for ATP940.

You can also phone: **(07) 3337 0017** to arrange for a hard copy to be posted to you**.**



Written submissions on the UWIR may be made to Drillsearch Energy Limited and mailed to:

Drillsearch Energy ATP940 UWIR
Consultation
Via email: ATP940UWIR@arcadis.com
Via post:
C/- Arcadis Australia Pacific
Level 25, 288 Edward St
BRISBANE QLD 4000

Your submission must be:

- In writing; and
- Received by COB **22 February 2016**

Please note that as required by section 382(d) of the Water Act copies of all received submissions must be provided to the chief executive. The submission will be considered as part of the assessment process for the UWIR.