GROUNDWATER SUPPLY INVESTIGATION

AUDALIA RESOURCES LIMITED

MEDCALF VANADIUM PROJECT

Prepared for

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EXECUTIVE SUMMARY

Audalia Resources Limited (Audalia) is proposing to develop their Medcalf Vanadium Project, located approximately 100 km west of Norseman. The project will comprise three shallow open pits mined over a period of thirteen years, and associated infrastructure. The pits are not expected to extend below the water table. Audalia has indicated that the project requires approximately 0.8 GL per annum (25 L/s) of groundwater for the purposes of beneficiation, dust suppression and camp supplies (which will need to be treated via reverse osmosis). Audalia engaged GRM to undertake a water supply investigation to assess the potential water supply options within tenements M63/656, E63/1133 and E63/1134.

A groundwater exploration drilling programme was undertaken which included drilling 14 of 29 identified targets. The exploration drilling found two fractured rock water supply bore locations and one palaeochannel bore location. The palaeochannel aquifer comprised a medium grained sand channel, which was 10 m thick and at least 150 m wide. The fractured rock aquifers comprised multiple zones of fracturing within ultramafic and granodiorite sequences. Nine monitoring bores were installed to facilitate groundwater level measurements and stygofauna sampling. Groundwater samples collected during the investigations indicate that the fractured rock aquifer is hypersaline and highly variable, ranging from 54,000 to 170,000 mg/L TDS with a circum neutral pH. The palaeochannel aquifer is hypersaline (76,000 mg/L TDS) and significantly acidic (pH 3.7). A gravity survey was undertaken to confirm the palaeochannel extent to the north.

The results of the field investigations indicate that the project water demand could potentially be met by a combination of two fractured rock bores and two palaeochannel bores, assuming the acidity of the groundwater in the palaeochannel aquifer is acceptable. The yields were higher in the two fractured rock bores, yet the palaeochannel bores are likely to be more reliable in the longer term, as fractured rock aquifers commonly have low storage and yields can diminish with time. Further assessment (i.e. review of gravity survey data, exploration aircore drilling, installation of production bores, and test pumping) would be necessary to determine the long term yields and required borefield configuration necessary for the project.

A conceptual model and preliminary groundwater flow model was developed for the palaeochannel and surrounding bedrock environment. However, it must be understood that in the absence of test pumping data, the modelling is considered generic and will require revision once the production bores are installed and tested. The modelling indicates abstraction from the bores will result in groundwater drawdown extending linearly along the higher permeability features (i.e. along the palaeochannel sand aquifer or along the fracture orientation), with limited drawdown extending laterally into the adjacent low permeability intact bedrock. The modelling suggests that the palaeochannel clay will likely act as a semi confining layer, limiting leakage to the underlying sand aquifer and resulting in minimal drawdown response in the shallow groundwater system, whilst abstraction from the fractured rock bores will result in the 1 m drawdown contour extending approximately 1.5 km along strike from the fractured rock bores.

The project is located in an unproclaimed groundwater area and whilst a CAW was not required for the exploration drilling, the results indicate that the palaeotributary is likely to be semi-confined, and Audalia will be required to submit an application to DWER for a bore construction licence prior to the installation and test pumping of the proposed palaeotributary bores. A groundwater licence may also be required for the long-term operation of the bores. However, this will be assessed by DWER based on the results of the test pumping.

The risk of environmental impact to other groundwater users, the groundwater environment and the GDE's as a result of groundwater abstraction from the proposed water supply bores is considered low, given that the drawdown around the bores is likely to be localised, the nearest licenced groundwater user is 35 km from the project, the groundwater is hypersaline, and of limited use, other than for mining and industrial purposes.

GLOSSARY OF TERMS

Aquifer	A saturated geological unit that is permeable enough to yield economic quantities of water.
Aquitard	A geological unit that is permeable enough to transmit water but not sufficient to yield economic quantities.
Aquiclude	A geological unit that is impermeable, *i.e.* cannot transmit water.
Confined Aquifer	An aquifer bounded above and below by an aquiclude, where the water level in the aquifer extends above the aquifer top and is represented by a pressure head, *i.e.* the aquifer is completely saturated.
Drawdown	The change in hydraulic head observed at a well in an aquifer, typically due to pumping.
Leaky Aquifer or Semi-Confined Aquifer	An aquifer with upper and/or lower boundaries as an aquitard, where the water level in the aquifer extends above the aquifer top and is represented by a pressure head. Pumping from the aquifer induces leakage from the neighbouring aquitard units.
Unconfined or Water table Aquifer	An aquifer that is bounded below by an aquiclude, but is not restricted on its upper boundary, which is represented by the water table.
Hydraulic Conductivity (K) **[Permeability]**	The volume of water that will flow in a unit time under a unit hydraulic gradient through a unit area. Analogous to the permeability with respect to fresh water (units commonly m/d or m/s).
Transmissivity (T)	The product of the hydraulic conductivity and the saturated aquifer thickness (units commonly $m^3/d/m$ or m^2/d)
Specific Storage (S_s)	The volume of water released from a unit volume of aquifer under a unit decline in hydraulic head, assuming confined aquifer conditions. Water is released because of compaction of the aquifer under effective stress and expansion of the water due to decreasing pressure (units commonly m^{-1}).
Storativity (S)	The volume of water released from a unit area of aquifer, i.e. the aquifer column, per unit decline in hydraulic head (dimensionless parameter).
Specific Yield (S_y)	The volume of water released from an unconfined aquifer per unit decline in the water table. The release of water is mostly from aquifer draining. Contributions from aquifer compaction are generally small. Analogous with effective porosity (dimensionless parameter).

Terms referenced from Kruseman GP and deRidder NA (1994) 2nd edition, Analysis and Evaluation of Pumping Test Data. ILRI Publication 47 The Netherlands

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1.0 INTRODUCTION

Audalia Resources Limited (Audalia) is proposing to develop their Medcalf Vanadium Project, located in the Bremer Range, near Lake Johnston, approximately 100 km west of Norseman (Figure 1).

The project will comprise three open pits (Egmont, Vesuvius and Fuji), a processing plant, tailings storage facility, waste dump, workshops and an accommodation village. The three pits (Figure 2) will be developed to a maximum depth of around 50 m below surface. The pits are not expected to extend below the water table and should not require mine dewatering.

The ore production rate is likely to be in the order of 1.5 million tonnes per annum (Mtpa), over a 13 year life of mine (LoM). Beneficiation will be undertaken on site, with the concentrate transported via haul trucks along an 80 km haul road east of the project, to a transfer depot adjacent to the Esperance Highway. The concentrate will then be transferred to smaller road trains and transported to the Esperance port for export.

Audalia has indicated that the project requires approximately 0.8 GL per annum (25 L/s) of groundwater for the purposes of beneficiation, dust suppression and camp supplies (via reverse osmosis treatment). Whilst no constraint on water quality for the process and dust suppression demand has been provided at this stage, lower salinity groundwater is preferred to reduce the corrosive impacts to infrastructure.

Groundwater Resource Management (GRM) has previously undertaken a scoping level desktop study for the project (GRM, 2014) and a pre-feasibility level desktop water supply assessment (GRM, 2015), which identified potential on-tenement and off-tenement water supply options for the project.

Audalia has since been granted a mining tenement and has submitted the Environmental Protection Authority (EPA) Scoping Document (Preston, 2019). The Scoping Document identified several key areas relating to groundwater, which require addressing to meet the EPA objectives.

Audalia subsequently engaged GRM to undertake field investigations to assess the potential on-tenement water supply options identified during the desktop water supply assessment (GRM, 2015). The aim of the investigations is to progress towards addressing the key areas identified in the EPA Scoping Document. This report presents the finding of the field investigations.

2.0 BACKGROUND

A description of the project, the climatic conditions, the regional geology and hydrogeology and publicly available information relating to other groundwater activities in the region are provided in the following sections.

2.1 Project Description

The project is located within the Shire of Dundas, approximately 100 km west south-west of Norseman. The current granted tenements comprising the project cover an area of 38 km^2, are shown in Figure 2, and include:

- Mining lease M63/656
- Exploration leases E63/1133, E63/1134, E63/1855

The project also includes a haul road corridor (tenement L63/75) which links the project tenements with the Norseman Esperance road, some 74 km east of the project.

The proposed project comprises three pits (Egmont, Vesuvius and Fuji), as shown in Figure 2, which will be developed to a maximum depth of 50 m below surface.

The surface elevation of the pits ranges from around 416 mRL at Egmont and Fuji to around 434 mRL at Vesuvius. The groundwater level is expected to be in the order of 305 to 310 m RL, based on regional conditions, which suggests that mine dewatering will not be required. However provision for the removal of rainfall runoff to the pits will be necessary.

2.2 Climate

The climate of the Dundas region is semi-arid with the highest rainfall recorded in the winter months between May and July, related to frontal activity extending up from the Great Australian Bight. Summer rainfall is generally restricted to irregular thunderstorm activity associated with the southern extension of the inter-tropical convergence zone, although the region can be affected by remnant tropical cyclones. These form rain-bearing depressions that travel south after crossing the Pilbara coast.

The nearest Bureau of Meteorology (BoM) station to the project is Norseman (Station Number 012065), which has collected rainfall data since 1897. The closest stations with evaporation data is Salmon Gums, located about 100 km south-east of the project. The rainfall and evaporation data indicate a mean annual rainfall of around 289 mm per year and a mean annual evaporation of 1,534 mm, with evaporation exceeding rainfall in all months of the year.

Mean monthly rainfall and evaporation data are presented in Table 1.

Table 1: Long Term Average Rainfall and Evaporation Data

Month	Norseman (BoM station 12065)	Salmon Gums (BoM station 012071)
	Mean Monthly Rainfall (mm)	Mean Monthly Pan Evaporation (mm)
January	19.9	245
February	24.9	189
March	24.4	158
April	23.4	99
May	30.5	56
June	30.1	42
July	26.8	47
August	24.8	62
September	21.4	93
October	20.3	140
November	20.4	183
December	21.4	223
TOTAL	288.9	1,534

2.3 Geology

The description of the geological conditions associated with the project is derived from the 1:250000 LAKE JOHNSTON geological sheet (Figure 3), the regional interpretation by Gower and Bunting (1976), as well as local geological interpretation provided by Audalia.

The project lies within the southern extension of the Archean Lake Johnston greenstone belt. The belt lies along the southern margin of the Yilgarn Craton, and forms a narrow, north-west trending zone of approximately 110 km in extent.

The greenstone belt comprises three formations, listed from deepest to shallowest:

- Maggie Hays Formation – consisting predominantly of extrusive pillow-form mafic sequences, some mafic and ultramafic intrusive rocks, and minor sedimentary horizons (banded iron formation and stratified metasediments of tuffaceous origin).
- Honman Formation – consisting of banded iron formation, clastic sedimentary rocks and minor felsic volcanics. Commonly these sequences are completely altered and contain predominantly quartz and kaolinite.
- Glasse Formation – consisting of fine grained mafic units, with mafic intrusives and ultramafic sequences in the lower part of the formation.

The project's vanadium (and titanium) mineralisation is associated with a magnetite rich pyroxenite, which forms a distinct band within a layered gabbro of the lower Maggie Hays Formation. The pyroxenite lies near-surface in the vicinity of the project area due to the north plunging Gordon Anticline, of which the project area is located on the southern margin. North-south trending faults have also been observed in the project area, resulting in lateral displacement of the ore.

The bedrock geology is overlain by Quaternary and Tertiary deposits comprising lacustrine deposits, alluvium, colluvium and laterite.

2.4 Regional Hydrogeology

The description of the regional hydrogeological conditions associated with the project is derived from regional hydrogeological assessments completed by Kern (1995) for the nearby BOORABBIN 1:250,000 sheet (there is currently no hydrogeological assessment of the LAKE JOHNSTON sheet), Commander's report on the hydrogeology of Tertiary palaeochannels (1991), and GRM's previous experience in the Lake Johnston greenstone belt.

The hydrogeology of the project area is characterised by low relief and north easterly draining palaeo-drainage systems, underlain by Archean sequences.

Groundwater typically occurs in (from deepest to shallowest):

- Regional catchment controlled flow systems in fresh and weathered fractured rock aquifers.
- Tertiary palaeochannel sands.
- Surficial laterite, alluvium and calcrete.

Groundwater occurrences in the fresh bedrock are associated with discrete interconnected fractures. The fracturing is characterised by secondary permeability resulting from tectonic and decompression fracturing enhanced by chemical dissolution. Permeability of the fractures is often further enhanced by the deep weathering profile common in the region. Fractured bedrock aquifers occur more commonly in mafic, ultramafic and granitic rocks than in sedimentary or felsic volcanic / volcanoclastic units. In contrast the mafic and ultramafic dykes which are prevalent in the region typically form hydraulic barriers to groundwater flow.

Fractured bedrock aquifers in the Lake Johnston area can be high yielding (i.e. up to 100 L/sec when intercepted during underground mining). However, as a result of their discrete nature (i.e. having low storage characteristics), they typically dewater rapidly and consequently are not always reliable as a long term water supply. Permeability in the bedrock away from these features is low, with low storage characteristics.

The Tertiary paleo-drainage systems of the region typically provide the largest source of groundwater in the area. The project area is located at the southern extent of a tributary along the Lefroy palaeo-drainage system (Figure 4), a large north easterly draining system which once carried surface water to the Eucla Basin. The sedimentary sequence of the Lefroy palaeo-drainage is dominated by the Wollubar Sandstone, a high yielding sequence of quartz sand, with minor conglomerate, silt, clay and lignite. Overlying the Wollubar Sandstone is the Perkollili Shale, which provides a semi confining layer to the main channel aquifer.

Groundwater occurrences are also found in the surficial sediments, when they extend below the water table. However, these sources historically provide the smallest source of groundwater in the area.

Recharge is by direct rainfall infiltration or by stream flow during episodic rainfall events. The recharge occurs mainly on or adjacent to the catchment divides, beneath which there are corresponding, subdued groundwater divides. The groundwater moves from these divides to discharge into salt lakes along the palaeo-drainages. In the salt lakes the groundwater is evaporated and concentrated to brine, which then descends and moves downstream in the palaeochannel sand to eventually discharge into the Eucla Basin.

Groundwater salinities typically range from fresh to hypersaline. Low salinity groundwater is known to occur in areas most affected by direct rainfall recharge, e.g. near catchment divides and within shallow alluvium and calcrete units. The highest salinity groundwater occurs low down in the catchments within palaeochannel sands and deeper fractured rock aquifers.

The local groundwater environment is discussed in more detail in Section 4.2.1.

2.5 Other Groundwater Users

A search of bore records within a 50 km radius of the project was carried out using the Water Information Reporting (WIR) database, which is managed by the Department of Water and Environment Regulation (DWER).

The WIR data indicates that there are 57 registered bores within 50 km of the project. A summary of the bores is provided in Table 2 below, and the bore locations shown in Figure 5.

The WIR data indicates that:

- The closest registered bores to the project are a cluster of 34 bores located 37 km south east of the project (No1 Hand to No23 Hand and No1 Machine to No11 Machine). The data indicates that the bores were drilled in 1929 to depths of between 1 and 49 m. The bores were drilled into weathered granite, with only three of the bores reportedly providing small winter supplies. There is no groundwater quality data in the database, although it is likely, given the shallow depth and rock type, that the bores were targeting fresh water supplies.
- The next closest bores are the Mhp series bores (Mhp1 and Mhp2), which are reported as being operational and understood to be the dewatering bores for Poseidon Nickel Limited’s Maggie Hays mine within their Lake Johnston Operation, which are currently under care and maintenance.
- The next closest bores are a second cluster of bores, installed during 1929 (No1 Hand to No11 Hand and No1Machine to No3 Machine), which are located 46 km south east of the project. Similarly to the earlier cluster, these bores are shallow (1 to 53 m deep) and drilled into the weathered granite, presumably for the purpose of locating a fresh water source.
- The next closest are a series of six bores (FW44, FW50, FW51, FW2, FW56 and FW57), located 46 km north west of the project. The bores were drilled in 1970 for Amax Exploration Australia. The bores were reportedly low yielding (<1 L/s), to a depth of up to 92 m.
- The next closest bores are the EAP1 to EAP7 series bores, which are located 48 km north west from the project. The bores were installed in 2000 and are understood to comprise the dewatering and water supply bores for Poseidon Nickel Limited’s Emily Ann mine within their Lake Johnston Operation.

Table 2: WIR Bores Within 50 km

Site Name	Coordinates (MGA Zone 51)		Owner	Date Drilled	Depth (m bgl)	TDS (mg/L)	Distance from The project (km) and direction	Comments
	Easting	Northing						
No1 Hand to No23 Hand	315,861	6,367,492	Unknown	1929	0.91 to 4.88	-	37 km SE	Decomposed granite
No1 Machine to No11 Machine	315,861	6,367,492	Unknown	1929	0.91 to 48.77	-	37 km SE	Decomposed granite
Mhp1	264,450	6,430,950	Unknown	1997	73	-	44 km NW	Operational production bore
Mhp2	264,650	6,430,450	Unknown	1997	140	-	44 km NW	Operational production bore
No1 Hand to No5 Hand	320,208	6,359,725	Unknown	1929	1.22 to 3.35	-	46 km SE	-
No1 Machine to No 3 Machine	322,066	6,359,954	Unknown	1929	36.58 to 52.74	-	46 km SE	-
FW44	265,240	6,432,802	Amax Exp Aust	1977	85	2,400	46 km NW	Yield <0.1 L/s
FW50	262,551	6,432,952	Amax Exp Aust	1977	26	-	46 km NW	Yield dry
FW51	262,940	6,433,382	Amax Exp Aust	1977	23	-	46 km NW	-
FW52	263,326	6,432,909	Amax Exp Aust	1977	92	13,200	46 km NW	Yield 0.5 L/s
FW56	263,480	6,433,432	Amax Exp Aust	1977	70	-	46 km NW	Yield dry
FW57	262,372	6,433,484	Amax Exp Aust	1977	67	16,800	46 km NW	Yield 0.4 L/s
EAP1	262,458	6,434,031	Maggie Hays	1997	109	-	48 km NW	Operational production bore
EAP2	262,500	6,434,000	Maggie Hays	1998	220	-	48 km NW	Operational production bore
EAP3	262,250	6,434,450	Maggie Hays	1998	270	-	48 km NW	Operational production bore
EAP4	262,350	6,434,200	Maggie Hays	1998	315	-	48 km NW	Operational production bore
EAP5	263,000	6,434,350	Maggie Hays	1998	83	-	48 km NW	Operational production bore
EAP6	262,519	6,433,860	Lion Ore	2000	252	-	48 km NW	Operational production bore
EAP7	262,756	6,433,814	Lion Ore	2000	208	-	48 km NW	-

Notes: m bgl metres below ground level, TDS total dissolved solids.

2.6 Resource Area and Licensing Requirements

The project area lies within the Nullabor Sub-Area of the Nullabor Groundwater Area.

The project is located with an unproclaimed groundwater area and, in accordance with the Rights in Water and Irrigation Act (1914), is not subject to groundwater licensing unless abstraction is from a confined (artesian) or semi-confined aquifer. This applies to both licences to Construct or Alter Wells (CAWs), as well as long term operational groundwater licensing (GWL).

Clarification was sought from the DWER prior to the groundwater supply study, via email communications in October 2018, to confirm the required protocol when the aquifer conditions (confined, semi-confined or unconfined) were unknown. It was advised that the exploration drilling should be undertaken without a CAW. However if the investigations indicated semi confined or confined aquifers, then a CAW would be required prior to the installation and test pumping of investigation bores, and a GWL would be required prior to groundwater abstraction form the bores.

Further discussion relating to ongoing licensing requirements is documented in Section 4.4.

2.7 Water Register

The DWER online water register was interrogated to identify the presence of existing licensed groundwater users in the vicinity of the project. The existing licensed groundwater users are shown in Figure 6, and the licence details summarised in Table 3 below.

The information shows that:

- The nearest groundwater licence holder is Poseidon Nickel Limited’s tenements 35 km north-west of the project. The licence allocation is for 10 GL per annum from the fractured rock groundwater resource. The allocation is understood to supply their Lake Johnston operation, which is currently under care and maintenance.
- Neil Alan Hoey is the next closest licence holder, located 45 km north north-west of the project. The licence is for a small allocation of 99,000 kL per annum from the fractured rock resource, over a small tenement M63/549.

Table 3: Nearby Groundwater Well Licences

GWL Holder	GWL	Allocation (kL/yr)	Aquifer	Expiry Date	Distance and Direction from Medcalf
Poseidon Nickel Limited	107400	10,000,000	Combined Fractured Rock West Fractured Rock	20 Jan 2026	35 km NW
Neil Alan Hoey	156852	99,000	Combined Fractured Rock West Fractured Rock	25 Feb 2025	45 km NNW

2.8 Groundwater Dependant Ecosystems

A review of the BoM’s Groundwater Dependant Ecosystem (GDE) Atlas for an area of 25 km surrounding the project area indicates that the project area is classified as having:

- No identified aquatic or subterranean GDE’s within the project tenements.
- A moderate potential within the immediate project area and to the north of the project for having terrestrial GDE’s, and a low potential for terrestrial GDE’s to the south of the project area. The assessment is based on the National GDE Assessment.

The BoM’s GDE Atlas assessment is provided in Appendix A.

Further assessment of GDE’s specific to the site has been provided by Audalia’s environmental consultant.

A rare flora (*Marianthus aquilonaris*) has been identified in the project area, which potentially relies on soil moisture. An assessment of potential impacts to the Marianthus plant communities is discussed in more detail in Section 4.6.

3.0 FIELD INVESTIGATIONS

The field investigations were based on the results of a desktop study undertaken by GRM (GRM, 2015). The desktop study was aimed at identifying potential water supply options within the project tenements and in the broader region.

Audalia requested the investigations were initially limited to the tenements closest to the proposed pits (i.e. M63/656, E63/1133 and E63/1134), with the understanding that if the study failed to identify suitable water sources then the study would be expanded to tenure further afield.

The desktop study identified two potential groundwater resources within the three nominated project tenements, which included:

- Palaeochannel sand aquifer, associated with the Lefroy palaeotributary in the north east of the project tenements.
- Fractured rock aquifers associated with the southern extension of the Lake Johnston greenstone belt.

Audalia had indicated that a previous drilling contractor had installed a temporary water bore in a resource exploration drill-hole (KJC034), near the proposed camp (Figure 7). The bore was utilised for drilling water supply purposes. However, the water quality and potential yields from the bore were not known.

Audalia indicated that there were no other water supply bores, or information pertaining to groundwater intercepts within the project tenements.

3.1 The Driller's Bore

Mr Tim Wetscott from TWD Consultants Pty Ltd, on behalf of GRM, undertook a site visit on 30 November 2018 to assess the condition and potential yield from the existing Driller's Bore.

The assessment included airlifting the bore using 25 mm poly pipe installed to the base of the bore (i.e. 42 m below surface). The groundwater was highly discoloured upon commencement of airlifting, with up to 10% solid content. The sediment content indicated that the bore was likely to have been constructed without gravel pack, and possibly using hand slotted casing (rather than machine slotted), which is not uncommon for temporary, drilling water supply bores.

The bore was airlifted for a period of 1.5 hours, at a yield of around 1 L/s to 1.5 L/s. Field data and photographs collected during the investigation are provided in Appendix B.

Mr Westcott indicated that the bore recovered very quickly after airlifting, but that the sediment content and discolouration did not improve with time. The results indicate that the bore is not suitable as a long term water supply bore for the project in its current condition, but that the location should be considered as a potential target for further groundwater investigation, which is discussed further in Section 3.3.

The details of the drillers bore are provided in Table 4 below. A sample of the groundwater for laboratory analysis was collected during the later field investigations and will be discussed further in Section 3.8.

Table 4: Drillers Bore

Bore ID	Easting (GDA94 z51)	Northing (GDA94 z51)	Depth (m bgl)	Casing Type	Slotted Interval	SWL (m bgl)	Airlift Yield (L/s)
Driller's Bore (KJC034)	295,955	6,397,105	42	100 mm diameter uPVC	Unknown	24	1 – 1.5

Notes: m bgl metres below ground level

3.2 Geophysical Surveys for Fractured Rock Targeting

The desktop study (GRM, 2015) recommended geophysical surveying to assist in groundwater target delineation of potential fractured rock targets. Consequently, ASST Pty Ltd was engaged by Audalia to undertake geophysical surveys of the project area. The surveys comprised:

- A preliminary review of publicly available survey data to identify initial target structures (results provided as Appendix C).
- Ground magnetic surveys over 12 target structures, conducted between 24 and 27 January 2019.
- Ground Electrical Resistivity Imaging (ERI) surveys of 8 target structures to further delineate the ground magnetic targets, conducted between 2 and 7 February 2019.

Which led to the Identification of 15 potential groundwater targets. A study report outlining the surveys and the resulting targets (provided as Appendix D).

3.3 Groundwater Targets

Twenty nine drilling targets were identified based on a combination of the desktop review, the assessment of the Drillers Bore and the geophysical survey results.

The targets are listed in Table 5 below, shown in Figure 7, and comprised:

- Fifteen potential fractured rock locations identified by geophysical surveying. These locations are denoted by the prefix "D".
- Ten palaeochannel locations, targeting the southern extent of a tributary to the Lefroy palaeo-drainage system. These locations are denoted by the prefix "PC".
- Four fractured rock locations surrounding the existing Driller's Bore, denoted by the prefix "DB".

The targets were ranked based on an assessment of the likelihood of success, with priority 1 targets representing the highest priority ranking. The target locations and the priority order are provided in Table 5 below.

Table 5: Drilling Targets

Target Type	Target ID	Coordinates (MGA Zone 51)		Priority
		Easting	Northing	
Fractured Rock	D601	297,325	6,397,977	1
	D501	297,091	6,397,624	1
	D201	291,954	6,398,260	1
	D301	293,315	6,398,269	1
	D303	293,417	6,398,216	1
	D304	293,201	6,398,327	1
	D801	296,078	6,399,750	1
	D802	296,259	6,399,758	1
	D302	293,288	6,398,282	1
	D102	291,021	6,397,899	1
	D401	295,211	6,398,236	1
	D402	295,075	6,398,232	2
	D403	295,164	6,398,234	2
	D101	291,198	6,397,905	2
	D701	294,750	6,399,677	2
Palaeochannel	PC01	296,450	6,400,157	1
	PC02	296,400	6,400,157	2
	PC03	296,350	6,400,157	2
	PC04	296,300	6,400,157	2
	PC05	296,250	6,400,157	2
	PC06	298,050	6,398,330	1
	PC07	298,000	6,398,330	2
	PC08	297,950	6,398,330	2
	PC09	297,900	6,398,330	2
	PC10	297,850	6,398,330	2
Fractured Rock	DB01	295,975	6,397,125	2
	DB02	295,935	6,397,085	2
	DB03	295,975	6,397,085	1
	DB04	295,935	6,397,125	2

3.4 Exploration Drilling

Fourteen groundwater exploration drill-holes were completed during the field investigations, between 10 September and 12 October 2019.

The drilling was undertaken by James Harrington, a Class 1 water well driller from Harrington Drilling, overseen by Richard Toll, an experienced GRM Hydrogeologist, who was responsible for the collection and field assessment of geological and hydrogeological data.

The exploration drilling did not require a CAW Licence, given that the project is located within an unproclaimed groundwater area, as discussed in Section 2.6.

The fractured rock exploration drilling was completed using direct circulation hammer drilling, whilst the palaeochannel drilling was carried out using aircore. Prior to commencement of the programme, Audalia had indicated that the drill-holes would be required for stygofauna sampling and consequently surface casing was extended to around 30 m in areas where the surface conditions were friable to reduce the risk of hole collapse. The monitoring bore construction is discussed further in Section 3.5.

The completed drill-holes were named using the prefix "MWH" and numbered in the order of drilling. A summary of the drilling results is provided in Table 6, locations shown in Figure 8 and the bore logs provided in Appendix E.

The exploration drilling results can be summarised as follows:

- Eight fractured rock targets were drilled resulting in two potential production bore locations at MWH009 (D801) and MWH012 (DB03), which yielded 14 and 10 L/s respectively.
- Permeability in MWH009 was associated with fracturing in an ultramafic unit between 52 to 66 m below surface. Whilst permeability in MWH012 was associated with fracturing in a granodiorite sequence from 29 to 75 m below surface.
- MWH013 (DB04) and MWH014 (DB01) are located adjacent to the MWH012 (DB03) and were drilled to provide additional stygofauna sampling locations. Both drill-holes intercepted high groundwater inflows and could be considered alternate bore locations, if the location of MWH012 (DB03) was unsuitable. It must be noted that only one production bore should be installed at MWH012, MWH013 or MWH014, as the locations are too close for multiple bores.
- MWH002 (D601) was abandoned after the surface casing was installed, to prioritise the palaeochannel drilling. This location should remain as a potential exploration target for future campaigns, if additional fractured rock supply bores are required.
- Six palaeochannel targets were drilled, resulting in the identification of a palaeochannel aquifer in the vicinity of MWH003 (PC06), MWH004 (PC08) and MWH005 (PC07). The sand aquifer is approximately 10 m thick, at least 150 m wide, with yields in the order of 4 to 5 L/s.
- The northern palaeochannel targets MWH007 (PC01) and MWH008 (PC02) intercepted more than 45 m of clay which suggests that the palaeochannel sand aquifer is further to the east.

Field measurements of pH, electrical conductivity (EC) and temperature were measured in the field. However, the groundwater salinity exceeded the range of the field instrument, and consequently the samples required dilution, which introduced a level of error in the data. Field measurements were used as a tool to provide a preliminary indication of salinity and are presented in the bore logs in Appendix E, but are not discussed further in this section. Groundwater quality, based on the laboratory analysis results are discussed in Section 3.8.

Table 6: Exploration Drilling Results

Bore ID	Target ID	Easting (GDA94 z51)	Northing (GDA94 z51)	Depth (m bgl)	Maximum Airlift Yield (L/s)	Main Aquifer Zone (m bgl)	Aquifer type
MWH001	D501	297,091	6,397,624	120	1	46 to 54 60 to 66	Fractured bedrock
MWH002	D601	297,325	6,397,977	30	<0.1	-	-
MWH003	PC06	298,050	6,398,330	39	4	16 to 26 34 to 36	Sand Weathered breccia
MWH004	PC08	297,950	6,398,330	45	5	16 to 27	Sand
MWH005	PC07	298,000	6,398,330	46	5	17 to 32	Sand
MWH006	PC10	297,850	6,398,330	30	0.5	29 to 30	Sand
MWH007	PC01	296,450	6,400,157	55	<0.1	-	-
MWH008	PC02	296,400	6,400,157	51	<0.1	-	-
MWH009	D801	296,078	6,399,750	102	14	52 to 66	Fractured bedrock
MWH010	D201	291,954	6,398,260	90	<0.1	-	-
MWH011	D401	295,211	6,398,236	120	<0.1	-	-
MWH012	DB03	295,975	6,397,085	114	10	29 to 75	Fractured bedrock
MWH013	DB04	295,935	6,397,125	54	6	35 to 54	Fractured bedrock
MWH014	DB01	295,975	6,397,125	54	7	35 to 54	Fractured bedrock

Notes: m bgl metres below ground level

3.5 Sieve Analysis

A sample of the sand aquifer from MWH003 was submitted for sieve analysis, with the results presented in Table 7 and the laboratory certificate provided in Appendix F. The sieve analysis indicates that the aquifer comprises medium grained sand, which is consistent with known regional conditions.

The results of the sieve analysis should be considered when designing the palaeochannel production bore, to ensure maximum bore efficiency.

Table 7: Sieve Analysis

Sieve	Unit	MWH003 (PC06) 22 to 28m	
		Passing	Retaining
9.5 mm	%w/w	98	2
4.75 mm	%w/w	97	3
2.36 mm	%w/w	94	6
1.18 mm	%w/w	81	19
710µm	%w/w	58	42
600µm	%w/w	50	50
425µm	%w/w	35	65
300µm	%w/w	23	77
150µm	%w/w	6	94
75µm	%w/w	<1	100

3.6 Monitoring Bore Installation

Nine monitoring bores were installed during the field investigations comprising seven fractured rock and two palaeochannel monitoring bores. The monitoring bores were designed primarily as sampling locations for stygofauna sampling and consequently care was taken to ensure drilling additives were minimised.

The fractured rock monitoring bores were constructed using 50 mm Class 9 uPVC casing, installed after the drill rods were removed. The casing lengths were joined using screws (i.e. not glued), fitted with an endcap and suspended on casing clamps from the surface casing. The monitoring bores were not gravel packed, but were completed at the surface with a concrete plinth and lockable cap.

The palaeochannel monitoring bores were completed with threaded 50 mm uPVC casing, which was fed into the drill-hole through the aircore rods. The rods were then removed from the drill-hole, allowing the formation to collapse against the casing (i.e. no gravel packing was used). The monitoring bores were completed at the surface with a concrete plinth and lockable cap.

The monitoring bore details, including the Driller's Bore details are provided in Table 8, and locations are provided in Figure 8.

Table 8: Monitoring Bores

Bore ID	Target ID	Easting (GDA94 z51)	Northing (GDA94 z51)	Hole Depth (m bgl)	Casing Depth	Slotted Interval (m)	SWL (m btoc)
MWH001	D501	297,091	6,397,624	120	66	6 to 66	17.43
MWH003	PC06	298,050	6,398,330	39	39	18 to 27 33 to 39	6.48
MWH008	PC02	296,400	6,400,157	51	30	3 to 30	6.35
MWH009	D801	296,078	6,399,750	102	66	6 to 66	9.45
MWH010	D201	291,954	6,398,260	90	66	30 to 66	tbc
MWH011	D401	295,211	6,398,236	120	66	30 to 66	45
MWH012	DB03	295,975	6,397,085	114	54	18 to 54	23.48
MWH013	DB04	295,935	6,397,125	54	54	18 to 54	tbc
MWH014	DB01	295,975	6,397,125	54	54	18 to 54	tbc
Drillers Bore	KJC034	295,955	6,397,105	42	42	Unknown	24

3.7 Hydraulic Testing

Falling head tests were attempted on four drill-holes; MWH003 (PC06), MWH008 (PC02), MWH009 (D801) and MWH012 (DB03). The aim of the hydraulic testing was to provide an indication of permeability in the absence of test pumping data.

The testing methodology comprised filling the monitoring bore with water and measuring the rate of water level recovery. However, three of the tests (MWH003, MWH009 and MWH012) were unsuccessful as a result of rapid recovery due to high permeability of the aquifer.

Testing of MWH008 (PC02) was successful and indicated a transmissivity of 0.02 m^2/day (hydraulic conductivity of 0.001 m/d), which is indicative of the palaeochannel clay. The analysis is provided in Appendix G.

3.8 Groundwater Quality

Groundwater samples were collected from selected drill-holes and submitted to SGS Environmental for laboratory analysis. The samples were collected at the end of drilling, with the exception of MWH003 from which a sample was collected from the sand aquifer and the underlying weathered basement. The samples were collected in laboratory supplied bottles, field filtered for metals, and stored in a chilled esky prior to submission the laboratory.

The results of the analysis are provided in Table 9 below, and indicate that:

- Groundwater in the fractured rock aquifer is hypersaline, ranging from 54,000 mg/L Total Dissolved Solids (TDS) in the Drillers Bore to 170,000 mg/L TDS in MWH009 (D801). The high variability in salinity is consistent with known regional conditions and is indicative of the complex nature of fractured rock environments.

- The salinity in the fractured rock aquifer in the vicinity of the Driller's Bore increases with depth, ranging from around 55,000 mg/L TDS in the shallower drill-holes (the Driller's Bore, MWH013 and MWH014) to 89,000 mg/L TDS in the deeper drill-hole (MWH012).
- The pH in the fractured rock bores is circum-neutral, ranging from 7.0 to 7.9, and the groundwater is of sodium chloride type.
- The groundwater in the palaeochannel sand aquifer (MWH003) is acidic (pH 3.7) and hypersaline (76,000 mg/L TDS). The groundwater chemistry is quite different to the fractured rock aquifer, with the palaeochannel groundwater reporting significantly higher aluminium and iron concentrations which are likely attributed to the high acidity, mobilising these elements from within the palaeochannel sediments.
- The weathered basement underlying the palaeochannel aquifer in MWH003 has similar groundwater chemistry to the palaeochannel sands, indicating hydraulic connection between the two aquifer types.

Laboratory certificates are provided in Appendix H.

Table 9: Groundwater Quality

Analyte	**Unit**	**MWH003**	**MWH003**	**MWH001**	**MWH009**	**MWH012**	**MWH013**	**MWH014**	**Driller's Bore**
		PC06 Sand	**PC06 Bedrock**	**D501**	**D801**	**DB03**	**DB04**	**DB01**	**KJC034**
pH	pH units	3.7	3.8	7.2	7.0	7.6	7.9	7.6	7.7
Electrical Conductivity	µS/cm	100,000	110,000	140,000	170,000	89,000	55,000	56,000	54,000
Total Dissolved Solids	mg/L	76,000	85,000	120,000	160,000	62,000	41,000	42,000	36,000
Total Alkalinity as $CaCO_3$	mg/L	<5	<5	150	96	420	560	580	630
Carbonate Alkalinity as CO_3	mg/L	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as HCO_3	mg/L	<5	<5	180	120	520	680	710	760
Chloride	mg/L	39,000	45,000	63,000	90,000	36,000	20,000	21,000	19,000
Sulfate	mg/L	8,900	11,000	12,000	15,000	5,700	4,300	4,300	4,200
Nitrate	mg/L	<0.2	<0.2	0.4	0.3	0.3	0.85	0.82	<0.2
Calcium	mg/L	240	290	450	700	980	610	610	570
Magnesium	mg/L	3,400	4,000	4,700	6,600	2,900	1,700	1,700	1,700
Potassium	mg/L	260	230	340	540	200	120	120	110
Soluble Silicon as Silica	mg/L	87	64	9.8	19	31	37	40	40
Sodium	mg/L	18,000	22,000	34,000	44,000	17,000	10,000	9,900	9,400
Total Hardness	mg/L	14,000	17,000	20,000	29,000	14,000	8,600	8,300	8,300
Aluminium	µg/L	63,000	16,000	<250	<500	<250	<100	<100	<100
Iron	µg/L	54,000	86,000	<250	3,400	<250	<100	<100	<100
Manganese	µg/L	1,400	2,000	2,100	2,600	1,100	630	700	700

3.9 Palaeochannel Gravity Survey

Upon completion of the drilling, and the identification of a palaeochannel aquifer, a gravity survey was initiated to further delineate the tributary.

The survey was undertaken by Atlas Geophysics between 8 and 11 October 2019. The survey included the acquisition and processing of 564 new gravity stations, across 9 transects. The southern transect included the successful drill-holes MWH003, MWH004 and MWH005 to enable calibration of the survey data with drilling data, with the remaining eight transects at 100 m spacing to the north.

The results of the survey are provided in Appendix I. A preliminary interpretation of the palaeochannel orientation, based on the results, was provided by Newexco Geophysiscists (also provided in Appendix I). The data indicates that the palaeochannel extends in a north north-westerly direction, which is consistent with the WASANT palaeovalley map (Figure 4).

However, there is some uncertainty in the channel alignment in the south, with the geophysics indicating a channel to the west of the successful drill locations (Appendix I). Newexco has recommended further assessment of the data prior to the next phase of field investigations. In additional, an aircore exploration drilling programme would be required to locate the deepest part of the channel, prior to bore installation.

4.0 PRELIMINARY WATER SUPPLY ASSESSMENT

Audalia has indicated that the project requires approximately 0.8 GL per annum (25 L/s) of groundwater for the purposes of beneficiation, dust suppression and camp supplies (via reverse osmosis treatment). It is understood that there is no constraint on water quality for the process and some dust suppression demand. However, lower salinity is preferred to reduce the corrosive impacts to infrastructure.

4.1 Estimated Bore Yields and Configuration

The exploration drilling results indicate that the project water demand of 0.8 GL per annum (25 L/s) could potentially be met by a combination of fractured rock and palaeochannel bores.

The yields measured during exploration drilling are higher in the two fractured rock bores, yet the palaeochannel bores are likely to be more reliable in the longer term, as fractured rock aquifers commonly have low storage and yields can diminish with time.

Further assessment (i.e. installation and test pumping of production bores) would be necessary to determine the long term yields and required borefield configuration necessary for the project. However, potentially two fractured rock bores (at MWH009 and MWH012) and two palaeochannel bores (at MWH003 and approximately 1 km further north, along the palaeochannel) could provide sufficient supply for the project.

This potential configuration is based on an assumed abstraction rate of 8 to 12 L/s per fractured rock bore and 5 to 10 L/s per palaeochannel bore, which is based on GRM's experience with similar projects in the region. Further hydrogeological testing (bore installation and test pumping) will be necessary to confirm these estimates.

4.2 Preliminary Modelling

A conceptual model and groundwater flow model has been developed for the project to assess likely drawdown impacts associated with groundwater abstraction from the fractured rock and palaeochannel aquifers. However, it must be understood that in the absence of test pumping data, the modelling is considered preliminary and will require revision once the production bores are installed and tested.

4.2.1 Conceptual Model

The conceptual model for the Medcalf project area is derived from hydrogeological information collected during the field investigations and publicly available information (as provided in Section 2.4).

The project area is located on the western flank of a northerly draining palaeotributary of the regionally extensive Lefroy Palaeodrainage system, which is one of many Cenozoic palaeodrainage systems across Australia. The majority of the palaeodrainage valleys across Australia were formed during the Permian continental glaciation, and then further developed at the end of the Cretaceous when Australia was rifted from Antarctica. Following the rift, associated epeirogenic uplift resulted in the development of inset-valleys within the precursor Permian valleys. The palaeodrainage systems we see today are the remnant Early Cenozoic inset valleys with an Early to Middle Tertiary sedimentary infill, overlain by a thin Quaternary cover (Magee, 2009).

The recent drilling indicates that the sand aquifer within the palaeotributary, which represents the regionally extensive Wollubar Sandstone, is approximately 10 m thick and at least 150 m wide in the vicinity of MWH003. Geophysical surveying has indicated the channel extends to the north north-west, which is consistent with the WASANT palaeovalley map (Figure 4). The sand sequence likely formed under wet climatic conditions of the Early Tertiary, which was characterised by wide-spread rainforests.

The overlying clayey sequence, which represents the Oligo-Miocene Perkolilli Shale, is approximately 16 m thick in the vicinity of MWH003 and contains predominantly clay, with lenses of calcrete and sand. The clayey sequence likely represents a lower energy, lacustrine environment, formed during a drier climate, consistent with palaeochannels across Australia (Magee, 2009). Hydraulic testing undertaken as part of the field investigations indicated a transmissivity of the Perkolilli Shale (at MWH008) of 0.02 m^2/d (Section 3.7). The Perkolilli Shale most likely acts as a semi-confining layer to the underlying Wollubar Sandstone (although test pumping from the palaeochannel combined with monitoring in the shallow system will be necessary to confirm this).

The depth to groundwater in the palaeotributary is less than 10 m below surface. The groundwater salinity, as measured in MWH003, is hypersaline (76,000 mg/L TDS) and the pH is low (3.7). The salinity is likely to increase down hydraulic gradient (i.e. to the north) as the groundwater becomes progressively more evolved.

Palaeochannel aquifers are recharged directly from rainfall in the upper channel reaches. Historically recharge to palaeodrainage systems across Australia has been episodic and most effective during the warm-wet interglacial periods (Magee, 2009). The sand unit is generally a continuous aquifer, on a regional scale, and has considerably greater storage potential and transmissivity than the adjacent fractured basement rocks. However, when fractured bedrock aquifers are in hydraulic connection to the palaeochannel aquifer, the volume of groundwater is the system may significantly increase as the bedrock systems can be far more extensive than the palaeovalley aquifers, even though they have a lower holding capacity per unit area.

Modern recharge rates to palaeochannel aquifers across Australia are typically low and involve a complex variety of sources. Recharge is usually dominated by slow vertical and lateral leakage from surrounding saturated weathered bedrock, and the overlying confining layer.

The palaeotributary is incised into weathered ultramafics of the Archean Lake Johnston greenstone belt. Drilling has indicated additional permeability in this underlying unit (in MWH003), which represents secondary permeability from chemical dissolution during weathering. The palaeochannel sand aquifer and the underlying weathered basement are likely to be in hydraulic connection, evidenced by the similar groundwater chemistry in both these units (Table 9).

In the western portion of the tenements, away from the palaeochannel, groundwater occurrences in the fresh bedrock are associated with discrete interconnected fractures. The fracturing is characterised by secondary permeability resulting from tectonic and decompression fracturing enhanced by chemical dissolution. Drilling has indicated modest yields from two drill-holes intercepting fractured bedrock aquifers (MWH009 and MWH012), which is consistent with other fractured bedrock aquifers in the Lake Johnston area. However, as a result of their discrete nature (i.e. having low storage characteristics), bedrock aquifers can dewater rapidly, and consequently are not always reliable as a long term water supply. Permeability in the bedrock away from these features is low, with low storage characteristics as evidenced by drill-holes MWH002, MWH010 and MWH011 which reported yields of less than 0.1 L/s.

The orientation of the fractured bedrock aquifers intercepted in MWH009 and MWH012 are not clearly understood at this stage, and likely comprise numerous sets of interconnected, crosscutting structures. The primary orientation, as evidenced by the magnetic surveys (Appendix D) is north-west to south-east, which is consistent with the trend of the Lake Johnston greenstone belt.

The depth to groundwater in the fractured rock aquifer ranges from about 9 m below surface to over 66 m below surface, depending upon the surface topography. The groundwater flow direction is expected to be to the north-east, towards the palaeotributary. However, survey data for the recent drilling is not available to confirm this. The fractured rock aquifer is recharged by direct rainfall infiltration or by stream flow during episodic rainfall events. The groundwater salinity in the fractured rock aquifer ranges from 54,000 mg/L TDS in the Drillers Bore to 170,000 mg/L TDS in MWH009. The high variability in salinity is consistent with known regional conditions and is indicative of the complex nature of fracture rock environments.

The bedrock geology is overlain by Quaternary deposits comprising lacustrine deposits, aeolian deposits, alluvium, colluvium and laterite. These units are typically unsaturated within the project area, with the exception of the larger drainage lines and the small playa lake to the north of MWH003.

For the purposes of groundwater flow modelling (discussed in the next section), the conceptual model for the area recognises six distinct hydrogeological units as shown schematically in Figure 9, which are described below:

- Hydrogeological Unit (HU) 1 comprises the surficial deposits which may extend below the water table. These sediments are restricted to the larger of the modern drainage lines and the playa lakes. The HU1 comprises a combination of mixed alluvium, and provides zones of recharge to the broader groundwater environment.
- HU2 comprises the low permeability clayey sequence that forms the broader shallow groundwater environment across the palaeovalley (the Perkolilli Shale). The HU2 has a saturated thickness of about 16 m in MWH003. Hydraulic test data indicates a hydraulic conductivity in the HU2 of 0.001 m/d. However, this value should be validated with further testing. The HU2 has low permeability and generally forms an aquitard. The unit is recharged via leakage from the HU1, and potentially also the fractured bedrock (HU5) in localised areas where the two units are in contact.
- HU3 comprises the sand aquifer at the base of the palaeochannel, the Wollubar Sandstone. The unit comprises medium grained sand with minor basal gravel. The aquifer is 10 m thick in the vicinity of MWH003 and 150 m wide. The HU3 has a modest permeability and modest aquifer storage. Recharge to the aquifer is primarily via adjacent fractured rock (HU5) in contact with the sand, with limited recharge via leakage from the overlying HU2.
- HU4 comprises the weathered bedrock beneath the sand aquifer. The HU4 is in hydraulic connection to the HU3, and recharged via adjacent fractured bedrock (HU5).

- HU5 comprises the fractured bedrock aquifers, with modest permeability but low aquifer storage. The HU5 is recharged predominantly by other similar structures and ultimately by the HU1 or direct rainfall recharge .
- HU6 comprises the bedrock, away from the HU5 fracture zones. This unit is characterised by intact crystalline bedrock, with minor intermittent fracturing. The unit is considered an aquitard, with low permeability and low aquifer storage.

4.2.2 Groundwater Flow Model

A numerical groundwater flow model was developed for the palaeochannel and surrounding bedrock environment, based on the conceptual model described above.

The model was developed to provide a preliminary assessment of drawdown impacts associated with groundwater abstraction from four proposed production bores (Figure 10), namely:

- MWB01, installed into the Wollubar Sandstone and underlying weathered basement, adjacent to exploration drill-hole MWH003.
- MWB02, installed into the Wollubar Sandstone and underlying weathered basement, located 1 km north of MWH003.
- MWB03, installed into the fractured bedrock aquifer, adjacent to exploration drill-hole MWH012.
- MWB04, installed into the fractured bedrock aquifer, adjacent to exploration drill-hole MWH009.

The model was developed using the pre- and post-processor PMWIN and the MODFLOW finite difference code. The model consists of four layers (L1 to L4), 363 rows and 307 columns; and covers an area of approximately 80 km^2. Model cell sizes range from 10 m by 10 m in the area of the bores, to 500 m by 500 m along the margins of the model.

The model layers represent the following hydrogeological units:

- L1 comprises the Perkolilli Shale in the palaeochannel (HU2), two fractured bedrock zones (HU5s) oriented in a north-west to south-east direction intercepting the two proposed fractured rock bores, and the intact bedrock (HU6) in the remainder of the model domain.
- L2 represents the Wollubar Sandstone in the palaeochannel (HU3), two fractured bedrock zones (HU5s) oriented in a north-west to south-east direction intercepting the two proposed fractured rock bores, and the intact bedrock (HU6) in the remainder of the model domain.
- L3 represents the weathered bedrock beneath the palaeochannel (HU4), two fractured bedrock zones (HU5s) oriented in a north-west to south-east direction intercepting the two proposed fractured rock bores, and the intact bedrock (HU6) in the remainder of the model domain.
- L4 represents the two fractured bedrock zones (HU5s) oriented in a north-west to south-east direction intercepting the two proposed fractured rock bores, and the intact bedrock (HU6) in the remainder of the model domain.

The model layers are flat and horizontal. The top of the L1 was set to zero, the top of L2 was set at 17 m below surface, the top of L3 set to 34 m and the top of L4 set to 44 m. The layer thicknesses corresponded to the lithological contacts observed in MWH003. The base of the model was set at 100 m below surface and the static water level was set at 6 m below surface. The model boundary cells were defined as no-flow boundaries.

The values for hydraulic conductivity used in the model for the Perkolilli Shale were based on the hydraulic test data. The remaining values adopted in the model were based on published values (Kruseman and de Ridder 1994) and experience with other palaeochannel modelling studies in Western Australia. The values are considered preliminary and will require revising once further hydrogeological studies are undertaken for the project.

The parameters used in the model are presented in Table 10 below. The HU1 (surficial deposits) has been excluded from the modelling at this stage. This unit may be included in subsequent modelling revisions, if consideration of rainfall recharge to the model is deemed necessary.

Table 10: Adopted Aquifer Parameter Values

Hydrogeological Unit	**Kh (m/d)**	**Kv (m/d)**	**Sy (m-1)**	**Ss**
HU1	tba	tba	tba	tba
HU2	0.001	0.0001	0.03	0.0001
HU3	2	1	0.2	0.0001
HU4	1	0.1	0.05	0.0001
HU5	5	5	0.05	0.0001
HU6	0.001	0.001	0.01	0.0001

Groundwater abstraction was simulated using MODFLOW’s well package. The well package applies a groundwater abstraction rate corresponding to the cell and layer within which the production bores are located, i.e. abstraction from the palaeochannel bores were assigned to L2 and the fractured rock bores assigned to L4. The borefield demand was based on a preliminary rate of 4 L/s for each of MWB01 and MWB02 and 8.5 L/s for each of MWB03 and MWB04, operating continuously for 13 years.

An unconfined model layer type was specified for L1 and unconfined/confined layer type for all subsequent layers. All layers were set to calculate transmissivity and storativity.

4.3 Modelling Results

The preliminary modelling results are presented as drawdown contours in L1 at the end of the 13 year mine life in Figure 10. The modelling results indicate:

- Abstraction from the bores results in groundwater drawdown extending linearly along the higher permeability feature (i.e. along the palaeochannel or along the fracture orientation).

- There is limited drawdown extending laterally into the adjacent low permeability intact bedrock.
- The overlying Perkolilli Shale will likely act as a semi confining layer, limiting leakage to the underlying Wollubar Sandstone aquifer and resulting in limited drawdown in the shallow groundwater system.
- At the end of the 13 year simulation, drawdown along the palaeochannel is less than 2 m at the southern extent of the palaeochannel (south east from MWB01) and less than 1 m across the remainder of the palaeochannel. The drawdown is limited in the palaeochannel due to the overlying semi-confining clay layer. Drawdown in more pronounced in the fractured bedrock with the 1 m drawdown contour extending approximately 2 km along strike from the fractured rock bores.

It must be understood that the modelling is considered preliminary, and will require revision once the bores are installed and further test data becomes available.

4.4 Groundwater Licensing Implications

As discussed in Section 2.6, the project is located with an unproclaimed groundwater area and, in accordance with the Rights in Water and Irrigation Act (1914), is not subject to groundwater licensing unless abstraction is from a confined (artesian) or semi-confined aquifer. This applies to both CAW licences, as well as long term operational GWLs.

The results of the exploration drilling indicate that the palaeochannel is likely to be semi-confined, although test pumping will be necessary to confirm this. Therefore Audalia will be required to submit an application to DWER for a CAW prior to the installation and test pumping of the proposed palaeochannel bores (MWB001 and MWB002). A CAW is not expected to be required for the fractured rock bores.

A GWL may also be required for the long-term operation of the palaeochannel bores. However, this will be assessed by DWER based on the results of the test pumping.

4.5 Groundwater Monitoring

A groundwater monitoring programme will be required to monitoring the response to groundwater drawdown associated with the water supply bores.

The water supply bores will need to be fitted with flow meters to record cumulative abstraction rates and dip tubes to measure the water level within the bores.

A shallow and deep monitoring bore should be installed adjacent to (i.e. within 10 to 20 m of) the palaeochannel bores, and a single monitoring bore adjacent to (i.e. within 10 to 20 m of) the fractured rock bores. Additional monitoring bores may be required for environmental purposes.

The proposed monitoring schedule is provided below:

- Monthly abstraction rates from the water supply bores.
- Monthly water level measurement from the water supply bores.
- Monthly water level measurement from the monitoring bores.

- Quarterly field parameters (pH, EC, temperature) from the water supply bores.
- Annual laboratory analysis (major component analysis) from the water supply bores.

4.6 Assessment of Impacts

Abstraction from the proposed water supply bores will result in localised groundwater drawdown in proximity to the bore.

The risk of environmental impact to other groundwater users, the groundwater environment and the GDE's as a result of groundwater abstraction from the proposed water supply bores is considered low, given that:

- The drawdown around the bores will be localised, perhaps in the order of 1.5 km from the bores.
- The nearest licenced groundwater user is 35 km from the project (Poseidon Nickel).
- The nearest registered bore is 37 km from the project.
- The groundwater is hypersaline, and of limited use, other than for mining and industrial purposes.
- The groundwater level, as measured during the field investigations, is at least 6 m below ground level in the area of the palaeochannel and over 50 m below ground level in the elevated areas.

A rare flora (*Marianthus aquilonaris*) has been identified in the project area, which potentially relies on soil moisture. However, from investigations undertaken to date on these plant communities the *Marianthus* plants are unlikely to have direct interaction with the regional groundwater table, and groundwater drawdown associated with the proposed water supply bores is unlikely to impact the plants. This is discussed in more detail in a separate report on the Marianthus habitat (GRM, 2019).

5.0 SUMMARY AND CONCLUSIONS

Audalia Resources Limited (Audalia) is proposing to develop their Medcalf Vanadium Project, located in the Bremer Range, near Lake Johnston, approximately 100 km west of Norseman. The project will comprise three open pits (Egmont, Vesuvius and Fuji) mined over a period of seven years, a processing plant, tailings storage facility, waste dump, workshops and an accommodation village. The three pits will be developed to a maximum depth of around 50 m below surface. The pits are not expected to extend below the water table and should not require mine dewatering. However provision for the removal of rainfall runoff to the pits will be necessary following high rainfall events.

Audalia has indicated that the project requires approximately 0.8 GL per annum (25 L/s) of groundwater for the purposes of beneficiation, dust suppression and camp supplies (via reverse osmosis treatment). It is understood that there is no constraint on water quality for the process and dust suppression demand. However, lower salinity is preferred to reduce the corrosive impacts to infrastructure.

Audalia engaged GRM to undertake a water supply investigation to assess the potential water supply options within tenements M63/656, E63/1133 and E63/1134. The aim of the investigation was to progress towards addressing the key areas identified in the EPA Scoping Document.

The results of the water supply investigation can be summarised as follows:

- Twenty nine exploration drilling targets were identified within the tenements. The targets comprised 15 potential fractured rock locations identified by geophysical (magnetic and ERI) surveying, 10 palaeochannel locations targeting the southern extent of a palaeotributary to the extensive Lefroy palaeodrainage system, and four fractured rock locations surrounding the existing Driller's Bore.
- A groundwater exploration drilling programme was undertaken during September and October 2019, which included drilling 14 of the 29 proposed targets. The exploration drilling identified two potential fractured rock water supply bore locations (with yields of 10 and 14 L/s) and one palaeochannel bore location (with reported yields of 4 to 5 L/s).
- The palaeochannel aquifer comprises a medium grained sand unit, which was 10 m thick and at least 150 m wide, overlain by a 16 m thick clay sequence. Hydraulic testing of the clay indicated a hydraulic conductivity of 0.001 m/d.
- The fractured rock aquifers comprised multiple zones of fracturing within ultramafic and granodiorite sequences.
- Nine monitoring bores were installed across the palaeochannel and fractured rock groundwater environments to facilitate groundwater level measurements and stygofauna sampling.
- Laboratory analysis indicates that the fractured rock aquifer is hypersaline and variable, ranging from 54,000 to 170,000 mg/L TDS with a circum neutral pH. The palaeochannel aquifer is hypersaline (76,000 mg/L TDS) and acidic (pH 3.7).
- Upon completion of the drilling a gravity survey was undertaken to delineate the palaeochannel aquifer. The results of the survey suggest that the palaeochannel extends in a north north-westerly direction, which is consistent with known regional conditions.
- The results of the field investigations indicate that the project water demand of 0.8 GL per annum (25 L/s) could potentially be met by a combination of fractured rock and palaeochannel bores, assuming the acidic groundwater in the palaeochannel aquifer is

acceptable. The exploration yields were higher in the two fractured rock bores, yet the palaeochannel bores are likely to be more reliable in the longer term, as fractured rock aquifers commonly have low storage and yields can diminish with time.

- Further assessment (i.e. review of the gravity survey data, additional aircore exploration drilling in the palaeochannel, installation of production bores and test pumping of production bores) would be necessary to determine the long term yields and required borefield configuration necessary for the project. However, potentially two fractured rock bores (at MWH009 and MWH012) and two palaeochannel bores (at MWH003 and approximately 1 km further north, along the palaeochannel) could provide sufficient supply for the project, based on an assumed abstraction rate of 8 to 12 L/s per fractured rock bores and 5 to 10 L/s per palaeochannel bores.
- A conceptual model for the project was developed, based on the investigation results. The project area is located on the western flank of a northerly draining palaeotributary of the regionally extensive Lefroy Palaeodrainage system. The sand aquifer within the palaeochannel represents the regionally extensive Tertiary Wollubar Sandstone and the overlying clayey sequence represents the Oligo-Miocene Perkolilli Shale. The Perlolilli Shale most likely acts as a semi-confining layer to the underlying Wollubar Sandstone. The palaeochannel is incised into weathered ultramafics of the Archean Lake Johnston greenstone belt, with drilling indicating additional permeability in this weathered unit. In the western portion of the tenements, away from the palaeochannel, groundwater occurrences in the fresh bedrock are associated with discrete interconnected fractures with modest yields, but storage is likely to be limited. The orientation of the fractured bedrock aquifers are not clearly understood at this stage, and likely comprise numerous sets of interconnected, crosscutting structures. The primary orientation of structures is likely to be to the north-west, consistent with the trend of the Lake Johnston greenstone belt. Permeability in the bedrock away from these features is low, with low storage characteristics.
- A preliminary groundwater flow model was developed for the palaeochannel and surrounding bedrock environment, based on the conceptual model described above. However, it must be understood that in the absence of test pumping data, the modelling is considered generic and will require revision once the production bores are installed and tested. The modelling indicates:
  - Abstraction from the bores will result in groundwater drawdown extending linearly along the higher permeability feature (i.e. along the palaeochannel or along the fracture orientation).
  - There will be limited drawdown extending laterally into the adjacent low permeability intact bedrock.
  - The overlying Perkolilli Shale will likely act as a semi confining layer, limiting leakage to the underlying Wollubar Sandstone aquifer and resulting in minimal drawdown response in the shallow groundwater system.
  - At the end of the 13 year simulation the 1 m drawdown contour extends approximately 2 km along strike from the fractured rock bores.
- The project is located with an unproclaimed groundwater area and, in accordance with the Rights in Water and Irrigation Act (1914), is not subject to groundwater licensing unless abstraction is from a confined (artesian) or semi-confined aquifer. Whilst a CAW was not required for the exploration drilling, the results indicate that the palaeochannel is likely to

be semi-confined, and Audalia will be required to submit an application to DWER for a CAW prior to the installation and test pumping of the proposed palaeochannel bores. A GWL may also be required for the long-term operation of the bores. However, this will be assessed by DWER based on the results of the test pumping.

- A groundwater monitoring programme has been proposed which includes the installation of shallow and deep monitoring bores adjacent to each palaeochannel bore and a single monitoring bore adjacent to each fractured rock bore. The proposed monitoring comprises monthly abstraction volumes from the water supply bores, monthly water level measurements in all water supply bores and monitoring bores, quarterly field parameter measurements from the water supply bores, and annual laboratory analysis from the water supply bores.
- The risk of environmental impact to other groundwater users, the groundwater environment and the GDE's as a result of groundwater abstraction from the water supply bores is considered low, given that the investigations conducted to date suggest that:
  - The drawdown around the bores will be localised, perhaps in the order of up to 1.5 km from the bores.
  - The nearest licenced groundwater user is 35 km from the project (Poseidon Nickel).
  - The nearest registered bore is 37 km from the project.
  - The groundwater is hypersaline, and of limited use, other than for mining and industrial purposes.
  - The groundwater level, as measured during the field investigations, is at least 6 m below ground level in the area of the palaeochannel and over 50 m below ground level in the elevated areas.

Signatures

Groundwater Resource Management Pty Ltd

KmcDougall

Kathy McDougall

PRINCIPAL HYDROGEOLOGIST

Peter Mayers

PRINCIPAL HYDROGEOLOGIST

Doc Ref: J1843R03_final

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Bell, J.G., Kilgour, P.L., English, P.M., Woodgate, M.F., Lewis, S.J. and Wischusen, J.D.H. (compilers), 2012 WASANT Palaeovalley Map – Distribution of Palaeovalleys in Arid and Semi-Arid WA-SA-NT (First Edition), scale: 1:4,500,000. Geoscience Australia Thematic Map (Geocat No 73980)

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FIGURES

FIGURE 1
LOCATION PLAN

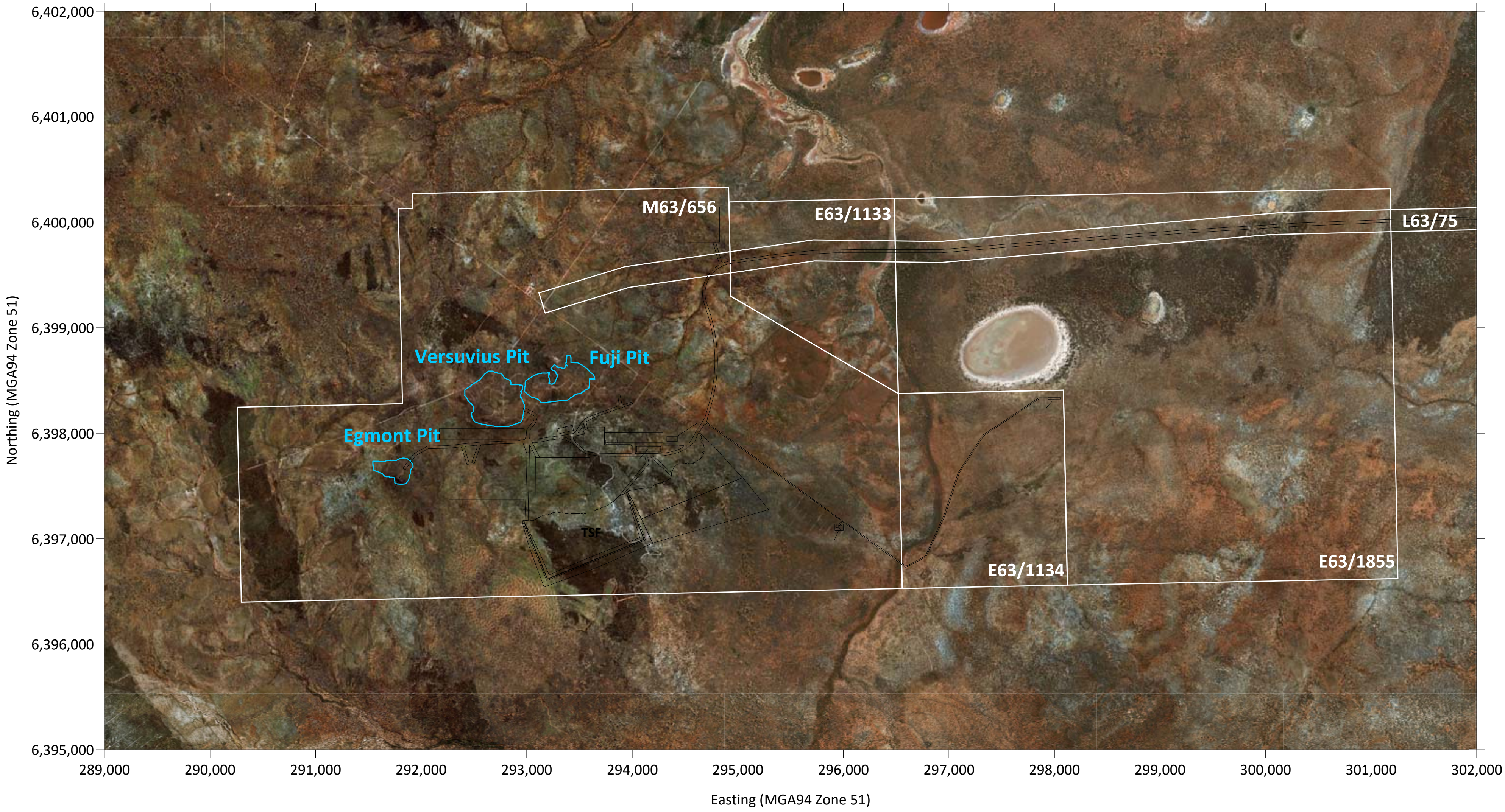
Date Nov 19
Client Audalia Resources
Project Medcalf Water Supply
Document J1843R03

Coordinate System

Notes

Data Sources

FILE://J1843 Audalia/figures/surfer/J1843R03/J1843R03 Fig1 loc plan.srf



GROUNDWATER
RESOURCE MANAGEMENT

FIGURE 2
SITE LOCATION PLAN

Date Nov 19

Client Audalia Resources

Project Medcalf Water Supply

Document J1834R03

Coordinate System
GDA94 Zone 51

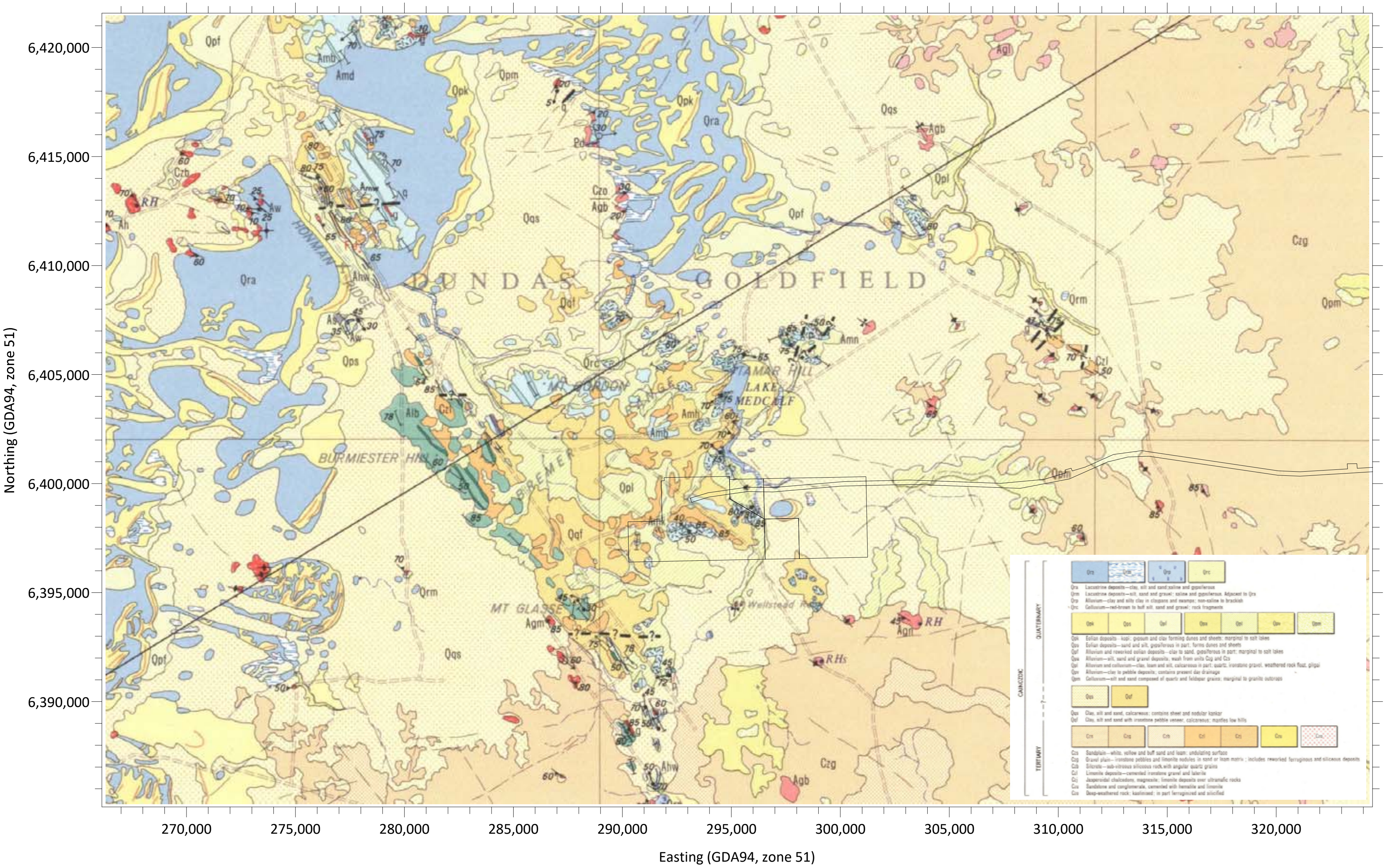
Notes

Data Sources
World Imagery

⬭ Proposed Pits

▭ Proposed Infrastructure

FILE://J1843 Audalia Medcalf/figures/surfer/J1843R03/J1843R03 Fig2 site plan.srf



GROUNDWATER
RESOURCE MANAGEMENT

FIGURE 3
GEOLOGY

Date Nov 19

Client Audalia Resources

Project Medcalf Water Supply

Document J1834R03

Coordinate System
GDA94 Zone 51

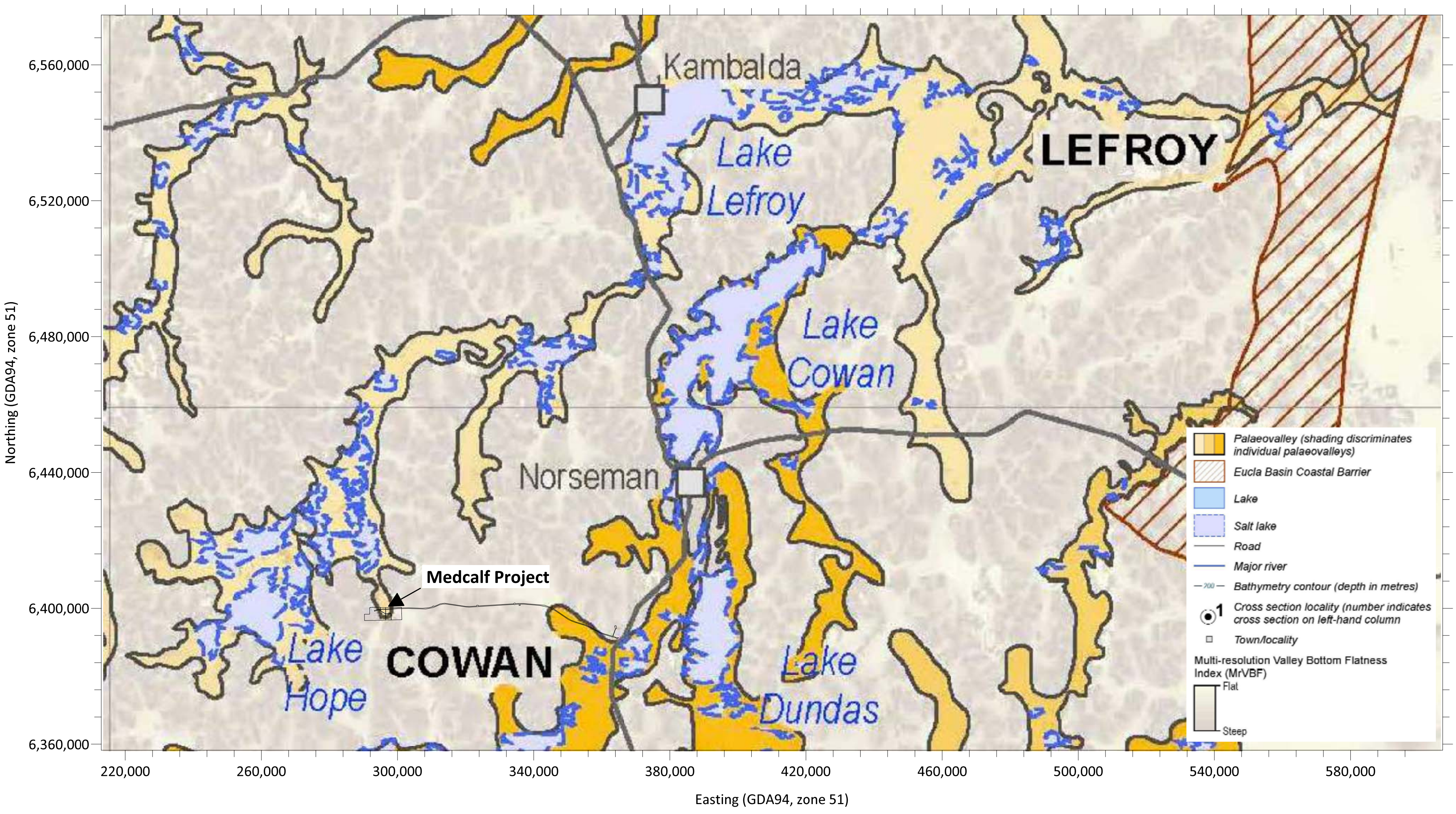
Notes

Data Sources
World Imagery
1:250 000 LAKE
JOHNSTON sheet

LEGEND

▭ Project Tenements

FILE://J1843 Audalia Medcalf/figures/surfer/J1843R03/J1843R03 Fig3 geology.srf



GROUNDWATER
RESOURCE MANAGEMENT

FIGURE 4
HYDROGEOLOGY

Date Nov 19
Client Audalia Resources
Project Medcalf Water Supply
Document J1834R03

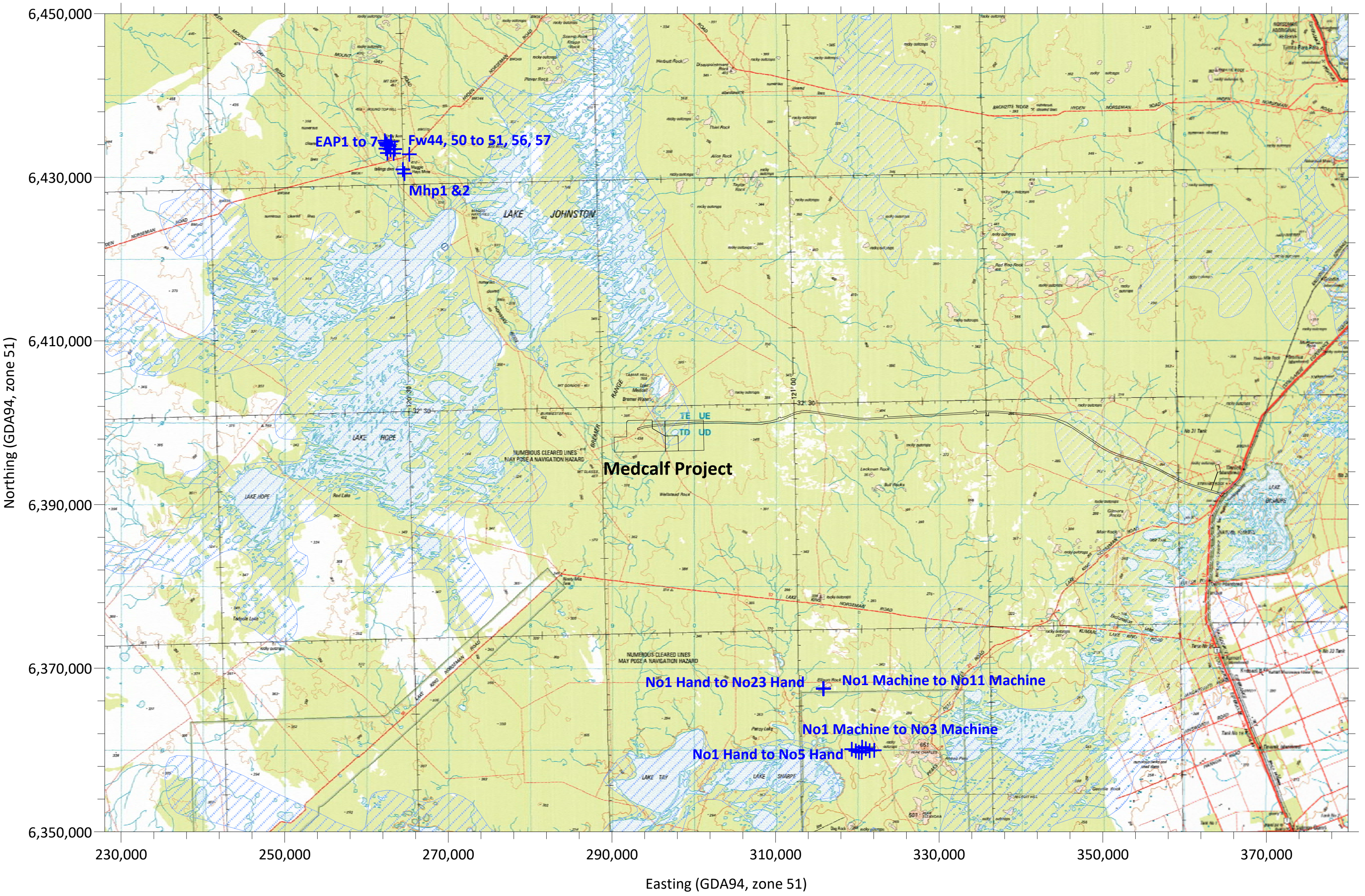
Coordinate System
GDA94 Zone 51
Notes

Data Sources
World Imagery
WASANT Palaeovalley Map

LEGEND

☐ Project Tenements

FILE://J1843 Audalia Medcalf/figures/surfer/J1843R03/J1843R03 Fig4 hydrogeology.srf



GROUNDWATER RESOURCE MANAGEMENT

FIGURE 5
OTHER
GROUNDWATER
USERS

Date Nov 19
Client Audalia Resources
Project Medcalf Water Supply
Document J1834R03

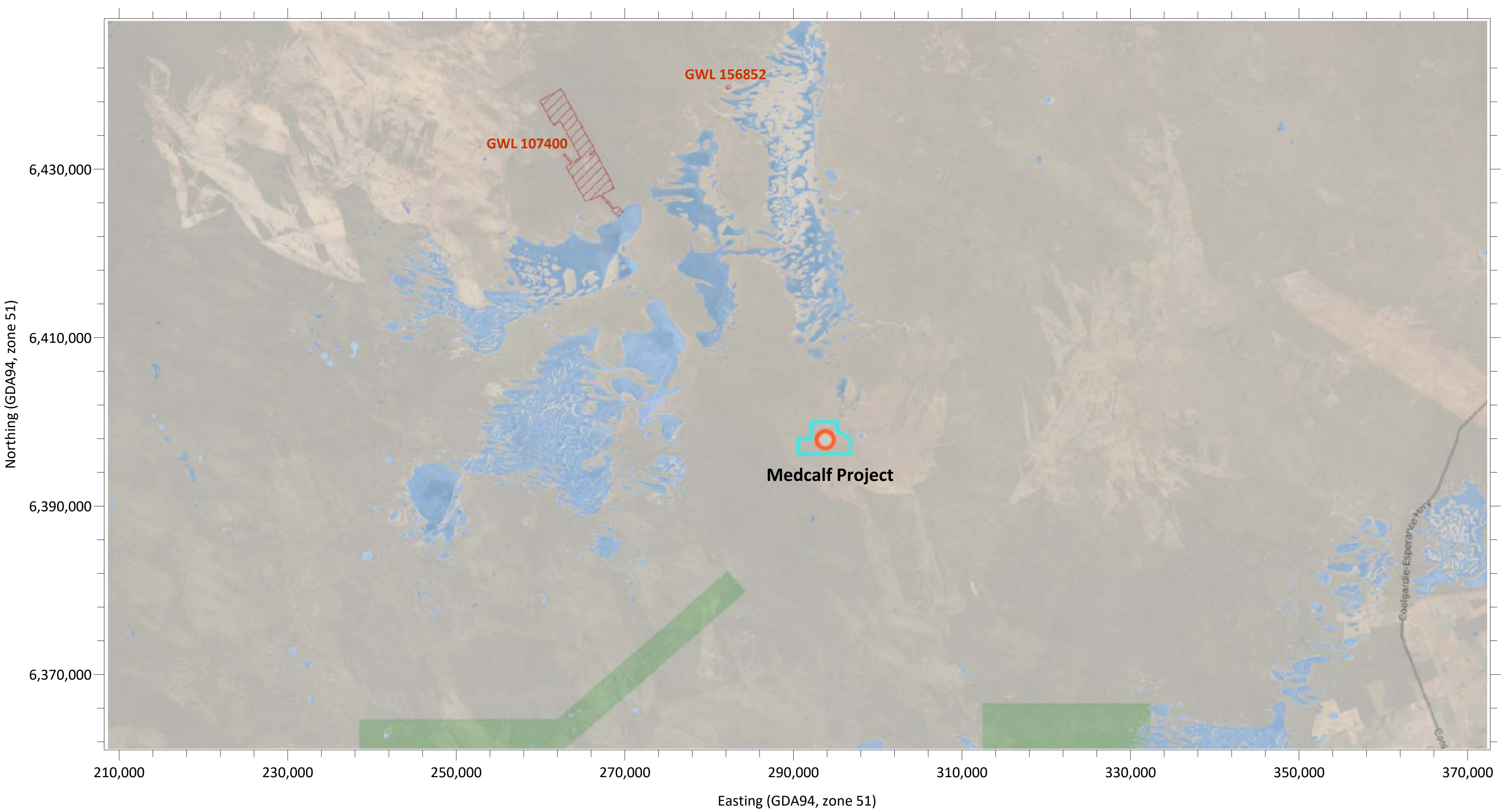
Coordinate System
GDA94 Zone 51
Notes

Data Sources
Lake Johnston topo
DWER WIR database
WASANT Palaeovalley
Map

LEGEND

☐	Project Tenements
+	WIR database bores
▨	Palaeovalleys

FILE://J1843 Audalia Medcalf/figures/surfer/J1843R03/J1843R03 Fig5 other groundwater users.srf



GROUNDWATER
RESOURCE MANAGEMENT

FIGURE 6
NEARBY GROUNDWATER LICENCES

Date Nov 19
Client Audalia Resources
Project Medcalf Water Supply
Document J1834R03

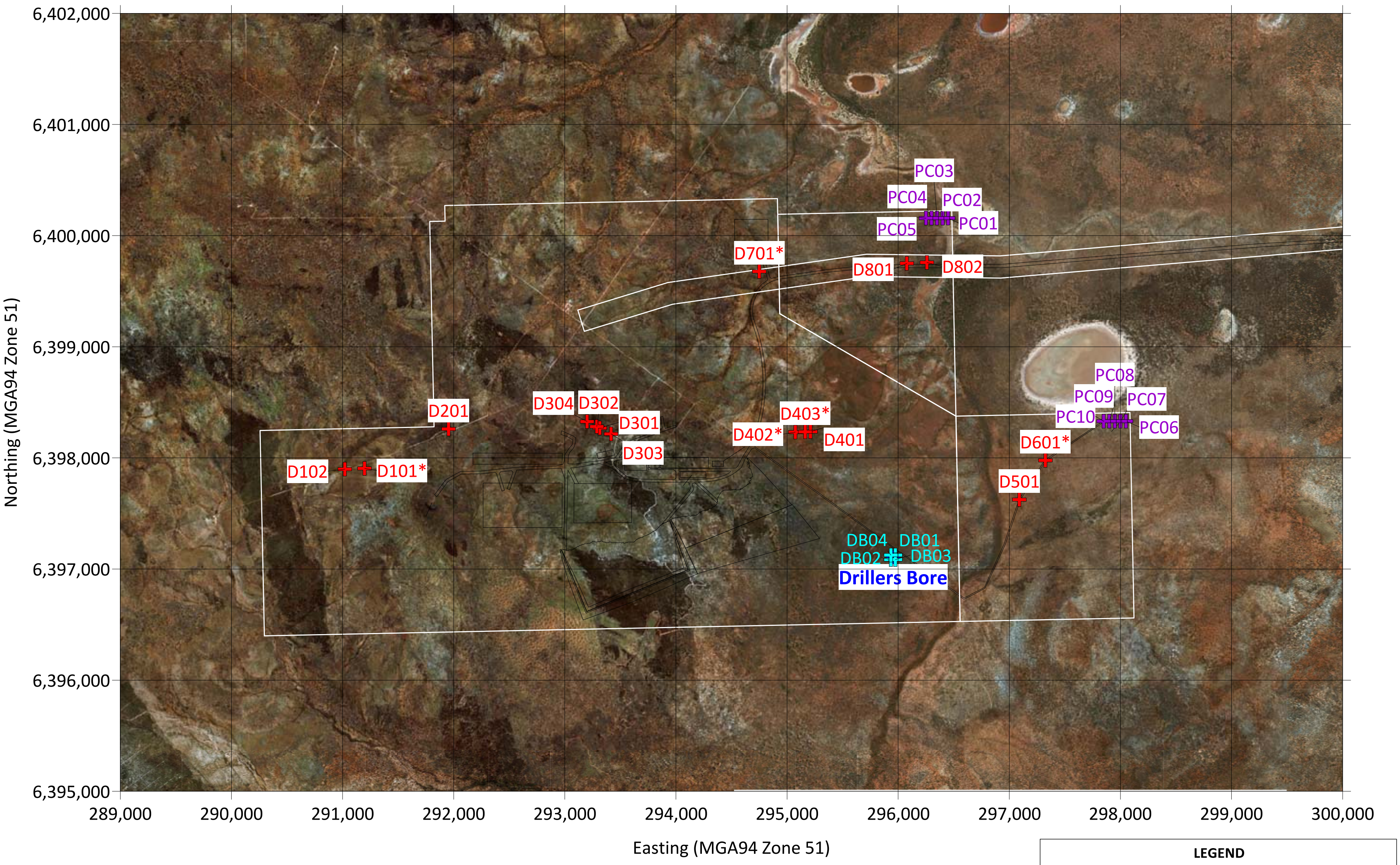
Coordinate System
GDA94 Zone 51
Notes

Data Sources
DWER Water Register

LEGEND

○ Project Tenemen M63/656
▨ Existing Groundwater Licences

FILE://J1843 Audalia Medcalf/figures/surfer/J1843R03/J1843R03 Fig6 nearby groundwater licences.srf



LEGEND

✚	ASST Targets
✚	Palaeochannel Targets
✚	Drillers Bore Targets

GROUNDWATER
RESOURCE MANAGEMENT

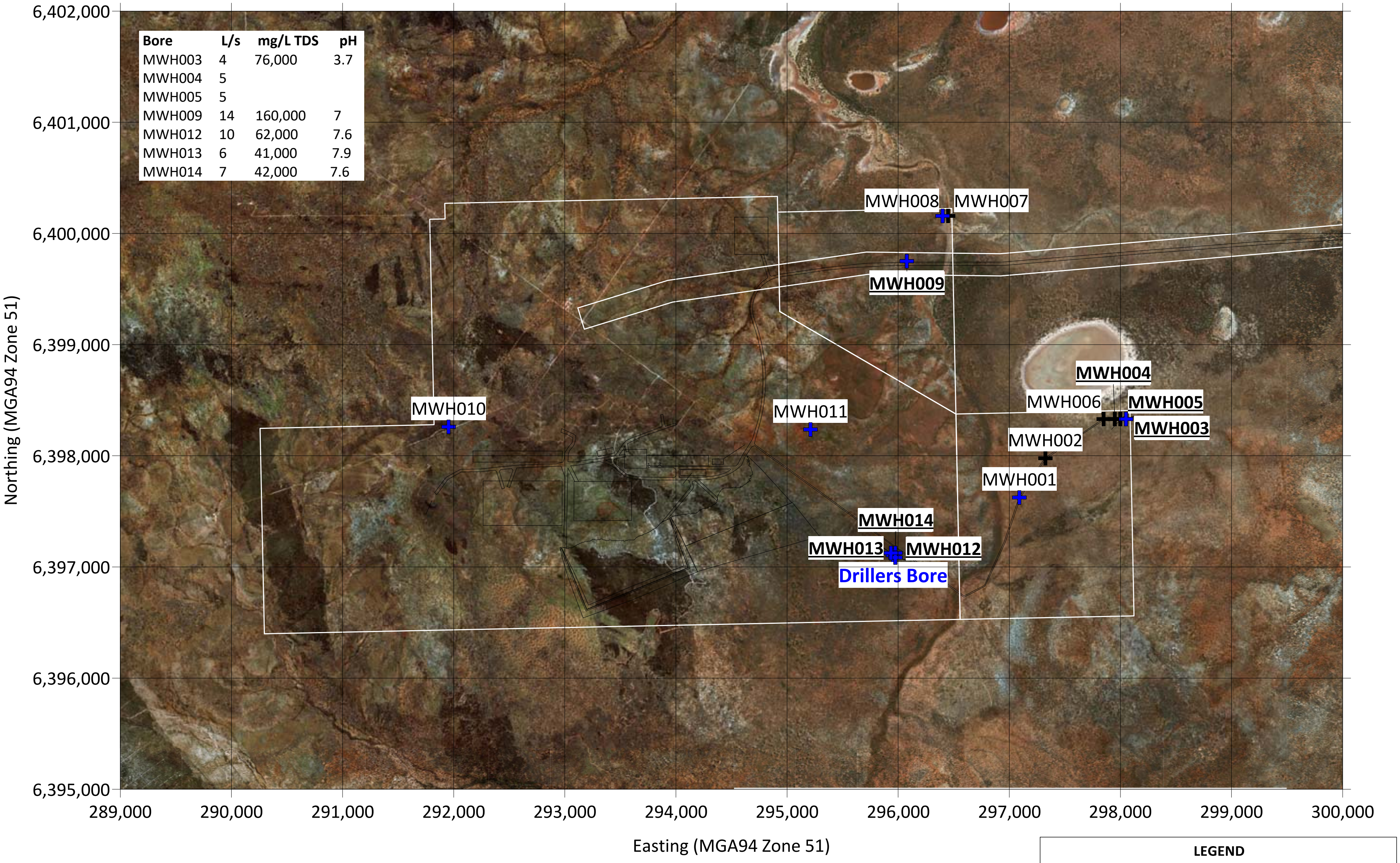
FIGURE 7
GROUNDWATER EXPLORATION TARGETS

Date Nov 19
Client Audalia Resources
Project Medcalf Water Supply
Document J1834R03

Coordinate System
GDA94 Zone 51
Notes

Data Sources

FILE://J1843 Audalia Medcalf/figures/surfer/J1843R03/J1843R03 Fig7 Drilling Targets.srf



Bore	L/s	mg/L TDS	pH
MWH003	4	76,000	3.7
MWH004	5		
MWH005	5		
MWH009	14	160,000	7
MWH012	10	62,000	7.6
MWH013	6	41,000	7.9
MWH014	7	42,000	7.6

LEGEND

✚ **MWH009**	Successful Targets Drilled
✚ MWH011	Unsuccessful Targets Drilled
✚	Monitoring Bores

GROUNDWATER RESOURCE MANAGEMENT

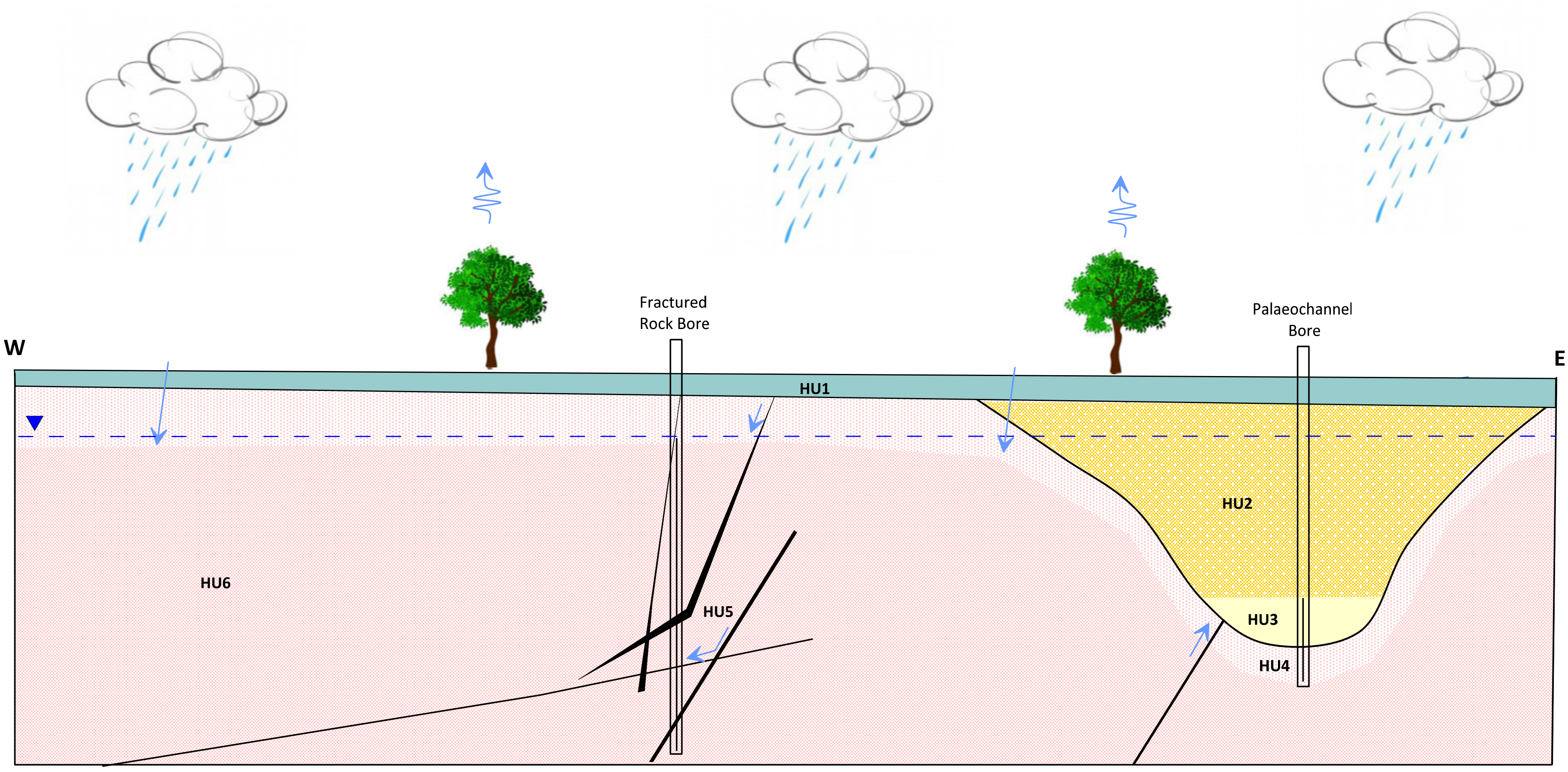
FIGURE 8
DRILLING RESULTS

Date Nov 19
Client Audalia Resources
Project Medcalf Water Supply
Document J1834R03

Coordinate System
GDA94 Zone 51
Notes

Data Sources

FILE://J1843 Audalia Medcalf/figures/surfer/J1843R03/J1843R03 Fig8 Drilling Results.srf



NOT TO SCALE

GROUNDWATER
RESOURCE MANAGEMENT

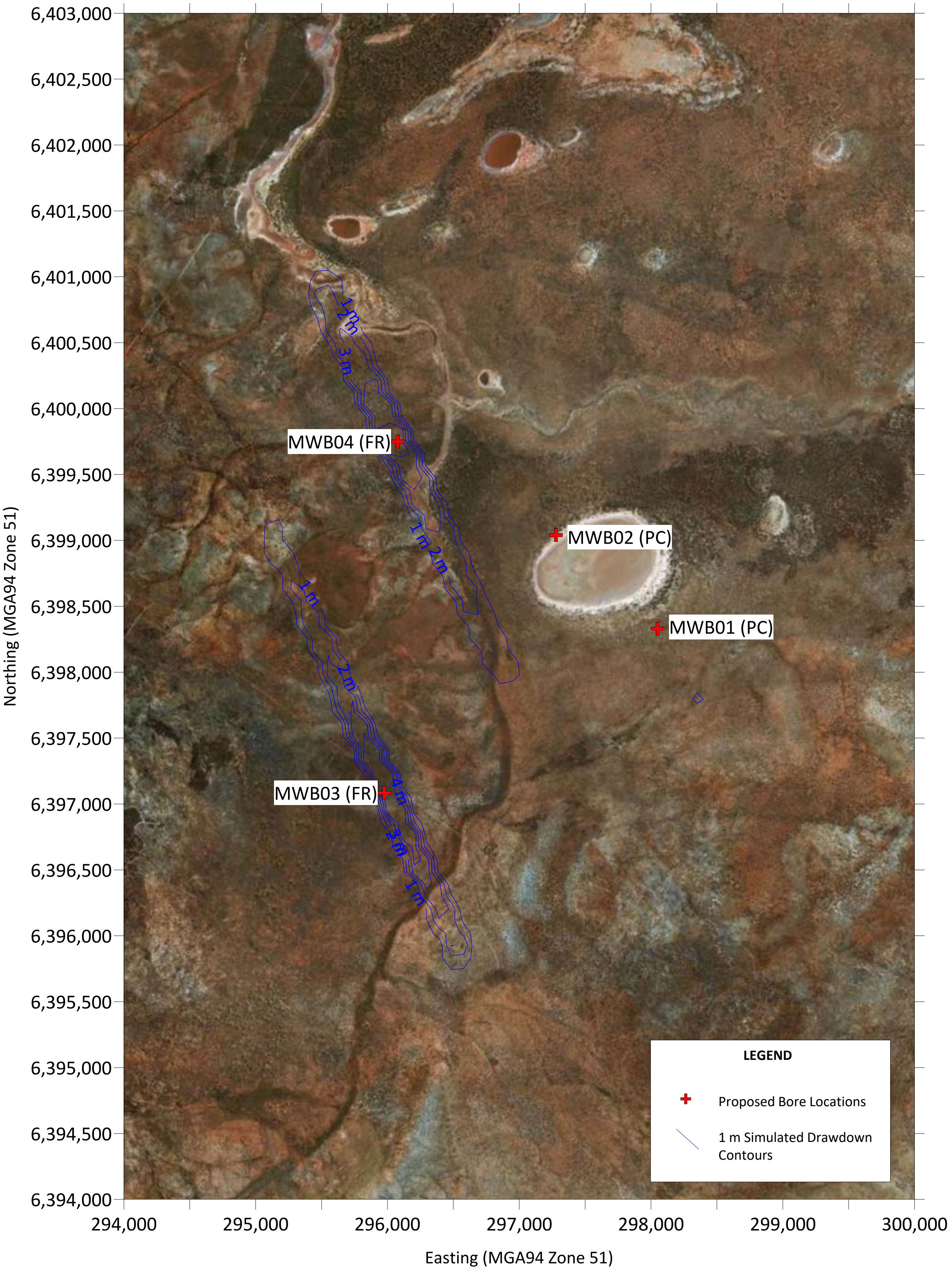
FIGURE 9
CONCEPTUAL MODEL

Date Nov 19
Client Audalia Resources
Project Medcalf Water Supply
Document J1834R03

Coordinate System
GDA94 Zone 51
Notes

Data Sources

FILE://J1843 Audalia Medcalf/figures/surfer/J1843R03/J1843R03 Fig9 conceptual model.srf



GROUNDWATER RESOURCE MANAGEMENT

FIGURE 10 MODELLING RESULTS LAYER 1 END OF 13 YR LOM

Date Nov 19
Client Audalia Resources
Project Medcalf Water Supply
Document J1843R03

Coordinate System
GDA94 Zone 51
Notes

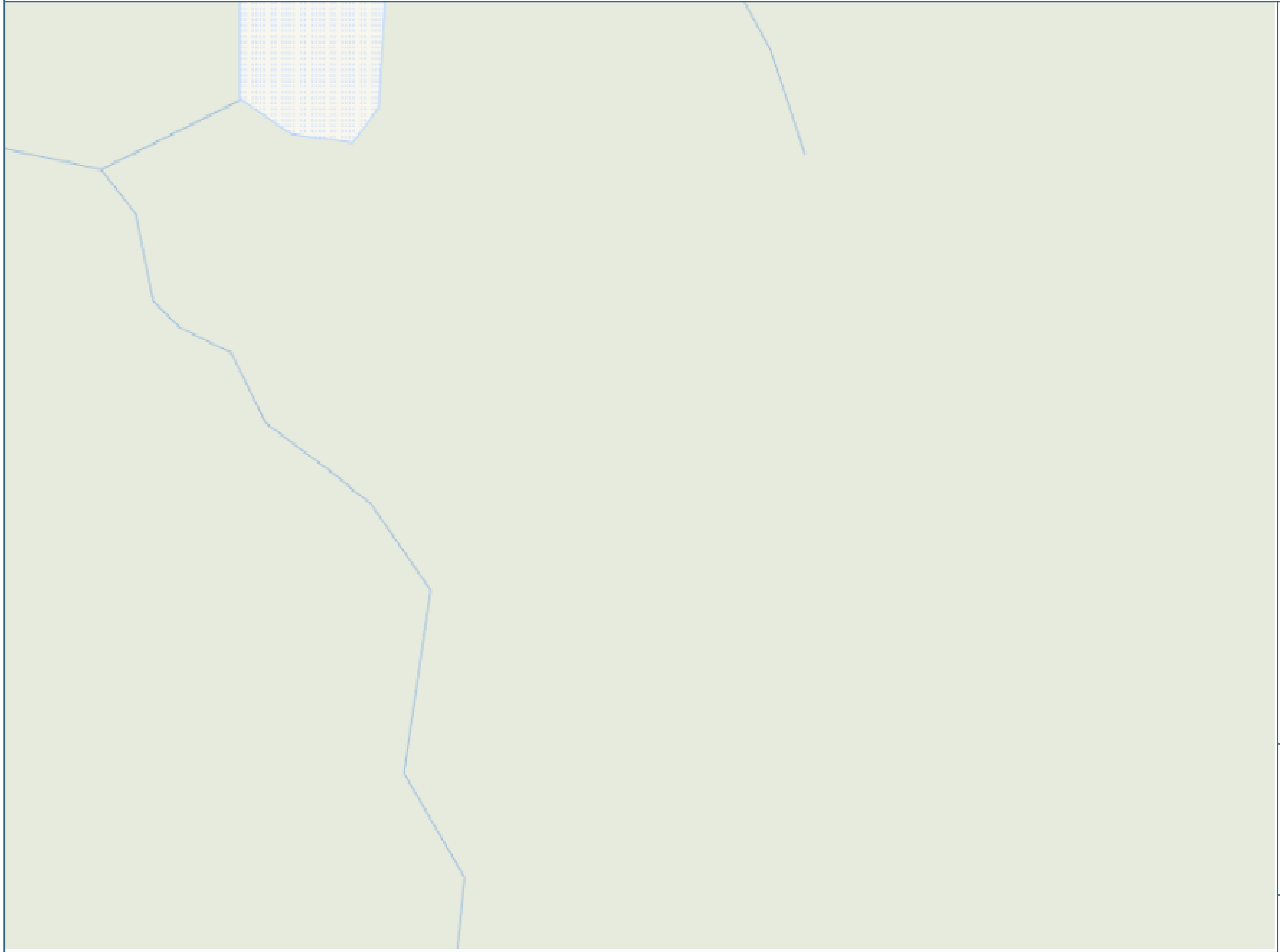
Data Sources
World Imagery
WASANT Palaeovalley Map

APPENDIX A

GDE ATLAS

Groundwater Dependent Ecosystems Atlas

25 km from Lake Medcalf



Aquatic GDE

- 🟪 Known GDE (regional study)
- 🟪 High potential GDE (regional study)
- 🟪 Moderate potential GDE (regional study)
- 🟪 Low potential GDE (regional study)
- 🟪 Unclassified potential G (regional study)
- 🟦 High potential GDE (national assessment)
- 🟦 Moderate potential GDE (national assessment)
- 🟦 Low potential GDE (national assessment)
- 🟦 Unclassified potential G (national assessment)

N

1:9,300

Kilometres 0.2 0.4

Data Source: Bureau of Meteorology, Geoscience Australia and State/Territory lead water agencies. Refer to metadata for further information: Click here

Australian Albers GDA94

Date: 7 November, 2019

Australian Government
Bureau of Meteorology

Groundwater Dependent Ecosystems Atlas

25 km from Lake Medcalf

Data Source: Bureau of Meteorology, Geoscience Australia and State/Territory lead water agencies. Refer to metadata for further information: Click here

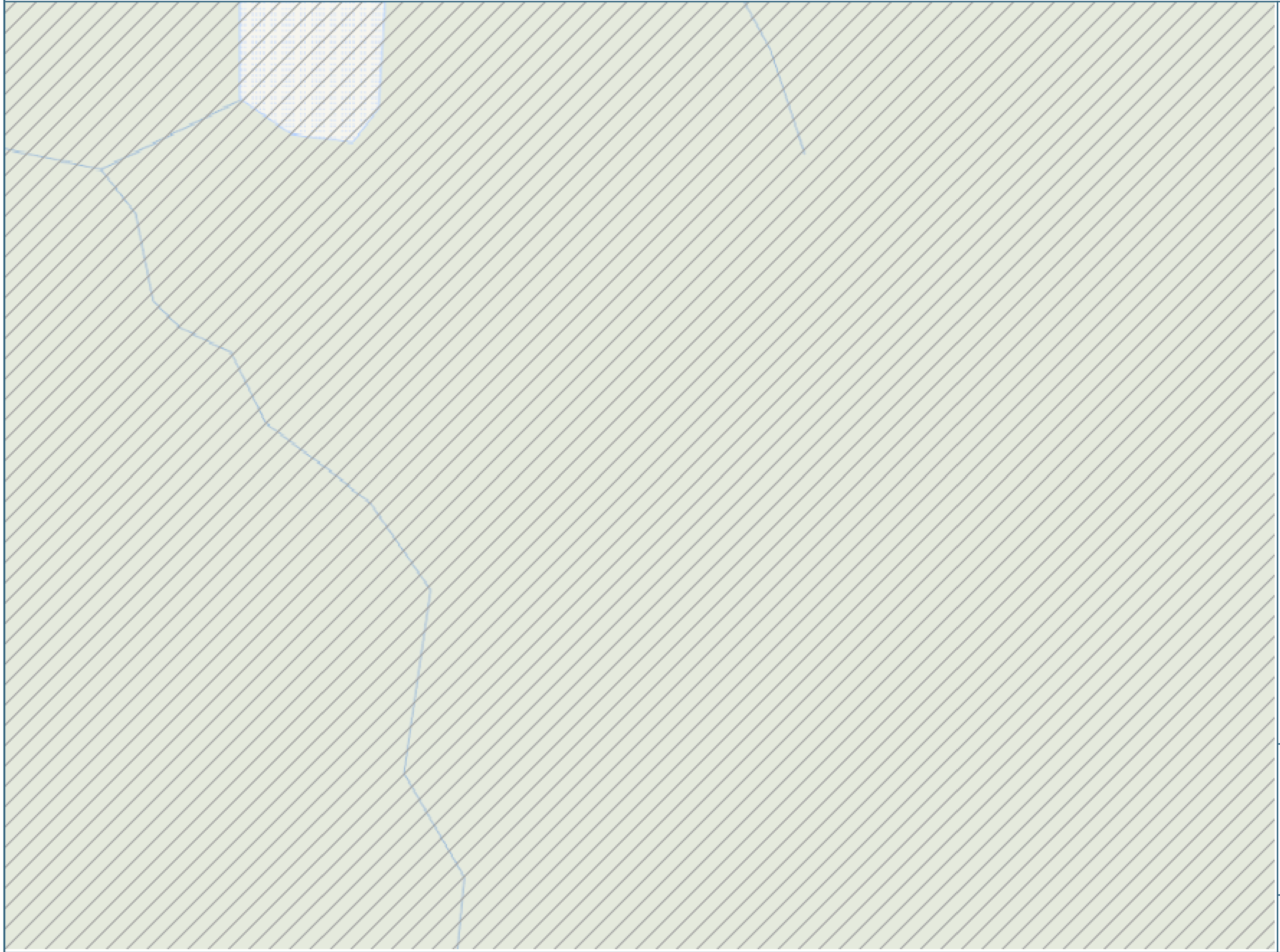
Australian Albers GDA94

Date: 7 November, 2019

Australian Government
Bureau of Meteorology

Groundwater Dependent Ecosystems Atlas

25 km from Lake Medcalf



Subterranean GDE

- 🟫 Known GDE (regional study)
- 🟫 High potential GDE (regional study)
- 🟫 Moderate potential GDE (regional study)
- 🟫 Low potential GDE (regional study)
- ⬜ Unclassified potential GI (regional study)

Subterranean GDE (no data)

- ▨ No ecosystems analyse

Data Source: Bureau of Meteorology, Geoscience Australia and State/Territory lead water agencies. Refer to metadata for further information: Click here

Australian Albers GDA94

Date: 7 November, 2019

DRILLER'S BORE DATA

TDW CONSULTANTS PTY LTD

Development Report

Location LAKE METCALF. Hole No KJC34 Site No________ Static Water Rest Level________ Pumping Level________

Jetting Pressure________ No of Nozzles ________ Diameter of Nozzles________ Jetting Head Dia_______

Screen Dia 4" PVC Screen/Slot interval 0 m to 42 m; ____m to ____ m

Development Technique - Airlifting☑ Airsurging☐ Airjetting☐ Waterjetting☐ Valve Surging☐ Backwashing☐ Pressure Induction☐ Chemical Injection☐ Solid Surging☐

Date	Duration	Method	Development Zone	Colour of Return Water	Estimated TDS	Flow Rate	Sand (1) Content	Time for Water to Clear	Wellclean (2)	Chlorine (2)	Comments
30/11/18.	hours		…m to …m		mg/l	l/Sec ~~m³/day~~		minutes	kg/m³	kg/m³	
〃	·15min	AirLift	42 mtrs	Brown / Heavy Sediment		~~V8~~ 1 ltr	10%	Remained			High Saline Water
〃	·30mins	〃				1 ltr/Sec		Dirty			to High to Read.
〃	45mins	〃				〃		↓			Hard to Accurately
〃	1 HR.	〃				〃					Record flows
〃	1·15	〃				〃		Good flow considering			Due to Casing
〃	1·30	〃				〃	Poor. Well Construction				Slotted to Top
											Losing Air Above
							Very Silty hole washing.				Water zone.
							Need Gravel Pack. etc.				
							Hole Still Recovery well After sizing				
							indicates Fractures Are Recovered.				

Contractor: Tim Westcott.

Drillers Name: Tim Westcott.

Notes: (1) Sand Content - ml sand in 20 litres bucket (2) Chemicals added

[Type here]

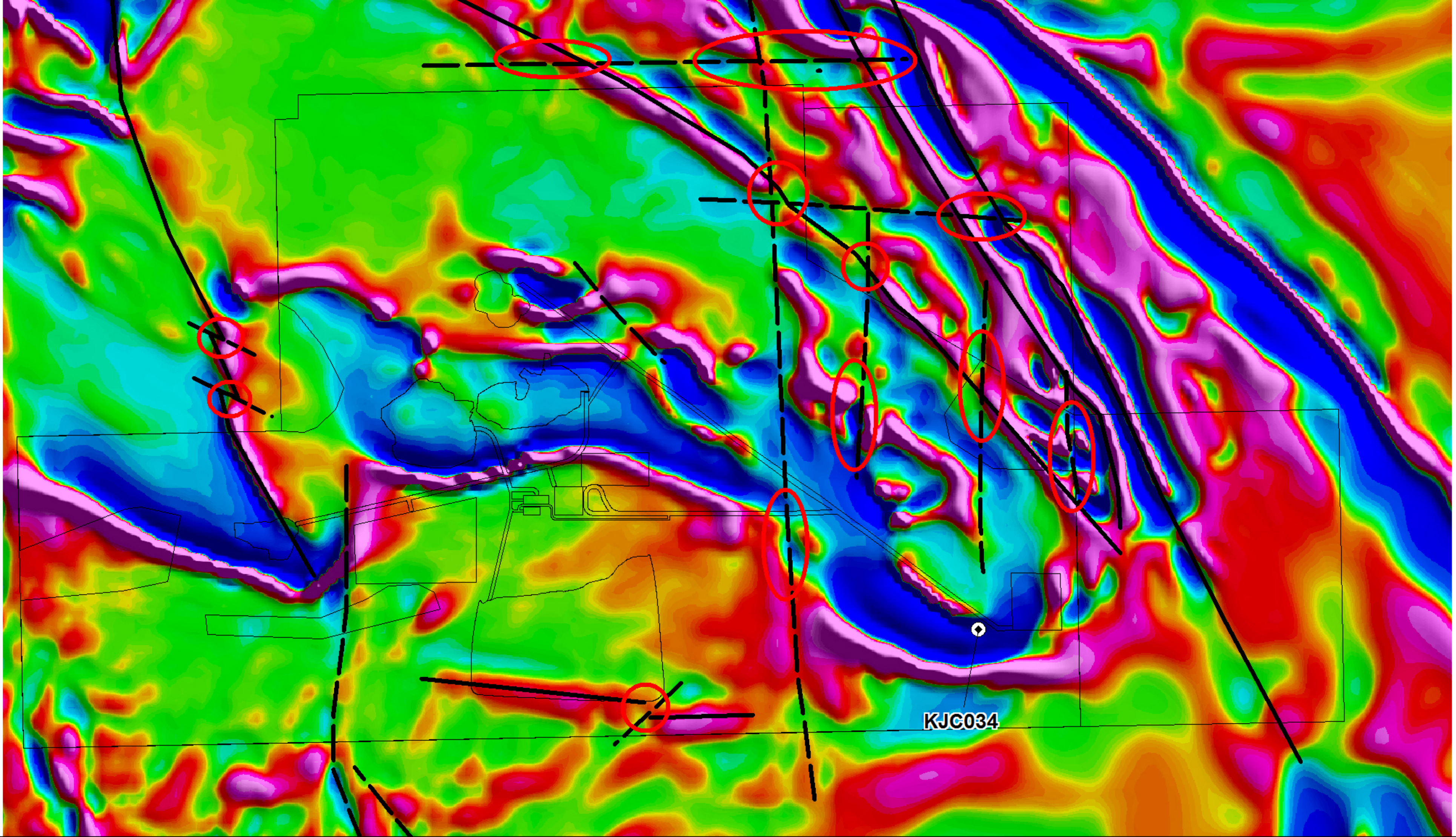
Discolouration at the end of development

Flow test

Silts and solids during airlifting

APPENDIX C

PRELIMINARY GEOPHYSICS


KJC034

APPENDIX D

GEOPHYSICS

Applied Scientific Services and Technology
ABN: 52 139 608 370
u6, 10 O'Connor Way, Wangara, Perth 6052, Western Australia ■ mobile: +61 (0)4 8850 0859 ■ office: +61 (0)8 6201 0715
email: riaan@asstgroup.com ■ skype: asstptyltd ■ www.asstgroup.com

FINAL REPORT ON THE RESULTS OF GEOPHYSICAL SURVEYS FOR AUDALIA RESOURCES, LAKE MEDCALF DSF, WA

A report for

Audalia Resources Limited

Att: Mr. Geoffrey Han

Level 1, Office F,

1139 Hay Street,

West Perth,

Western Australia 6005

Compiled by

Riaan Mouton

Principal Geophysicist

13 February 2019

Table of Contents

1. INTRODUCTION

ASST Pty Ltd (Australia) was contracted by Audalia Resources Limited (Audalia hereafter) to conduct geophysical investigations at their Lake Medcalf project in West Australia approximately 100km south-west of Norseman. Ground magnetic surveys took place between the 24th and 27th January 2019 over twelve (No 12) proposed sites for the drilling of water supply bores identified from airborne magnetic data. These were followed by ERI surveys between the 2nd and 7th February 2019 at eight (No 8) sites placed according to the ground magnetic data.

2. OBJECTIVES AND SCOPE OF WORK

The objective of the surveys was to delineate geological structures that can be targeted with drilling for groundwater extraction purposes. ASST aimed to achieve an investigation depth of approximately 40 m b.g.l.

3. COMPANY NAMES AND ROLES

Table 3-1 provides the list of the companies, their respective roles and the names of their on-site representatives.

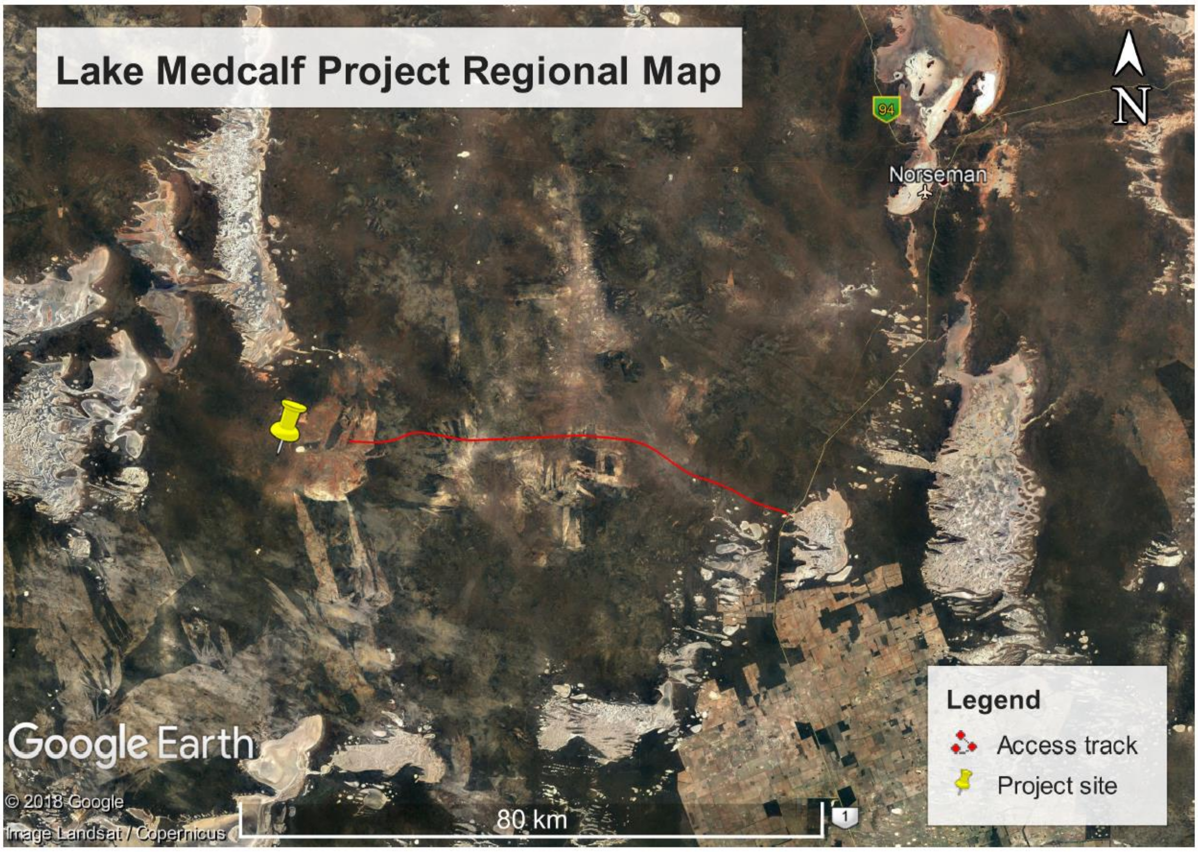
Table 3-1: List of company names, roles and names of on-site representatives.

Company	Role	Representative
Applied Scientific Services and Technology (Pty) Ltd	Geophysical contractor to Audalia	Mr. Riaan Mouton, Principal Geophysicist Mr. Kobus Raath, Principal Hydrogeologist Mr. Luke Cullen, Field Geophysicist
Groundwater Resource Management (Pty) Ltd	Hydrogeological contractor to Audalia	Mr. Kathy McDougall, Field Geophysicist
Audalia Resources Limited	Client	Mr. Geoffrey Han, Project Manager

4. LOCATION AND SITE PLAN

Figure 4-1 gives a regional perspective on the location of the project area. The aeromagnetic map of site, and survey lines for ground magnetics and ERI, are shown in Appendix B.

Figure 4-1: Regional location map of Audalia Resources' Lake Medcalf project



5. SURVEY PARAMETERS

The following section outlines the parameters used for subsurface imaging at site for both ground magnetic and electrical resistivity surveys. A brief explanation of survey methodology and background theory is given in Appendix A. All subsequent presentation of geophysical datasets was completed using the GDA94/MGA zone 51 coordinate system. The 2D ERI sections given in Appendix D are oriented to follow a W-E direction, with corresponding annotations denoted by 'SOL' and 'EOL' at the line start and end.

5.1 Ground Magnetics

ASST conducted ground magnetics using a Geometrics Proton Magnetometer with a base station to account for diurnal variation.

Table 5-1: Ground magnetic equipment and survey parameters.

Instrumentation	Geometrics Proton Magnetometer with base station
Line Spacing	~50m W-E direction
GPS positioning tolerance	2m horizontal / vertical

5.2 Electrical Resistivity

ERI surveys were conducted using an ABEM 12 channel Terrameter LS system with four (4) cables while utilising the roll-along method. Table 5-2 lists the ERI acquisition parameters used during the survey.

Table 5-2: ERI acquisition parameters.

Instrumentation	ABEM Terrameter LS 12 channel system
Survey Spread	Up to 21 × electrodes per cable at 5 m spacing 4 × 21 channel ERI cables with 5 m take-outs
Source	ABEM Terrameter LS with 12V external battery
Array	Dipole-Dipole

5.3 GPS Information

Electrode positions have been surveyed with a DGPS instrument. The GPS equipment used, and specifications are outlined in Table 5-3. The Australian Height Datum (AHD) was used for elevation purposes.

Table 5-3: GPS equipment and specifications

Instrumentation	DGPS - Navcom GNSS (StarFire)
Positioning tolerance setting	5 cm horizontal and vertical

6. RESULTS AND INTERPRETATION

6.1 Data Quality

Ground magnetic data is noisy, likely due to near surface magnetic material and /or noise cause by sensor motion with the crew having to zig-zag through dense vegetation. The data profiles for each survey line are shown in Appendix C displayed over the gridded magnetic data.

The overall quality of the ERI data is good despite highly resistive topsoil which can impede contact between electrodes and soil. Appendix C shows how ERI lines were chosen to cover anomalies of interest derived from the ground magnetic data and taking into consideration access. The data for each line shown as 2D apparent resistivity sections in Appendix D has been colour stretched and placed on a logarithmic scale of base 10 (e.g. a value of 3 on the colour scale gives a resistivity of 10^3 = 1,000 Ohm.m, a value of 4 on the colour scale gives a resistivity of 10^4 = 10,000 Ohm.m etc).

6.1.1 Resolution and Model Accuracy

Resolution for magnetic surveys depends largely on line spacing. Publicly available aeromagnetic data was acquired with lines spaced at 400 m, providing a low-resolution magnetic map for the area. This is considered low resolution data and ground surveying was conducted at 50 m spaced lines to improve the location accuracy of the lineaments targeted with the resistivity method.

For ERI it is important to emphasise that resolution falls off with increasing depth. This means that both lateral as well as vertical resolution will decrease with depth.

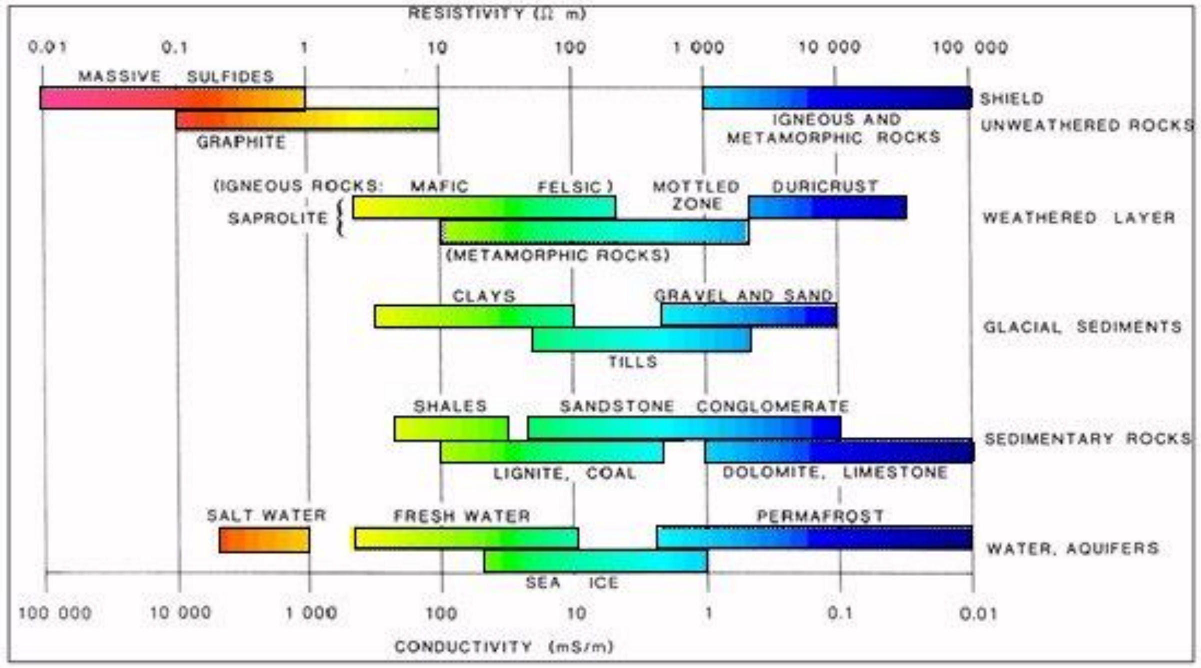
6.2 Data Interpretation

Aeromagnetic data for the tenements shown in Appendix B display linear features which have been interpreted as geological structures. From these lines, 11 investigation targets for ground surveying were identified and subsequently covered with ground magnetic surveys. The individual line profiles show poorly defined anomalies often near the structures identified from the aeromagnetics, best seen at location 1. This correlation supports the interpretation of the aeromagnetic data and provides better resolution as to the location of anomalous structures.

Clearly from the ERI sections however, the regolith appears to be fairly thick, consisting mostly of a layer of low resistivity (clays). Resistivities across the eight (8) ERI lines range between 0.6 Ohm.m and ~1000 Ohm.m, with a mean of ~23 Ohm.m. These values correspond to resistivities given for commonly observed clays and sandstones (See Table

6-1). The low end of the resistivity range observed is likely due to more saturated material, with salinity of the ground water in the area greatly increasing conductivity.

Table 6-1: Table of typical resistivities for different geology (source: www.eoas.ubc.ca)



Symbols "**T**" (regions of near surface sandy or lateritic lithologies), "**H**" (>20 m b.g.l more resistive lithologies, likely bedrock), "**W**" (weather or unconsolidated areas with higher conductivity than surroundings, interpreted as clays) and "**F**" (possible faults or fractures with potential for groundwater), are used to indicate different zones identified in the ERI sections.

In general, the method shows a distinct boundary between three layers namely;

- a resistive top layer interpreted as fine sand and dry sandy soils (symbol "**T**").
- a second conductive highly weathered rock or clayey layer (symbol "**W**") which varies in thickness and continuity across site.
- a progressively more resistive layer with depth (symbol "**H**"), likely indicative of a gradual change into bedrock material. This forms the base of most of the ERI sections and away from intrusions of less resistive vertical structures from the surface, appears fairly homogeneous laterally.

A geological structure was interpreted as potential permeable zone (symbol "**F**") when such a zone in the ERI lines corresponds to an anomaly in magnetic profiles extending across multiple ground magnetic lines. For this specific site the magnetic and resistivity responses are not always sharply defined due to the geological makeup.

The locations identified should be the principal target for drilling and suggested bore locations are displayed in Appendices C and D, with coordinates provided in the conclusion.

7. CONCLUSION AND RECOMMENDATIONS

The ground magnetic and resistivity surveys conducted at Lake Medcalf delivered encouraging results over some of the areas targeted for groundwater exploration. A list of drill targets follows in Table 7-1. Targets marked with an "*" can be excluded if a good water supply is found in some of the other bores. The targets have been ranked according to priority.

Table 7-1: Proposed water supply bore drilling locations.

Hole ID	Easting (MGA50)	Northing (MGA50)
D201	291954.0	6398260.0
D301	293315.0	6398269.0
D303	293417.0	6398216.0
D304	293201.0	6398327.0
D801	296078.0	6399750.0
D802	296259.0	6399758.0
D302	293288.0	6398282.0
D102	291021.0	6397899.0
D501	297091.0	6397624.0
D401	295211.0	6398236.0
D402 (*)	295075.0	6398232.0
D403 (*)	295164.0	6398234.0

D101 (*)	291198.0	6397905.0
D601 (*)	297325.0	6397977.0
D701 (*)	294750.0	6399677.0

8. REFERENCES

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Jansen, J. R. (2011). Geophysical Methods To Map Brackish And Saline Water in Aquifers. *Proceedings of the 2011 Georgia Water Resources Conference.* Georgia.

Loke, M. H., & Lane Jr, J. W. (2004). Inversion of data from electrical resistivity imaging surveys in water-covered areas. *Exploration Geophysics*, 35, 266-271.

Sjodahl, P., Dahlin, T., Johansson, S., & Loke, M. H. (2008). Resistivity monitoring for leakage and internal erosion detection at Hallby embankment dam. *Journal of Applied Geophysics*, 65, 155-164.

DISCLAIMER

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APPENDIX A

Appendix A provides technical information on the geophysical methods employed during the Lake Medcalf survey.

9. OVERVIEW OF THE GROUND MAGNETIC METHOD

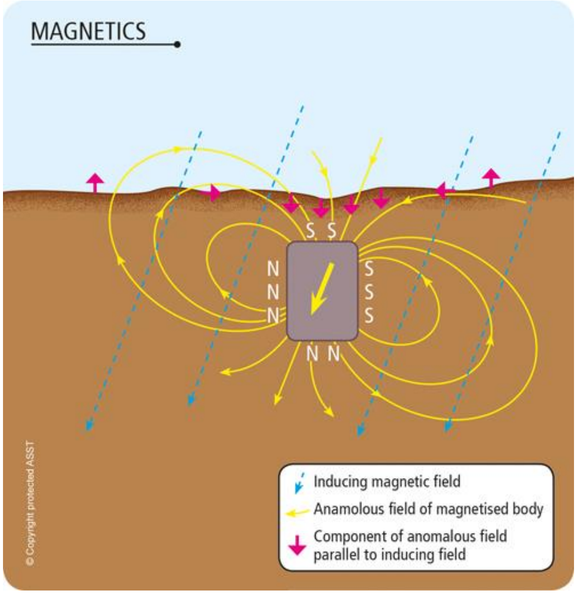
Magnetic profiling is a passive method that involves measurement of localised variations in the amplitude of the geomagnetic field.

These variations may result from buried ferrous objects, such as underground storage tanks and pipes, and changes in the magnetic susceptibility of near surface minerals. The amplitude and shape of the anomaly will depend on the shape, orientation and susceptibility of the target.

In certain instances, magnetic data can be interpreted quantitatively and transformed into constrained geological models. More typically, however, magnetic data are interpreted qualitatively and simply used to verify the presence or absence of magnetically susceptible materials or features.

Figure 9.1 shows the earth's magnetic field lines over a metal object and the corresponding response curve measured using a magnetometer.

Figure 9.1: A simple image of the magnetics technique.



10. OVERVIEW OF THE ELECTRICAL RESISTIVITY METHOD

The Electrical Resistivity (ER) method is based on the behaviour of the flow of direct current in the subsurface. Since the electrical source can be controlled, the depth of investigation can be controlled. For engineering purposes, the method delivers high resolution data similar to that of seismic refraction; therefore, the two methods often complement each other. However, the resistivity method is cheaper and more flexible in its application.

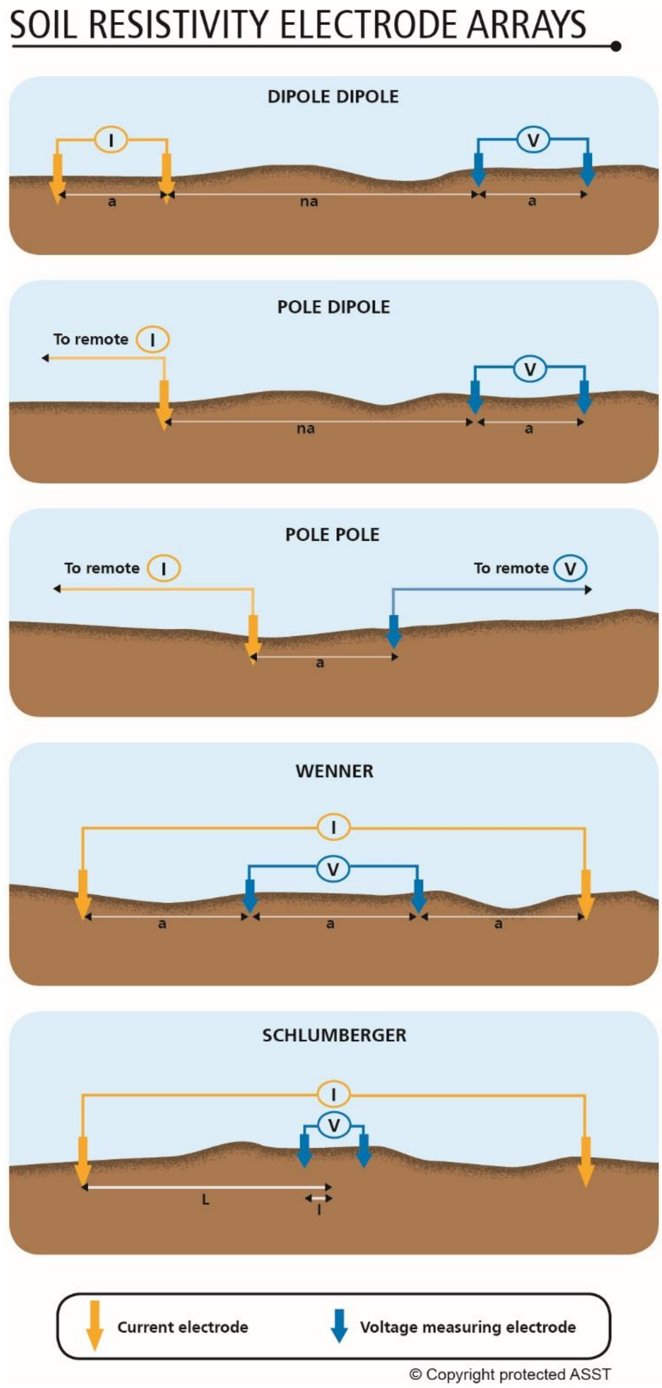
The two facets to the direct current (DC) method are as follows:

- Electrical soundings whereby the electrical resistivity distribution (electrical structure of soils) with depth is investigated by progressively changing the depth of investigation. In this case the method is most effective in the presence of flat lying or gently dipping (dip <15) lithologies with extensive laterally homogeneous extent.
- Horizontal profiling on the other hand measures the lateral distribution of electrical resistivity at a specific depth of investigation which makes this method most effective when lateral changes in resistivity are large.

At least four electrodes are needed to carry out resistivity measurements, two current electrodes ("I" in Figure 10-1) through which current is passed into the soil and two potential electrodes ("V" in Figure 10-1) between which a potential difference due to the current is measured.

The most common arrays in resistivity measurement techniques such as the Wenner and Schlumberger arrays employ all four electrodes symmetrically in a straight line. Other arrays more often used in mineral exploration include the Gradient array; where the potential electrodes are kept fixed and the current electrodes moved along lines parallel to the potential electrodes over an area where the primary electrical field is roughly uniform. Dipole–Dipole arrays are also commonly used where the distance between the current and potential dipoles is at least five times (×5) the dipole length. Variations of the dipole-dipole configurations include the Pole–Pole and Pole–Dipole arrays. Each configuration has its own limitations, advantages and disadvantages. For example, one configuration may be better to resolve lateral changes than others whilst another configuration may offer superior vertical resolution capabilities. Configuration setups for some of the most commonly used electrode arrays are illustrated in Figure 10-1.

Figure 10-1: Illustration of different electrode configurations.



Electrical Resistivity Imaging (ERI) uses the same principles as the Electrical Resistivity method. ERI differs from the ER method in that it is a multi-electrode imaging technique which can be used to find vertical and lateral variations in the electrical structure of the subsurface. The measurements are used to produce a coloured two-dimensional crosssection (also called a Pseudo Section) of the earth. Typical examples of the applications of this technique include:

- determining the depths and resistivities of geologic layers and the top of the water table,
- mapping contamination plumes, voids, fractures, faults, and other geologic features as well as archaeological investigations,
- characterizing landfills

Instead of using only four electrodes the complete electrode string consists of multiple electrode points (also referred to as take outs) which can be used both as current and potential electrodes. Similar to the VES method the ERI method employs a current source that injects electrical current into the earth through a pair of ground electrodes and the resulting potential field is measured along the ground surface using a second pair of electrodes. The transmitting and receiving electrode pairs are referred to as dipoles. By varying the unit length of the dipoles as well as the distance between electrode pairs, the horizontal and vertical distribution of electrical properties at different depths can be recorded.

A number of electrode configurations can be applied during measurements some of which include Dipole–Dipole, Schlumberger, Wenner, Pole–Pole, Pole–Dipole, and the Square array. As mentioned in Section 2 each configuration has its own limitations.

Modern ERI equipment provides a fast profiling method which sets it apart from traditional horizontal profiling and soundings techniques which are used to find the depths and resistivities of the geologic layers directly beneath the centre of the sounding spread. Instruments that employ automated switching systems control switching to the relevant dipoles which allows for many different electrode spacings and locations to be recorded in a relatively short time. The final result is an Apparent Resistivity pseudo section along the traverses surveyed. The measured resistivity values represent the Apparent Resistivity. This can be referred to as an integrated or volumetric resistivity measurement that includes contributions from all of the layers under the sounding site to the depth of investigation of the measurement. However, constrained modelling using existing borehole data can vastly improve modelling results.

Capabilities and Limitations

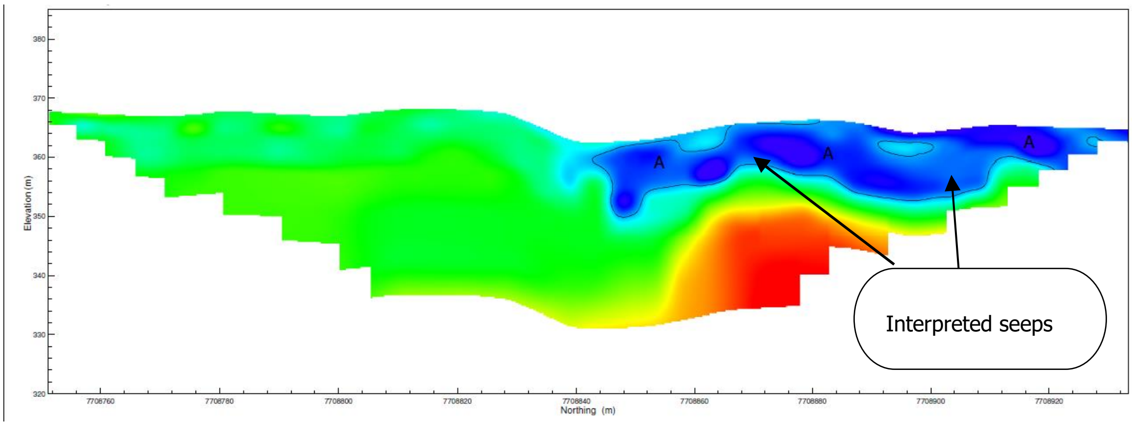
Proposed survey lines should avoid large underground metallic pipes, electric lines, grounded fences and overhead power lines.

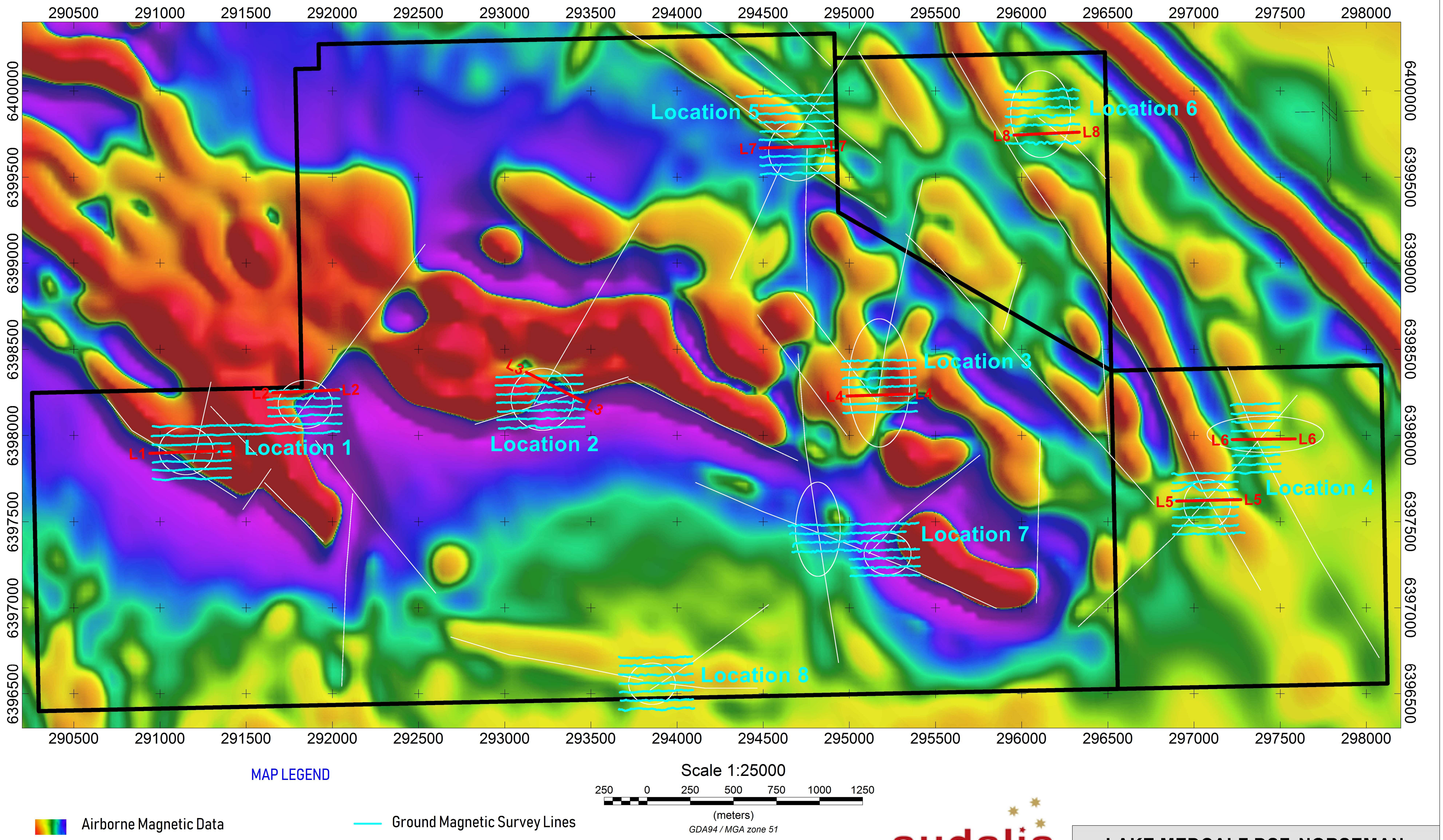
The depth of investigation is typically 20% of the total line length. However, resolution decreases rapidly with depth due to systematic widening of the dipoles. The highest resolution and most accurate depth conversion is provided in the upper 30% of the modelled section where the resolution is approximately 1/3 of the electrode spacing.

The method is labour intensive and in dry conditions saline water need to be poured around electrodes to allow better electrical contact between the electrodes and ground. The interpretation of resistivity soundings necessarily assumes that the subsurface is horizontally layered with no lateral variations in resistivity.

Figure 10-2 below shows an example of a resistivity survey carried out to detect water-saturated (low resistivity) zones in a dam wall. Three different electrode arrays were trialed with results showing that the dipole-dipole array performed best identifying two potential seeps.

Figure 10-2: Seepage detection using ERI.





MAP LEGEND

▨ Airborne Magnetic Data

╲ Airborne Magnetic Interpretation

○ Investigation Targets

— Ground Magnetic Survey Lines

— ERI Survey Lines

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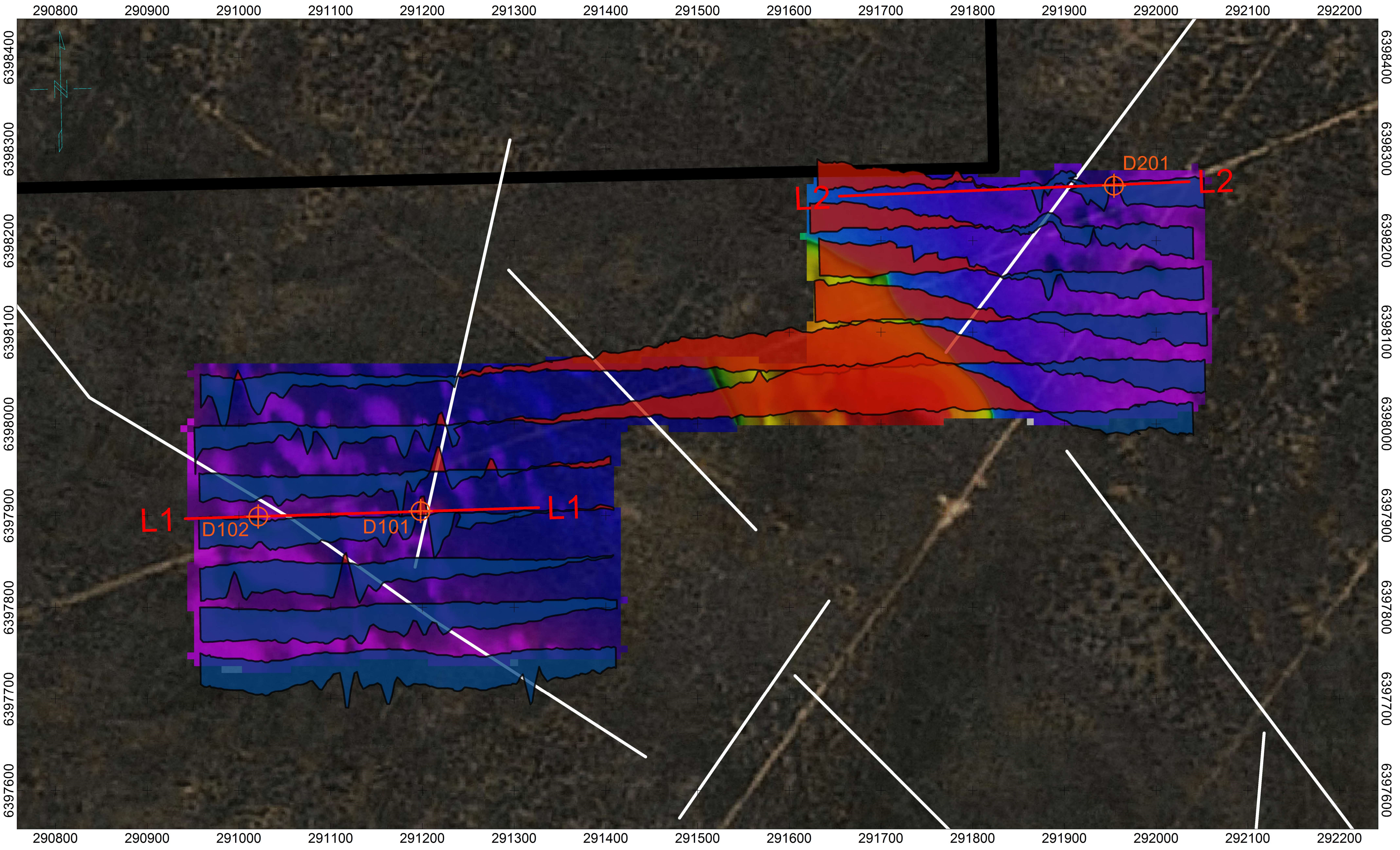
Survey location map

Appendix B



Scale 1:4200

GDA94 / MGA zone 51

MAP LEGEND

ERI Lines	Ground Magnetic Profiles
Airborne Magnetic Interpretation	Total Field Magnetic Data
Tenament Boundary	⊕ Proposed Borehole Locations

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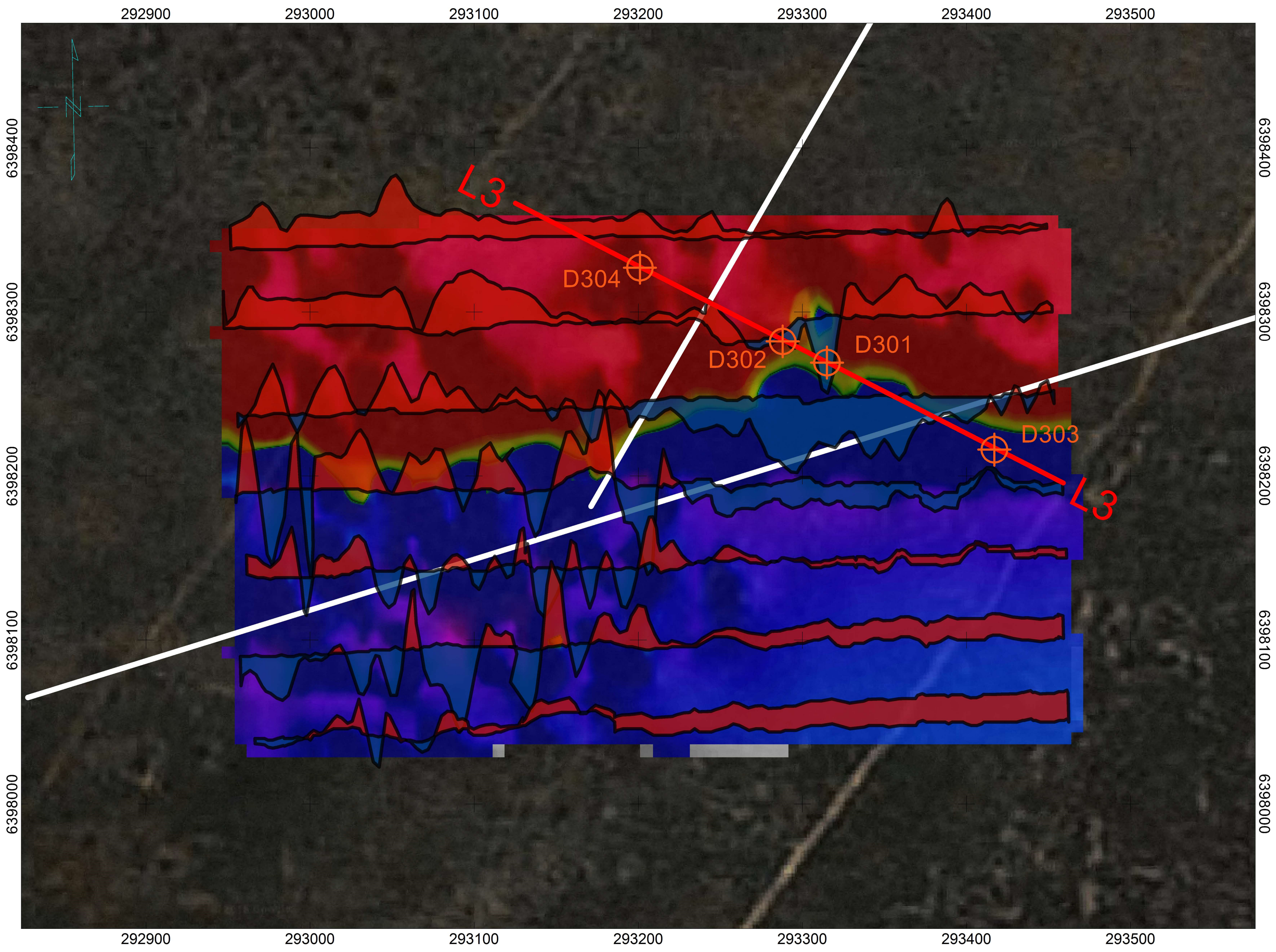
Ground Magnetics - Location 1

Appendix C1



Scale 1:2600

GDA94 / MGA zone 51

MAP LEGEND

╲	ERI Lines	▲	Ground Magnetic Profiles
╲	Airborne Magnetic Interpretation	▬	Total Field Magnetic Data
▬	Tenement Boundary	⊕	Proposed Borehole Locations

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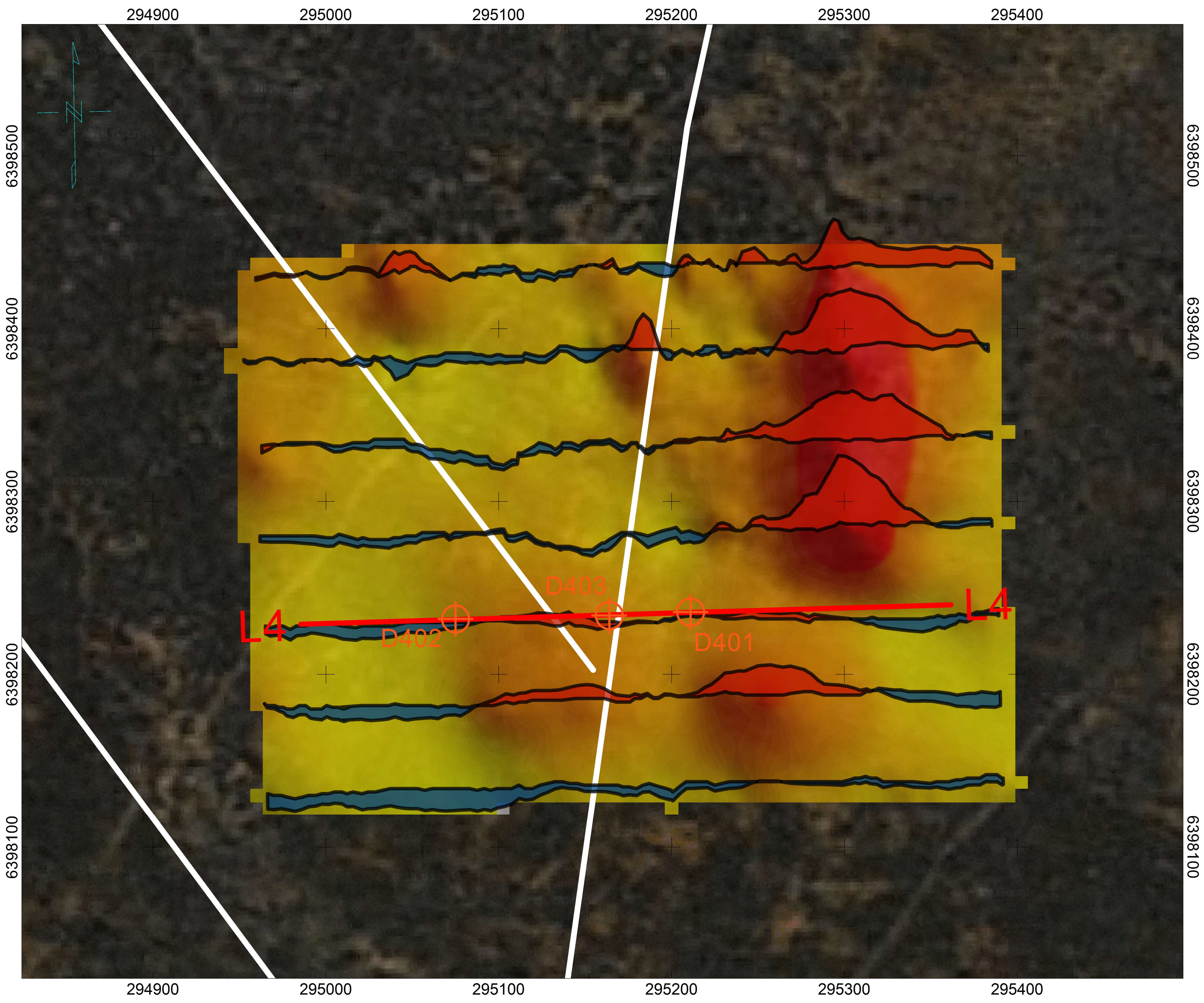
Ground Magnetics - Location 2

Appendix C2



Scale 1:2600

50 0 50 100

(meters)

GDA94 / MGA zone 51

MAP LEGEND

- ERI Lines
- Airborne Magnetic Interpretation
- Tenament Boundary
- Ground Magnetic Profiles
- Total Field Magnetic Data
- ⊕ Proposed Borehole Locations

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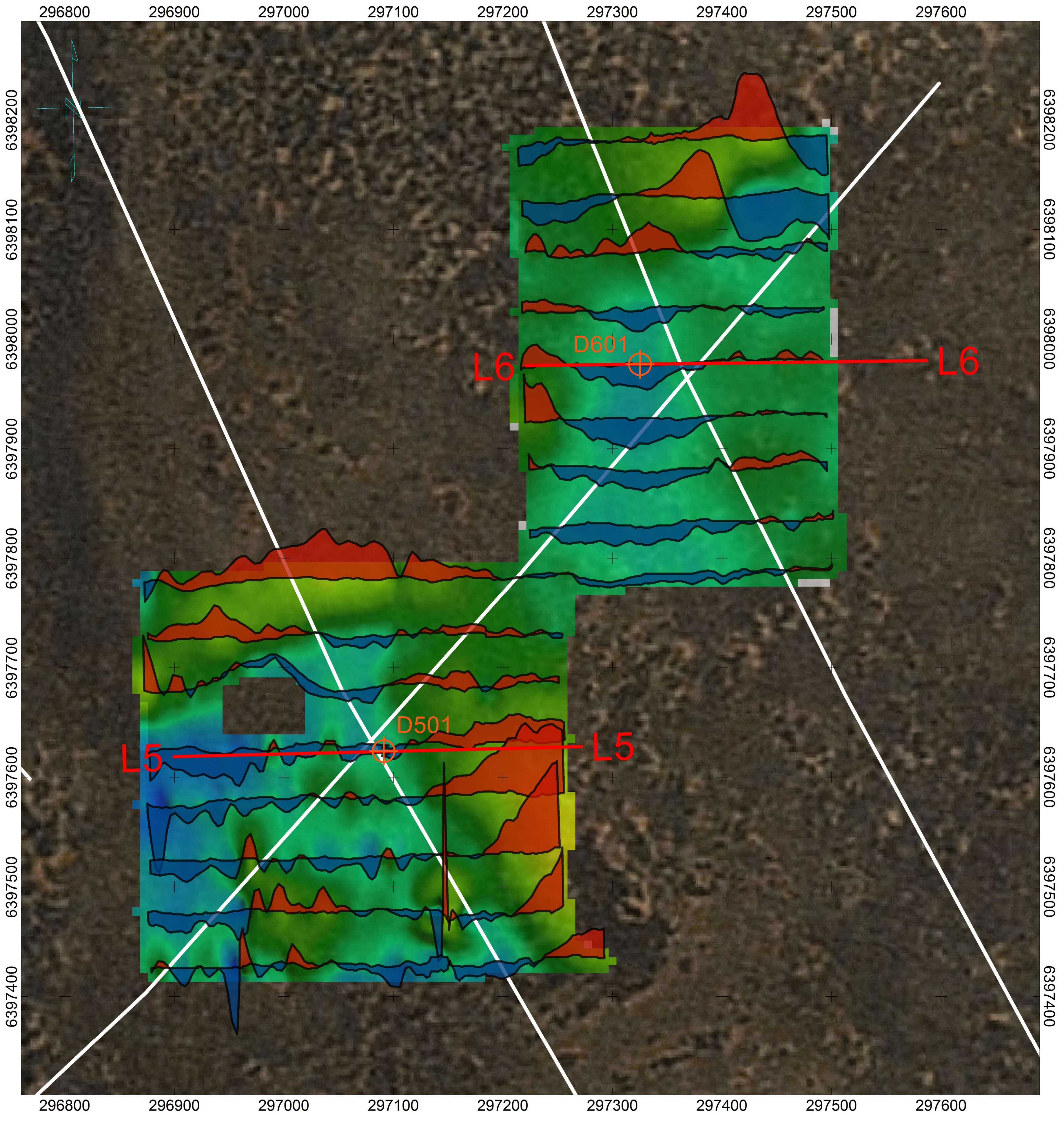
Ground Magnetics - Location 3

Appendix C3



MAP LEGEND

ERI lines

Airborne Magnetic Interpretation

⊕ Proposed Borehole Locations

Total Field Magnetic Data

Ground Magnetic Profiles

Scale 1:4000

50 0 50 100 150

(meters)

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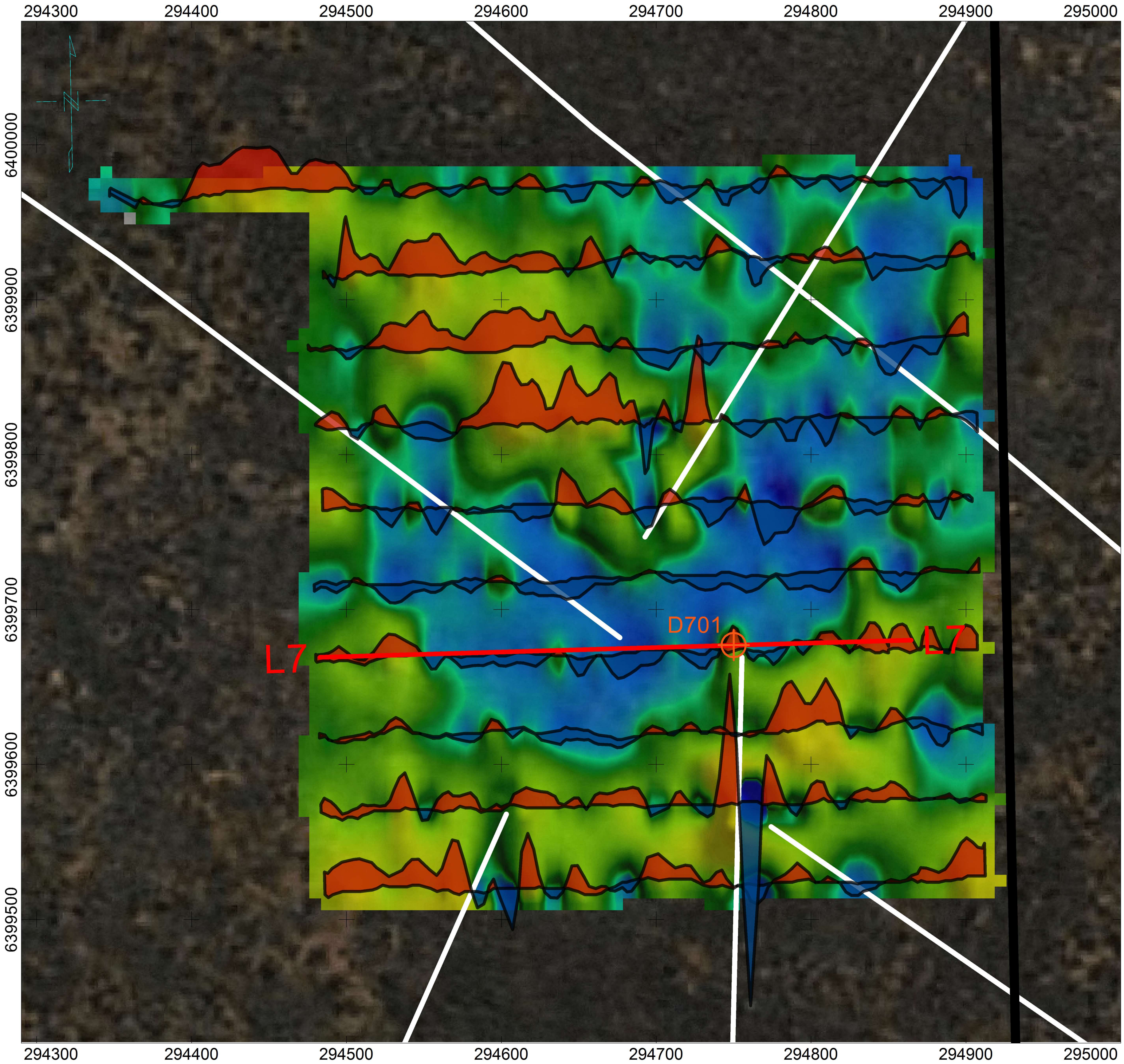
Ground Magnetics - Location 4

Appendix C4



MAP LEGEND

ERI Line

Airborne Magnetic Interpretation

⊕ Proposed Borehole Locations

Total Field Magnetic Data

Tenament Boundary

Ground Magnetic Profiles

Scale 1:3000

GDA94 / MGA zone 51

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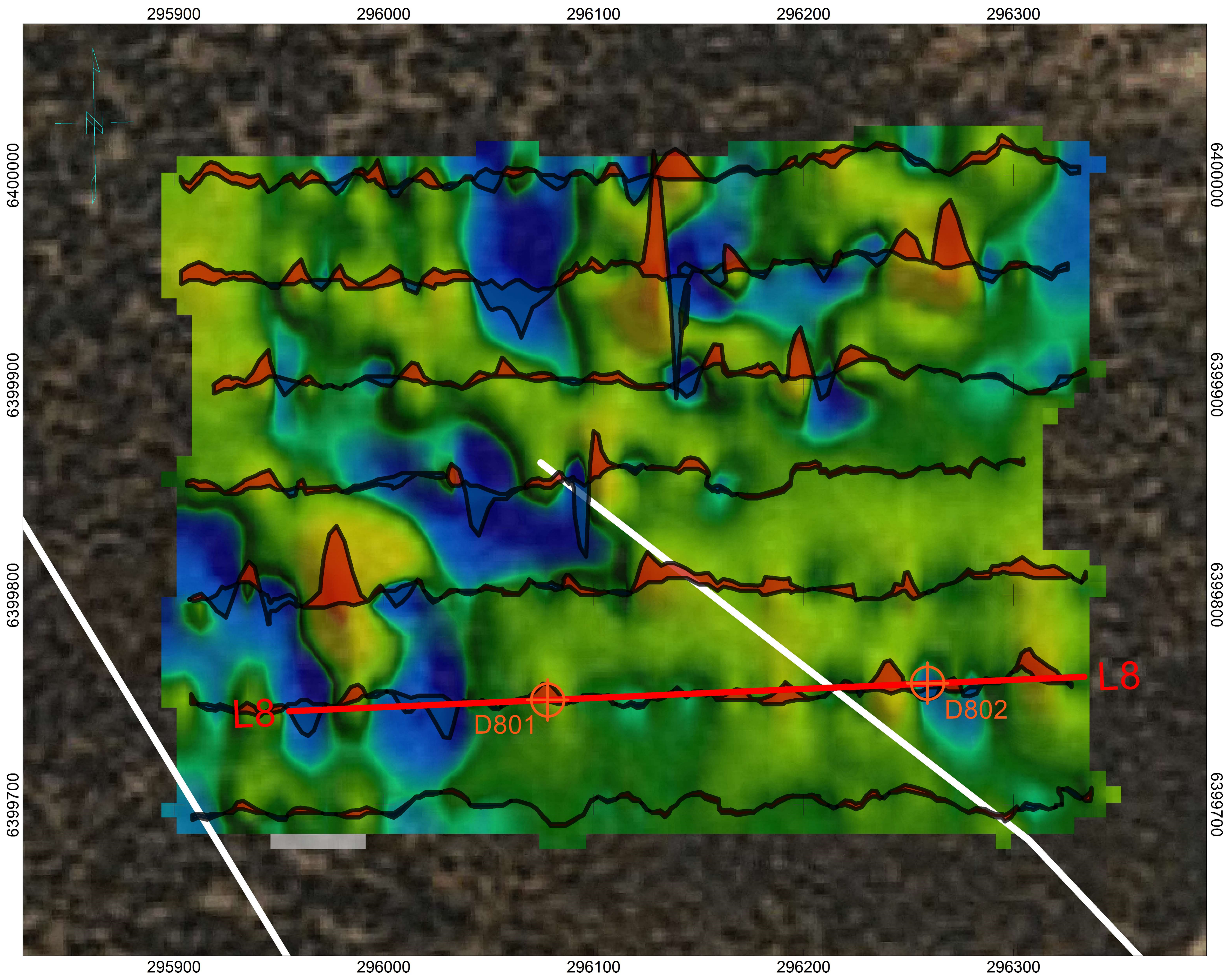
Ground Magnetics - Location 5

Appendix C5



MAP LEGEND

- ERI Line
- Airborne Magnetic Interpretation
- ⊕ Proposed Borehole Locations
- Total Field Magnetic Data
- Ground Magnetic Profiles

Scale 1:2200

25 0 25 50 75 100

(meters)

GDA94 / MGA zone 51

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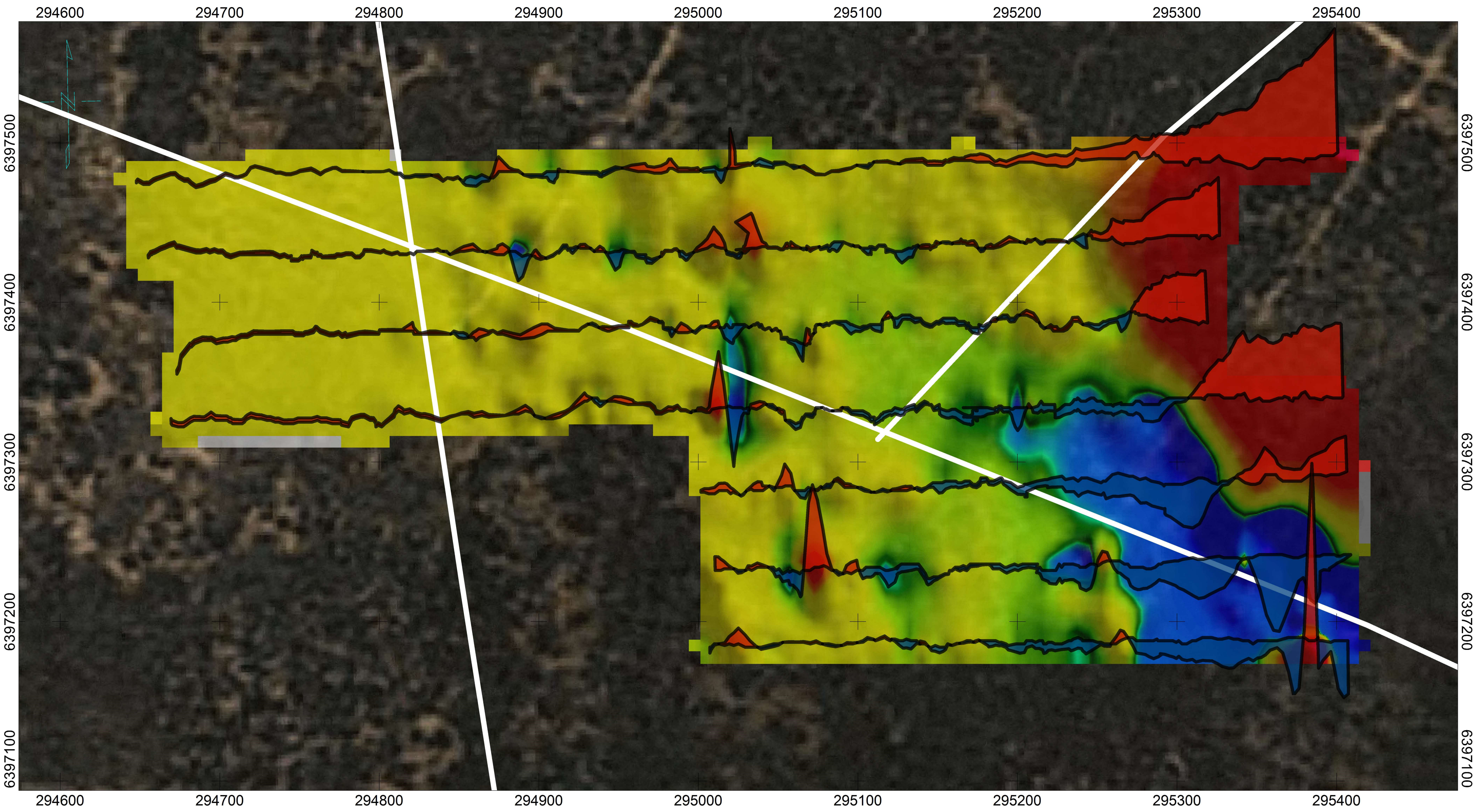
Ground Magnetics - Location 6

Appendix B6



Scale 1:2600

GDA94 / MGA zone 51

MAP LEGEND

╲	Airborne Magnetic Interpretation
🟥	Ground Magnetic Profiles
🟩	Total Field Magnetic Data

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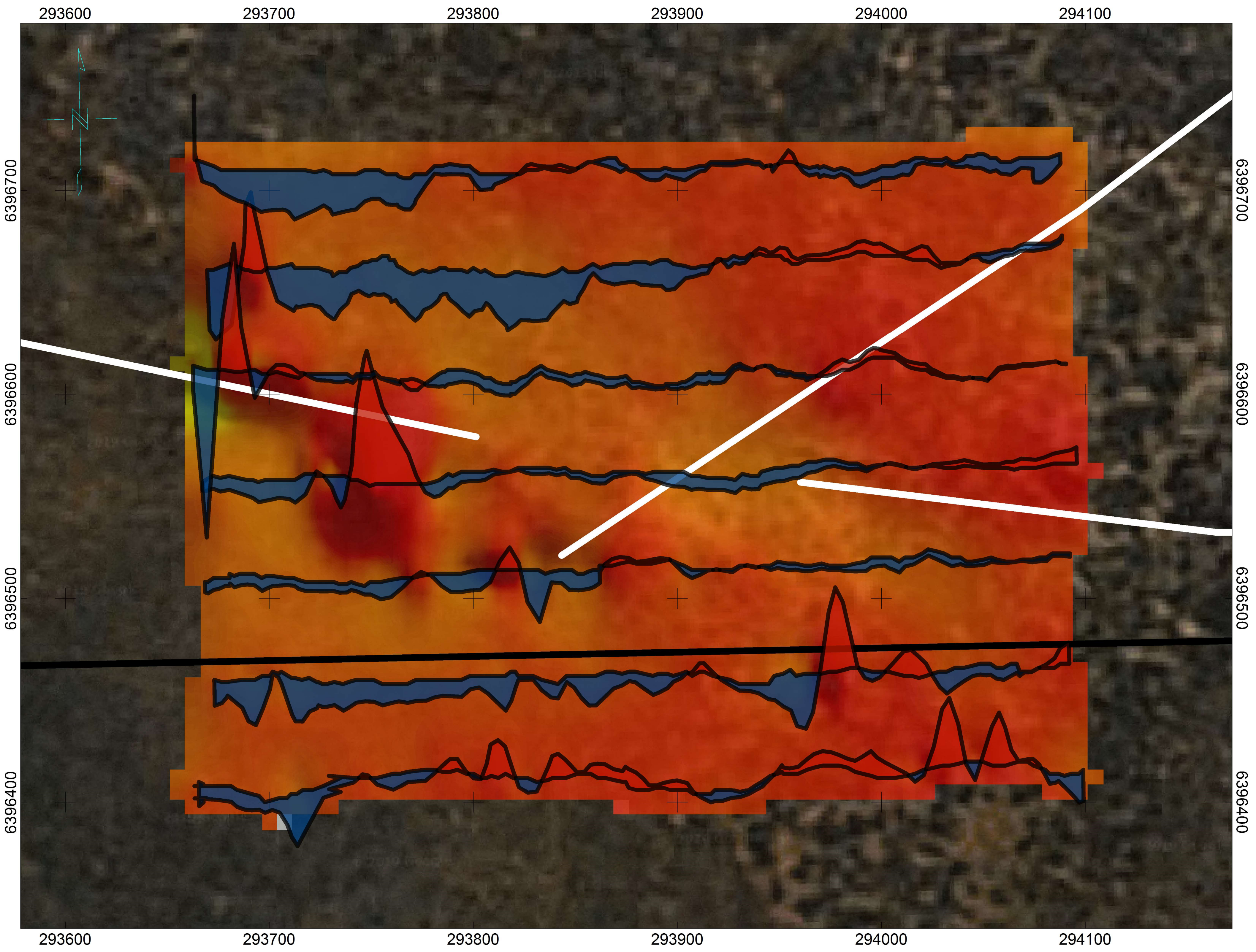
Ground Magnetics - Location 7

Appendix C7



MAP LEGEND

Airborne Magnetic Interpretation

Tenament Boundary

Ground Magnetic Profiles

Total Field Magnetic Data

Scale 1:2200

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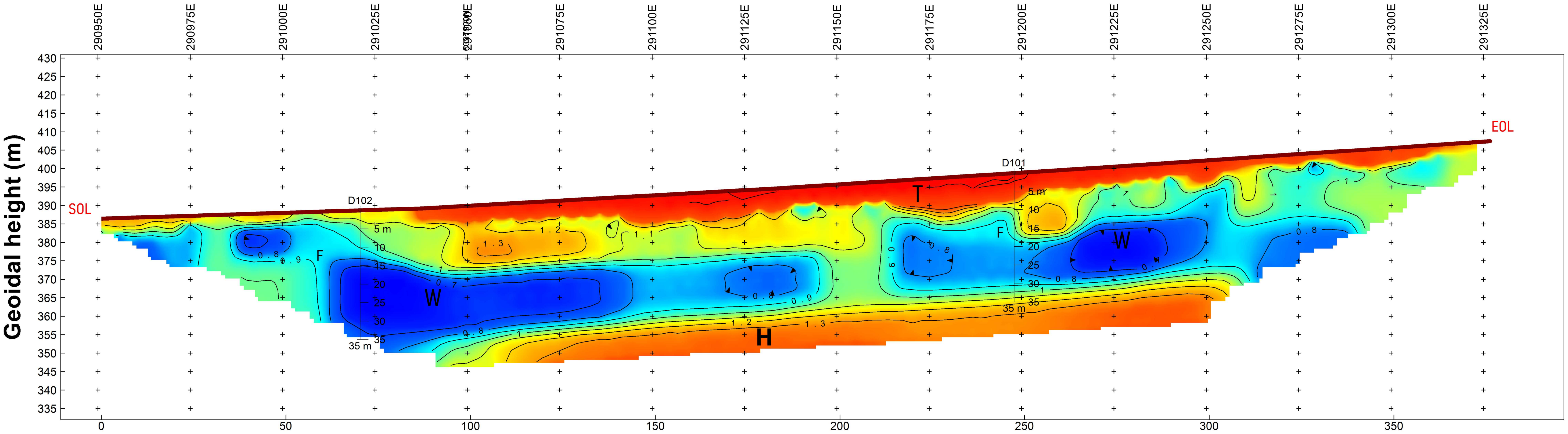
Ground Magnetics - Location 8

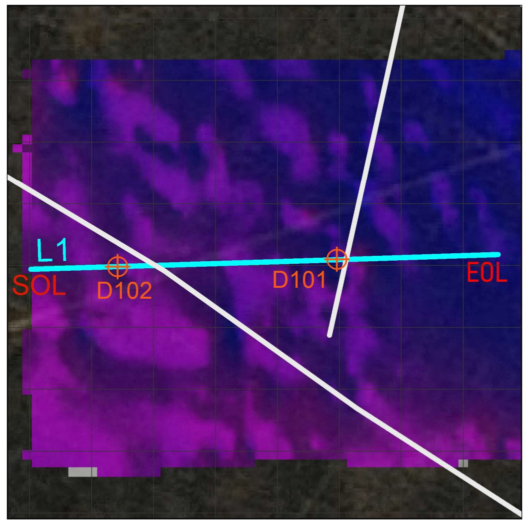
Appendix C8

Apparent Resistivity - Line 1



0.6 0.8 0.8 0.9 1.0 1.1 1.2 1.3 2.2

Logarithmic Apparent Resistivity
(Ω.m)



Section Trace Plan View

MAP LEGEND

╲	Displayed ERI Line
╲	Airborne Magnetic Interpretation
▨	Ground Magnetic Data
⊕	Proposed Drilling Locations
SOL	Start of Line
EOL	End of Line

INTERPRETATION KEY

T Dry Sandy Topsoil - Shallow Resistive Zones

H Hard Bedrock - Resistive Zones

W Weathered / Unconsolidated Rock - Conductive Zones

F Possible Fractures / Faults - Permeable Zones

40 m Proposed Borehole

Contour Interval: 0.1 log(Ω.m)

Depth Penetration: ~40 m

Scale 1:1100

Vertical Exaggeration: 1 25 0 25
(meters)
GDA94 / MGA zone 51

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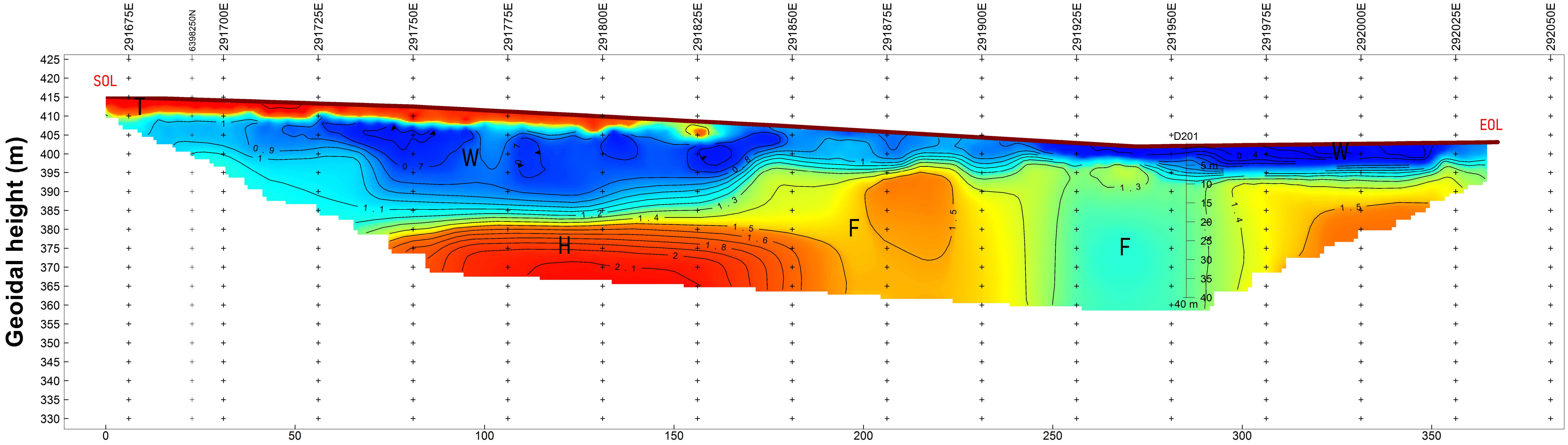
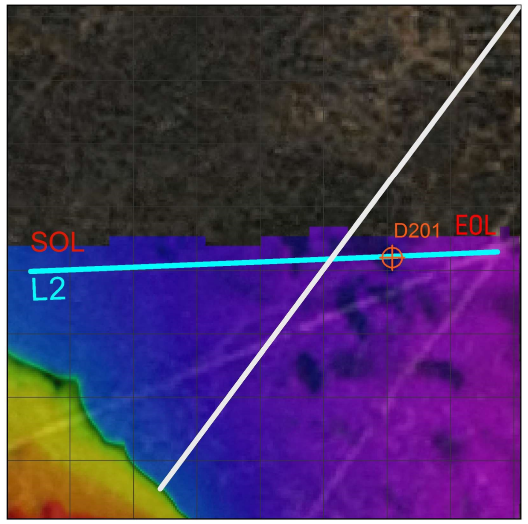
Apparent Resistivity - Line 1

Appendix D1

Apparent Resistivity - Line 2





Section Trace Plan View

MAP LEGEND

- ╱ Displayed ERI Line
- ╱ Airborne Magnetic Interpretation
- 🟥 Ground Magnetic Data
- ⊕ Proposed Drilling Locations
- SOL Start of Line
- EOL End of Line

INTERPRETATION KEY

- T Dry Sandy Topsoil - Shallow Resistive Zones
- H Hard Bedrock - Resistive Zones
- W Weathered / Unconsolidated Rock - Conductive Zones
- F Possible Fractures / Faults - Permeable Zones

⊥ Proposed Borehole
40 m

Contour Interval: 0.1 log(Ω.m)

Depth Penetration: ~45 m

0.3 0.8 0.9 1.1 1.3 1.4 1.5 1.5 2.0

Logarithmic Apparent Resistivity
(Ω.m)

Scale 1:1100

Vertical Exaggeration: 1

25 0 25
(meters)

GDA94 / MGA zone 51

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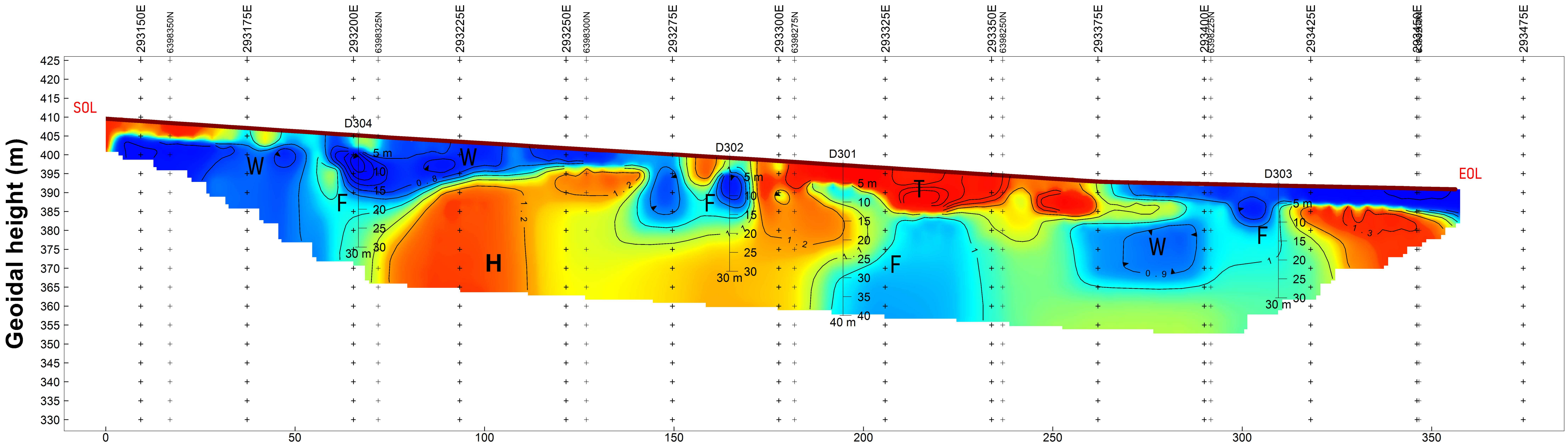
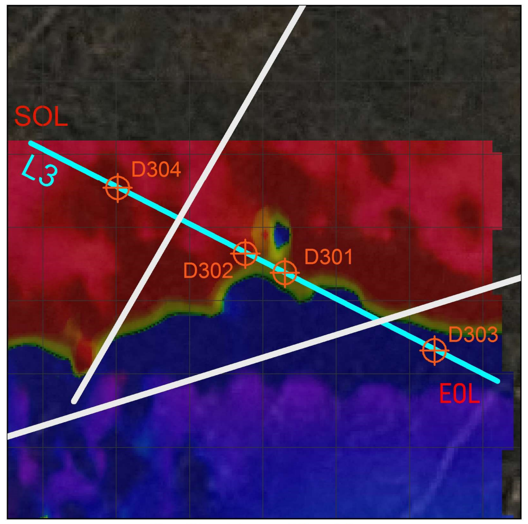
Apparent Resistivity - Line 2

Appendix D2

Apparent Resistivity - Line 3





Section Trace Plan View

MAP LEGEND

Displayed ERI Line

Airborne Magnetic Interpretation

Ground Magnetic Data

⊕ Proposed Drilling Locations

SOL Start of Line

EOL End of Line

INTERPRETATION KEY

T Dry Sandy Topsoil - Shallow Resistive Zones

H Hard Bedrock - Resistive Zones

W Weathered / Unconsolidated Rock - Conductive Zones

F Possible Fractures / Faults - Permeable Zones

Proposed Borehole

40 m

Contour Interval: 0.1 log(Ω.m)

Depth Penetration: ~40 m

0.3 0.8 0.9 1.0 1.0 1.1 1.2 1.2 1.3

Logarithmic Apparent Resistivity

(Ω.m)

Scale 1:1100

Vertical Exaggeration: 1

25 0 25

(meters)

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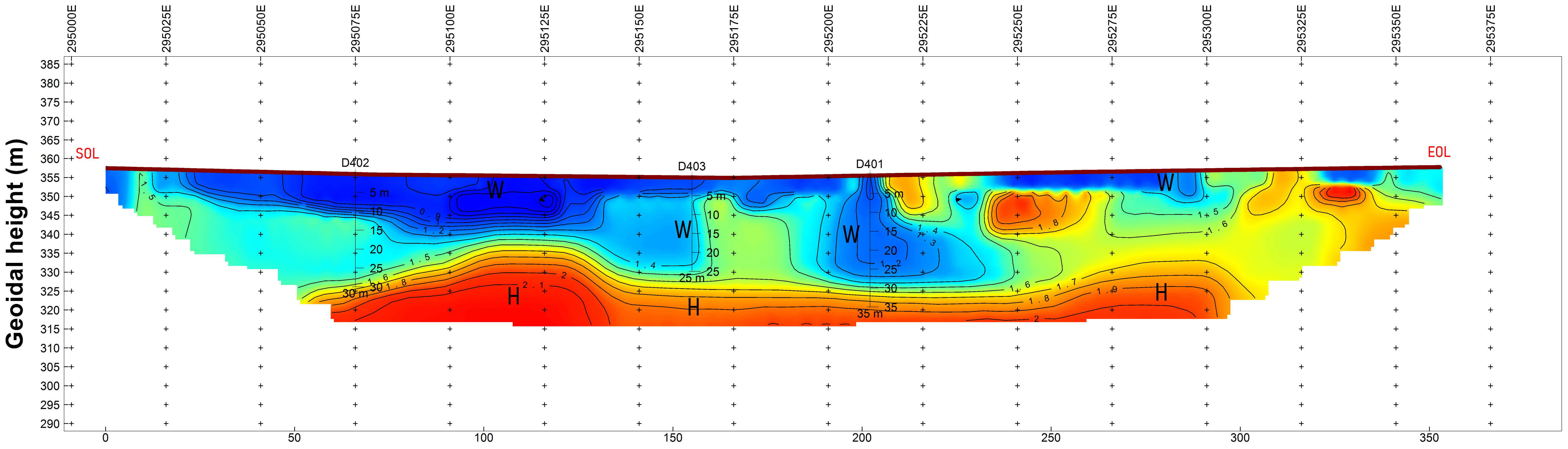
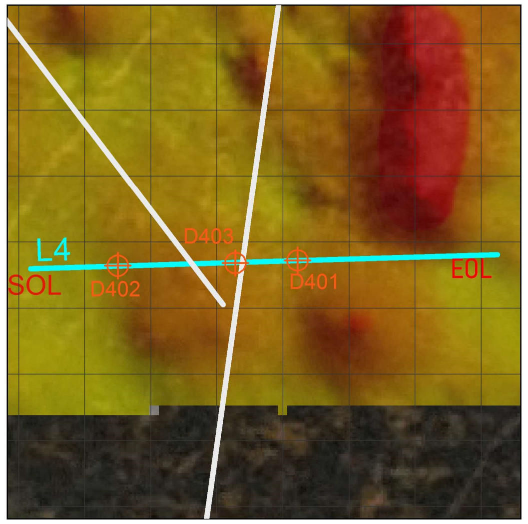
Apparent Resistivity - Line 3

Appendix D3

Apparent Resistivity - Line 4





Section Trace Plan View

MAP LEGEND

╲	Displayed ERI Line
╲	Airborne Magnetic Interpretation
▨	Ground Magnetic Data
⊕	Proposed Drilling Locations
SOL	Start of Line
EOL	End of Line

INTERPRETATION KEY

T Dry Sandy Topsoil - Shallow Resistive Zones

H Hard Bedrock - Resistive Zones

W Weathered / Unconsolidated Rock - Conductive Zones

F Possible Fractures / Faults - Permeable Zones

⊥ Proposed Borehole
40 m

Contour Interval: 0.1 log(Ω.m)

Depth Penetration: ~40 m

0.7 1.1 1.3 1.4 1.5 1.6 1.7 1.9 2.0

Logarithmic Apparent Resistivity
(Ω.m)

Scale 1:1100

Vertical Exaggeration: 1

25 0 25
(meters)

GDA94 / MGA zone 51

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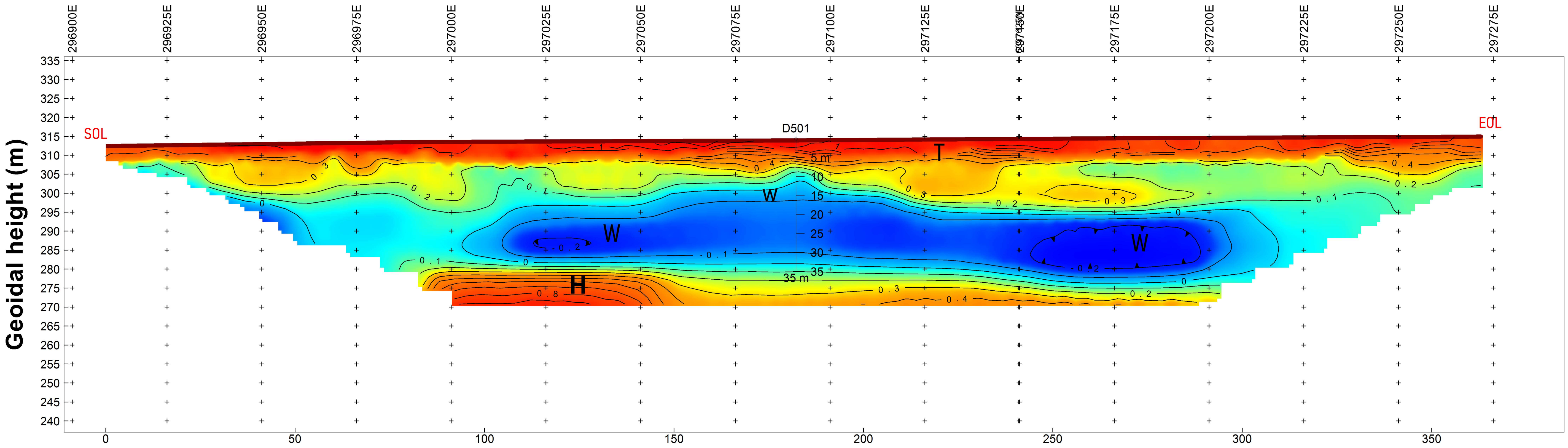
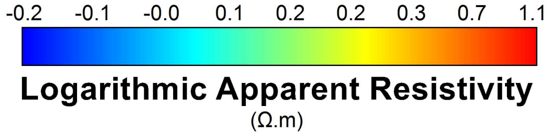
Apparent Resistivity - Line 4

Appendix D4

Apparent Resistivity - Line 5





Logarithmic Apparent Resistivity
(Ω.m)

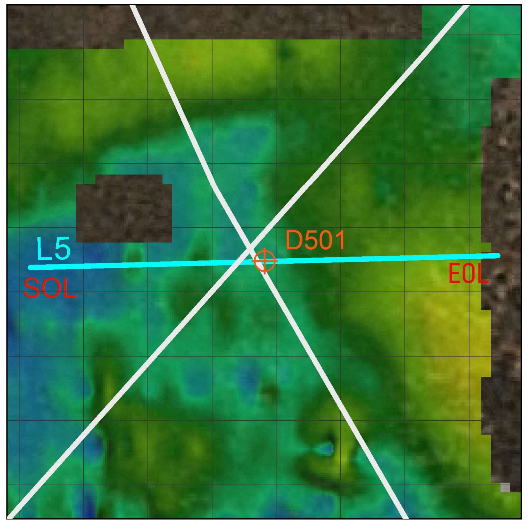
Scale 1:1100

Vertical Exaggeration: 1

25 0 25

(meters)

GDA94 / MGA zone 51



Section Trace Plan View

MAP LEGEND

▬	Displayed ERI Line
▬	Airborne Magnetic Interpretation
▨	Ground Magnetic Data
⊕	Proposed Drilling Locations
SOL	Start of Line
EOL	End of Line

INTERPRETATION KEY

T	Dry Sandy Topsoil - Shallow Resistive Zones
H	Hard Bedrock - Resistive Zones
W	Weathered / Unconsolidated Rock - Conductive Zones
F	Possible Fractures / Faults - Permeable Zones
⊥ 40 m	Proposed Borehole

Contour Interval: 0.1 log(Ω.m)

Depth Penetration: ~40 m

audalia
resources limited

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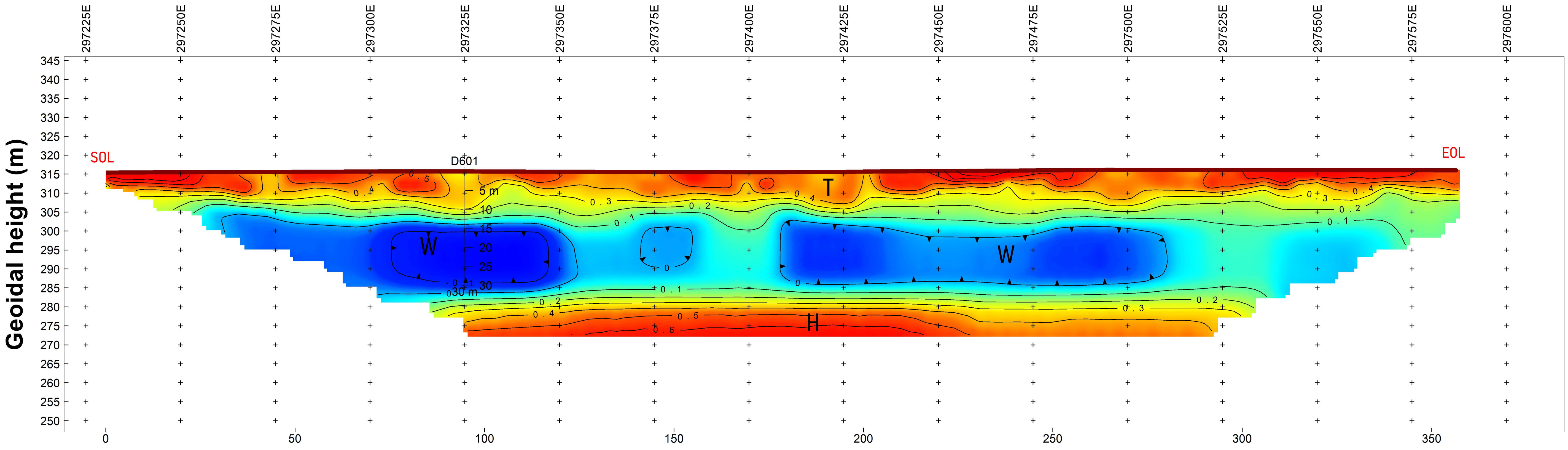
LAKE MEDCALF DSF, NORSEMAN

Apparent Resistivity - Line 5

Appendix D5

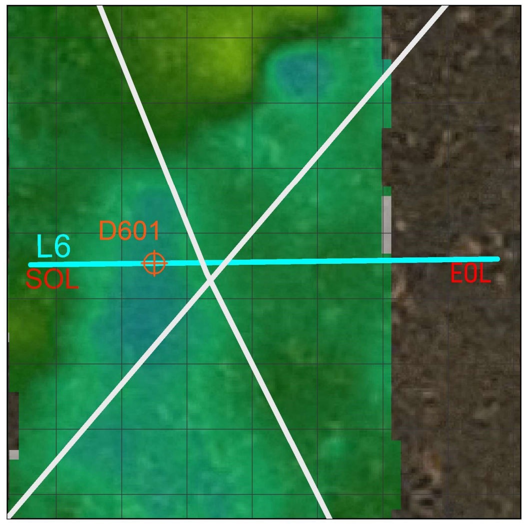
Apparent Resistivity - Line 6



-0.1 -0.0 0.0 0.1 0.1 0.2 0.4 0.5 0.6

Logarithmic Apparent Resistivity

(Ω.m)



Section Trace Plan View

MAP LEGEND

Displayed ERI Line

Airborne Magnetic Interpretation

Ground Magnetic Data

⊕ Proposed Drilling Locations

SOL Start of Line

EOL End of Line

INTERPRETATION KEY

T Dry Sandy Topsoil - Shallow Resistive Zones

H Hard Bedrock - Resistive Zones

W Weathered / Unconsolidated Rock - Conductive Zones

F Possible Fractures / Faults - Permeable Zones

40 m Proposed Borehole

Contour Interval: 0.1 log(Ω.m)

Depth Penetration: ~40 m

Scale 1:1100

Vertical Exaggeration: 1

25 0 25

(meters)

GDA94 / MGA zone 51

audalia resources limited

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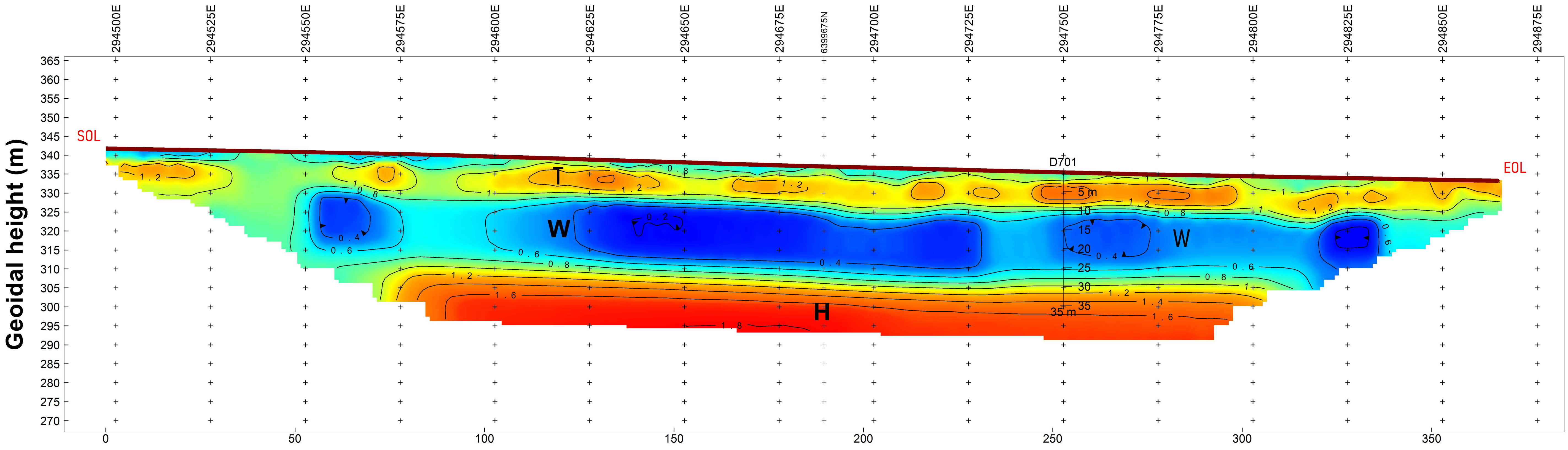
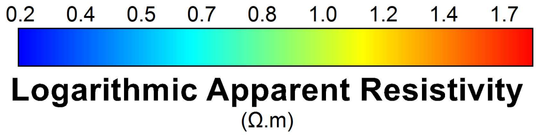
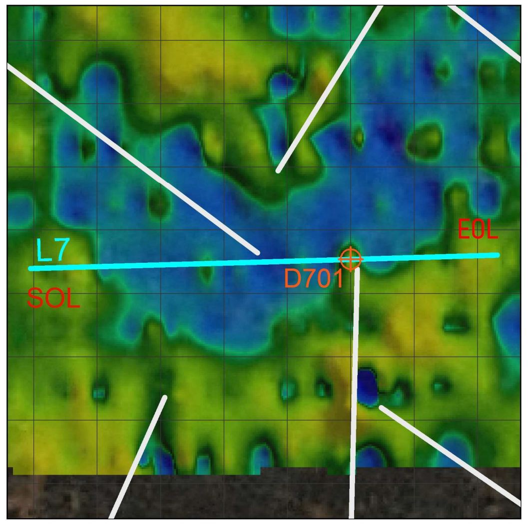
Apparent Resistivity - Line 6

Appendix D6

Apparent Resistivity - Line 7







Section Trace Plan View

MAP LEGEND

Displayed ERI Line
Airborne Magnetic Interpretation
Ground Magnetic Data
⊕ Proposed Drilling Locations
SOL Start of Line
EOL End of Line

INTERPRETATION KEY

T Dry Sandy Topsoil - Shallow Resistive Zones
H Hard Bedrock - Resistive Zones
W Weathered / Unconsolidated Rock - Conductive Zones
F Possible Fractures / Faults - Permeable Zones

⊥ Proposed Borehole
40 m

Contour Interval: 0.1 log(Ω.m)

Depth Penetration: ~40 m

Scale 1:1100

Vertical Exaggeration: 1

25 0 25
(meters)

GDA94 / MGA zone 51

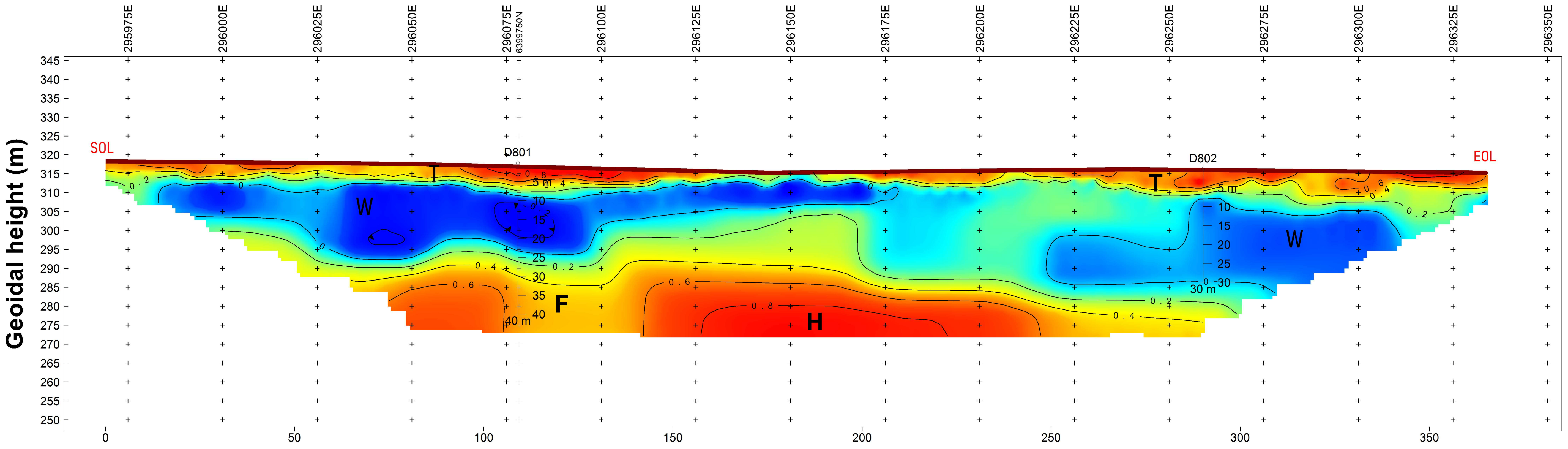
Created by

LAKE MEDCALF DSF, NORSEMAN

Apparent Resistivity - Line 7

Appendix D7

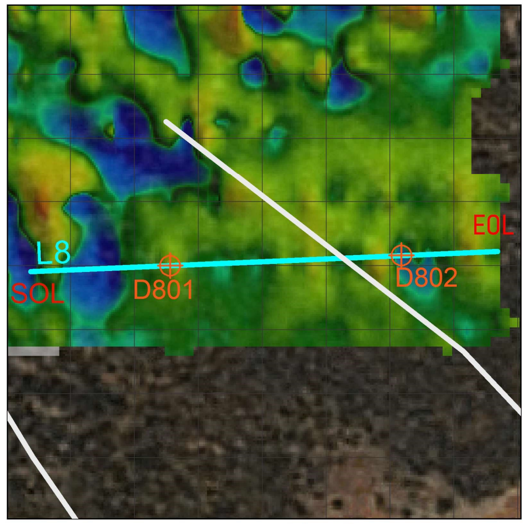
Apparent Resistivity - Line 8



-0.2 -0.1 0.0 0.1 0.2 0.3 0.5 0.6 0.8

Logarithmic Apparent Resistivity

(Ω.m)



Section Trace Plan View

MAP LEGEND

Displayed ERI Line

Airborne Magnetic Interpretation

Ground Magnetic Data

⊕ Proposed Drilling Locations

SOL Start of Line

EOL End of Line

INTERPRETATION KEY

T Dry Sandy Topsoil - Shallow Resistive Zones

H Hard Bedrock - Resistive Zones

W Weathered / Unconsolidated Rock - Conductive Zones

F Possible Fractures / Faults - Permeable Zones

40 m Proposed Borehole

Contour Interval: 0.1 log(Ω.m)

Depth Penetration: ~40 m

Scale 1:1100

Vertical Exaggeration: 1

25 0 25

(meters)

GDA94 / MGA zone 51

Created by

LAKE MEDCALF DSF, NORSEMAN

Apparent Resistivity - Line 8

Appendix D8

BORE LOGS

GROUNDWATER
RESOURCE MANAGEMENT

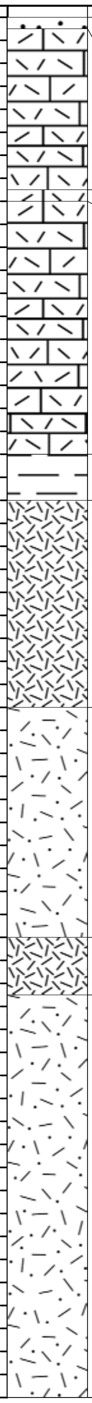
PO Box 244 Bayswater WA 6933
15 Harborne Street
Wembley WA 6014
Ph: +61 8 9433 2222 Fx: +61 8 9433 2322
Email: water@g-r-m.com.au

ID: **MWH001 (D501)**
JOB NUMBER: J1843
CLIENT: Audalia Resources Limited
PROJECT: Lake Medcalf

COMMENCED:	Sep-19	EASTING:	297,091	INCLINATION:	90 degrees
COMPLETED:	Sep-19	NORTHING:	6,397,624	AZIMUTH:	NA degrees
DRILLED BY:	Harrington	ELEVATION:	NA	SWL (date):	17.43 mbtoc ( )
LOGGED BY:	RFT	GRID SYSTEM:	MGA, Zn 51		

Depth (m bgl)	Graphic + Stratigraphy	Lithological Description	Field Notes	Bore Construction

Depth (m bgl): 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120

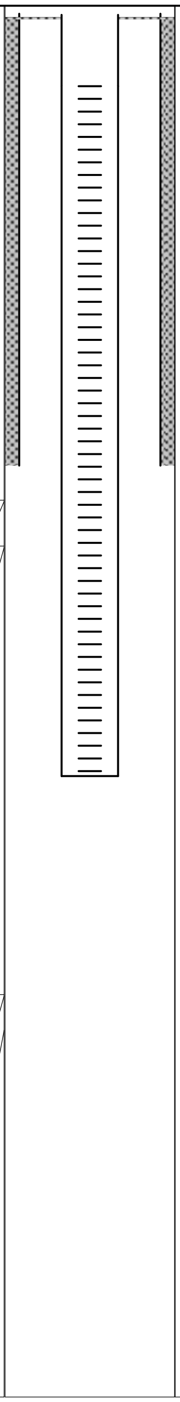


Lithological Description:

- SILT & SAND: red brown, fine grained moderately sorted sand
- SILCRETE & CALCRETE: pale grey, hard, low porosity
- CALCRETE: cream, Muscovite unit
- CALCRETE, SILT & SAND: cream, red brown, medium to fine grained, rounded, moderately sorted sand, minor shell fragments
- CLAY: brown
- DOLERITE: very fractured, oxidised, aquifer appears bettter than 1 l/s
- GRANITE
- DOLERITE
- GRANITE

Field Notes:

- 42m Groundwater intersect
- 46m: Flow 1L/s, EC 171mS/cm, pH 7.53, temp 24.5°C
- 85m: Flow 1L/s, EC 171mS/cm, pH 7.45, temp 24.8°C
- 88m: Flow 1L/s, EC 171mS/cm, pH 7.48, temp 28°C



Bore Construction:

- +0.2 - 6m 50mm ND class 9 uPVC casing
- 0-39m 8" diameter air rotary hammer drill-hole
- 0 - 38m annular seal
- +0.3 - 39m 8" PVC collar
- 6 - 66m 50mm ND class 9 uPVC slotted casing (1mm slots)
- 66m end cap
- 39-120m 5.25" percussion drill-hole

GROUNDWATER
RESOURCE MANAGEMENT

PO Box 244 Bayswater WA 6933
15 Harborne Street
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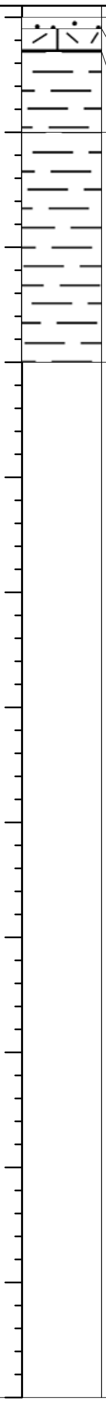
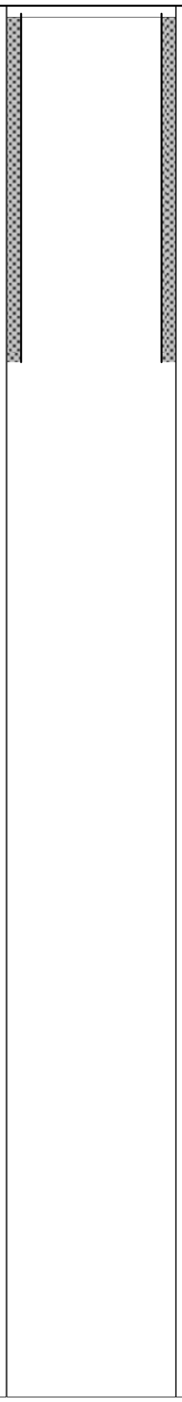
Ph: +61 8 9433 2222 Fx: +61 8 9433 2322
Email: water@g-r-m.com.au

ID:	**MWH002 (D601)**			JOB NUMBER:	J1843
CLIENT:	Audalia Resources Limited			PROJECT:	Lake Medcalf
COMMENCED:	Sep-19	EASTING:	297,325	INCLINATION:	90 degrees
COMPLETED:	Sep-19	NORTHING:	6,397,977	AZIMUTH:	NA degrees
DRILLED BY:	Harrington	ELEVATION:	NA	SWL (date):	9 mbtoc ( )
LOGGED BY:	RFT	GRID SYSTEM:	MGA, Zn 51		





Depth (m bgl)	Graphic + Stratigraphy	Lithological Description	Field Notes	Bore Construction
0		SILT & SAND: red brown, fine grained moderately sorted sand SILCRETE & CALCRETE: pale grey, hard, low porosity CLAY		0-30m 8" diameter air rotary hammer drill-hole
10				0 - 30m annular seal
20		CLAY: red brown		+0.3 - 30m 8" PVC collar
30				
40				
50				
60				
70				
80				
90				
100				
110				
120				

GROUNDWATER
RESOURCE MANAGEMENT

PO Box 244 Bayswater WA 6933
15 Harborne Street
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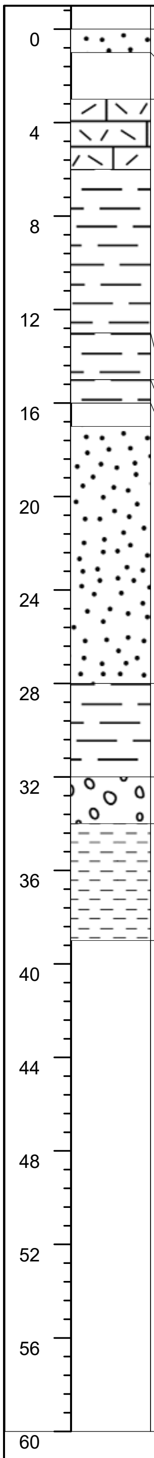
ID: **MWH003 (PC06)**

JOB NUMBER: J1843

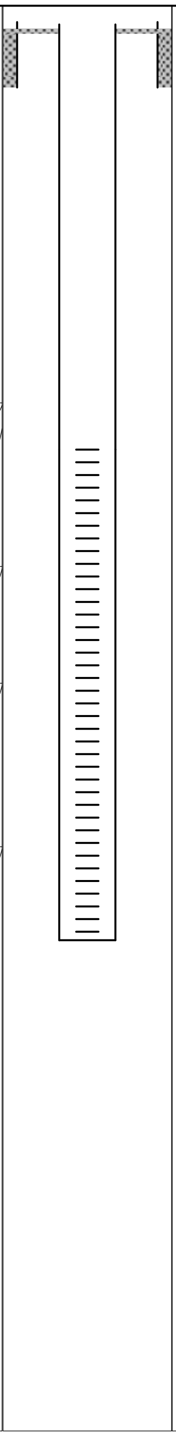
CLIENT: Audalia Resources Limited

PROJECT: Lake Medcalf

COMMENCED:	Sep-19	EASTING:	298,050	INCLINATION:	90 degrees
COMPLETED:	Sep-19	NORTHING:	6,398,330	AZIMUTH:	NA degrees
DRILLED BY:	Harrington	ELEVATION:	NA	SWL (date):	6.48 mbtoc (17-Sep-19)
LOGGED BY:	RFT	GRID SYSTEM:	MGA, Zn 51		



Lithological Description	Field Notes	Bore Construction
SILT & SAND: red brown, fine grained moderately sorted sand		0-2.5m 8" diameter drill-hole 0-2.5m annular seal +0.3-2.5m 6.5" PVC collar
SILCRETE & CLAY: pale grey, hard, low porosity		2.5- 39m 4" diameter aircore drill-hole
CLAY: brown - red		+0.3 - 18m 50mm ND class 9 uPVC casing
CLAY: brown - grey damp dense plastic	16m Groundwater intersect	
CLAY: grey wet sloppy		
SAND: grey, well sorted, medium grain size, rounded	17m: Flow 4L/s, EC 73.2mS/cm, pH 4.46, temp 19°C 23m: Flow 4L/s, EC 67.12mS/cm, pH 4.63, temp 20°C	
CLAY: cream, dense plastic	28m: Flow 4L/s, EC 89.75mS/cm, pH 5, temp 23.4°C	18 - 27, 33 - 39m 50mm ND class 9 uPVC slotted casing (1mm slots)
GRAVEL: mg-cg dry		
SAPROCK: pale green ultramafics, weathered to BR	35m: Flow 1.8L/s, EC 125.58mS/cm, pH 5.02, temp 21.5°C	
		39m end cap

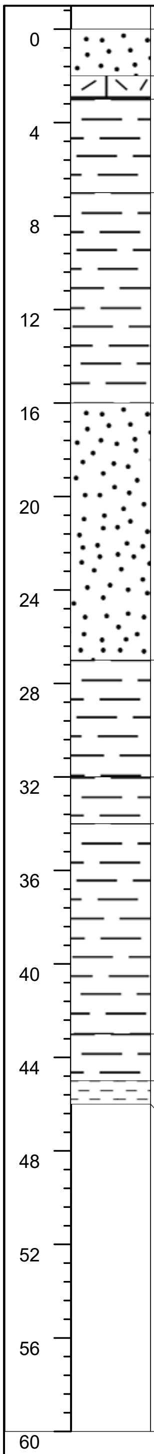


GROUNDWATER
RESOURCE MANAGEMENT

PO Box 244 Bayswater WA 6933
15 Harborne Street
Wembley WA 6014
Ph: +61 8 9433 2222 Fx: +61 8 9433 2322
Email: water@g-r-m.com.au

ID:	**MWH004 (PC08)**	JOB NUMBER:	J1843
CLIENT:	Audalia Resources Limited	PROJECT:	Lake Medcalf

COMMENCED:	Sep-19	EASTING:	297,950	INCLINATION:	90 degrees
COMPLETED:	Sep-19	NORTHING:	6,398,330	AZIMUTH:	NA degrees
DRILLED BY:	Harrington	ELEVATION:	NA	SWL (date):	7.2 mbtoc (17-Sep-19)
LOGGED BY:	RFT	GRID SYSTEM:	MGA, Zn 51		



Lithological Description	Field Notes	Bore Construction
SILT & SAND: red brown, fine grained moderately sorted sand		
SILCRETE & CLAY: cream, hard		
CLAY: cream, friable, damp		
CLAY: brown - grey damp dense plastic		
SAND: grey, well sorted, medium grain size, rounded	18m Groundwater intersect 19m: Flow 4.5L/s, EC 90.7mS/cm, pH 4.87, temp 19°C 23m: Flow 5L/s, EC 82.08mS/cm, pH 4.75, temp 19.6°C	
CLAY: cream, dense plastic		0- 45m 4" diameter aircore drill-hole
CLAY: grey, dense plastic		
CLAY: red - brown, dense plastic		
CLAY: khaki, saprolitic		
SAPROCK: pale green ultramafics, weathered to BR		

GROUNDWATER
RESOURCE MANAGEMENT

PO Box 244 Bayswater WA 6933
15 Harborne Street
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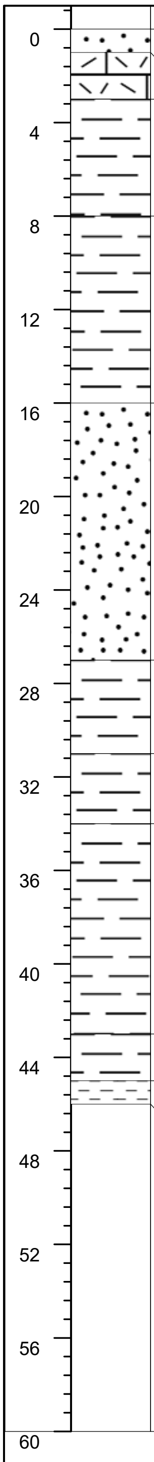
Email: water@g-r-m.com.au

ID:	**MWH005 (PC07)**	JOB NUMBER:	J1843
CLIENT:	Audalia Resources Limited	PROJECT:	Lake Medcalf

COMMENCED:	Sep-19	EASTING:	298,000	INCLINATION:	90 degrees
COMPLETED:	Sep-19	NORTHING:	6,398,330	AZIMUTH:	NA degrees
DRILLED BY:	Harrington	ELEVATION:	NA	SWL (date):	6.7 mbtoc (17-Sep-19)
LOGGED BY:	RFT	GRID SYSTEM:	MGA, Zn 51		

Depth (m bgl)	Graphic + Stratigraphy	Lithological Description	Field Notes	Bore Construction



Lithological Description	Field Notes
SILT & SAND: red brown, fine grained moderately sorted sand	
SILCRETE & CLAY: cream, hard	
CLAY: brown - grey damp dense plastic	
CLAY: grey damp	
SAND: grey, well sorted, medium grain size, rounded	18m Groundwater intersect 19m: Flow 4L/s, EC 61.4mS/cm, pH 5.07, temp 22.8C 23m: Flow 5L/s, EC 66.3mS/cm, pH 4.97, temp 21.6C
CLAY: cream, dense plastic	
CLAY: pale brown, dense plastic	
CLAY: red - brown, dense plastic	
CLAY: khaki, saprolitic	
SAPROCK: pale green ultramafics, weathered to BR	

Bore Construction: 0- 46m 4" diameter aircore drill-hole

GROUNDWATER
RESOURCE MANAGEMENT

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15 Harborne Street
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Ph: +61 8 9433 2222 Fx: +61 8 9433 2322
Email: water@g-r-m.com.au

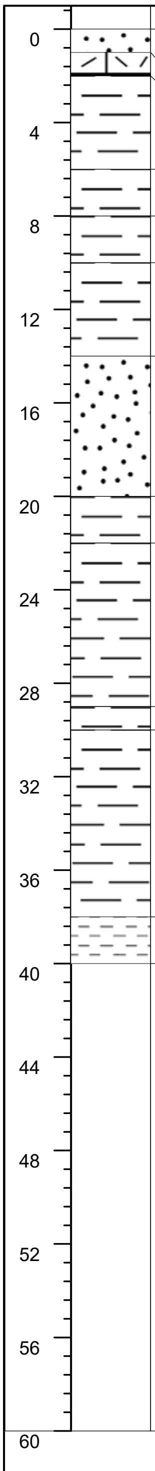
ID: **MWH006 (PC10)**

JOB NUMBER: J1843

CLIENT: Audalia Resources Limited

PROJECT: Lake Medcalf

COMMENCED:	Sep-19	EASTING:	297,850	INCLINATION:	90 degrees
COMPLETED:	Sep-19	NORTHING:	6,398,330	AZIMUTH:	NA degrees
DRILLED BY:	Harrington	ELEVATION:	NA	SWL (date):	7.1 mbtoc (17-Sep-19)
LOGGED BY:	RFT	GRID SYSTEM:	MGA, Zn 51		



Lithological Description	Field Notes	Bore Construction
SILT & SAND: red brown, fine grained moderately sorted sand		
SILCRETE & CLAY: cream, hard		
CLAY: brown - grey damp dense plastic		
CLAY: red - brown -purple, dense plastic		
CLAY: red - brown, dense plastic		
CLAY: khaki		
SAND: grey, well sorted, medium grain size, rounded		0- 30m 4" diameter aircore drill-hole
CLAY: cream - grey, dense plastic		
CLAY: pale brown, dense plastic		
CLAY: red - brown, dense plastic		
CLAY: pale green silty sands, very minor aquifer		
SAPROCK: pale green ultramafics, weathered to BR	38m Groundwater intersect 39m: Flow 0.5L/s, EC 99.12mS/cm, pH 4.91, temp 21.2°C	

GROUNDWATER
RESOURCE MANAGEMENT

PO Box 244 Bayswater WA 6933
15 Harborne Street
Wembley WA 6014
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Email: water@g-r-m.com.au

ID: **MWH007 (PC01)**

JOB NUMBER: J1843

CLIENT: Audalia Resources Limited

PROJECT: Lake Medcalf

COMMENCED: Sep-19	EASTING: 296,450	INCLINATION: 90 degrees
COMPLETED: Sep-19	NORTHING: 6,400,157	AZIMUTH: NA degrees
DRILLED BY: Harrington	ELEVATION: NA	SWL (date): 4.49 mbtoc (20-Sep-19)
LOGGED BY: RFT	GRID SYSTEM: MGA, Zn 51	

Depth (m bgl)	Graphic + Stratigraphy	Lithological Description	Field Notes	Bore Construction
0		CLAY: brown - grey damp dense plastic		
4		CLAY: light brown , dense plastic		
8		CLAY: light brown , dense plastic		
12				
16				
20		CLAY: cream, damp		
24				0- 55m 4" diameter aircore drill-hole
28		CLAY: cream, slop		
32				
36				
40		CLAY: grey, dense plastic		
44				
		CLAY: grey loose		
48		CLAY: grey, dense plastic		
52		SAPROCK: grey - green ultramafics, weathered to BR		
56				
60				

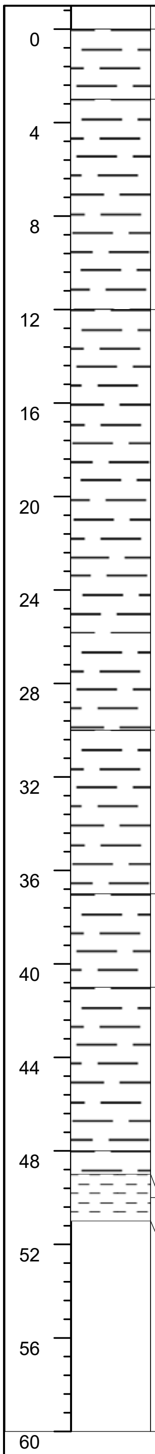
GROUNDWATER
RESOURCE MANAGEMENT

PO Box 244 Bayswater WA 6933
15 Harborne Street
Wembley WA 6014
Ph: +61 8 9433 2222 Fx: +61 8 9433 2322
Email: water@g-r-m.com.au

ID:	**MWH008 (PC02)**	JOB NUMBER:	J1843
CLIENT:	Audalia Resources Limited	PROJECT:	Lake Medcalf

COMMENCED:	Sep-19	EASTING:	296,400	INCLINATION:	90 degrees
COMPLETED:	Sep-19	NORTHING:	6,400,157	AZIMUTH:	NA degrees
DRILLED BY:	Harrington	ELEVATION:	NA	SWL (date):	6.35 mbtoc (20-Sep-19)
LOGGED BY:	RFT	GRID SYSTEM:	MGA, Zn 51		

Depth (m bgl)	Graphic + Stratigraphy	Lithological Description	Field Notes	Bore Construction



CLAY: brown - grey damp dense plastic

CLAY: light brown , dense plastic

CLAY: cream, damp

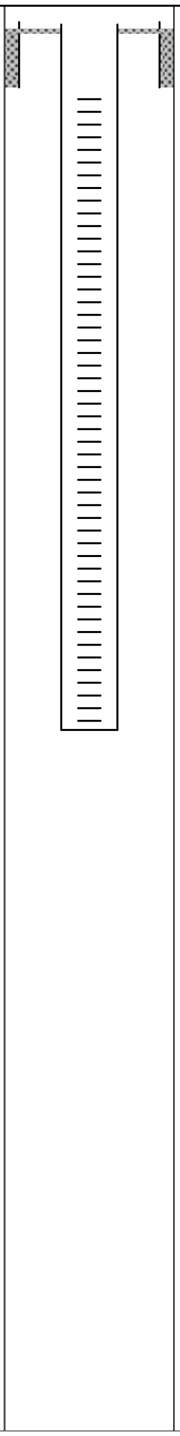
CLAY: cream - pale brown

CLAY: cream - grey

CLAY: grey loose

CLAY: grey, dense plastic

SAPROLITIC CLAY: grey - green ultramafics, weathered to BR



0-2.5m 8" diameter drill-hole
0-2.5m annular seal
+0.3-2.5m 6.5" PVC collar
+0.3 - 3m 50mm ND class 9 uPVC casing

2.5- 51m 4" diameter aircore drill-hole

3-30m 50mm ND class 9 uPVC slotted casing (1mm slots)

30m end cap

30-51m fallback

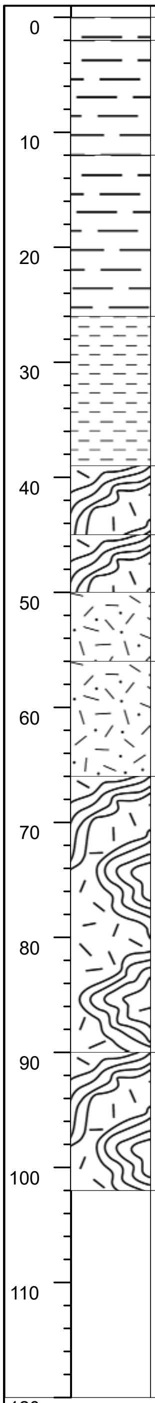
GROUNDWATER
RESOURCE MANAGEMENT

PO Box 244 Bayswater WA 6933
15 Harborne Street
Wembley WA 6014
Ph: +61 8 9433 2222 Fx: +61 8 9433 2322
Email: water@g-r-m.com.au

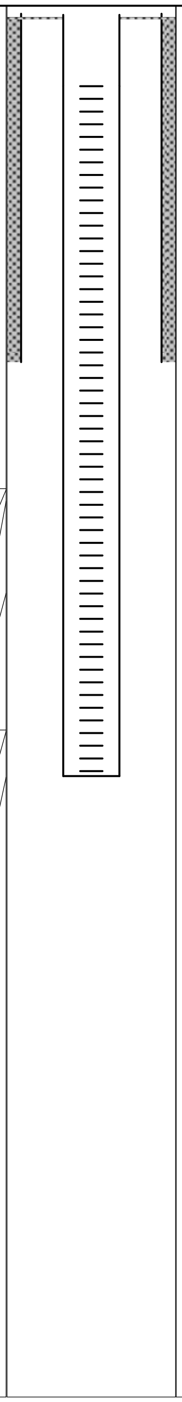
ID:	**MWH009 (D801)**	JOB NUMBER:	J1843
CLIENT:	Audalia Resources Limited	PROJECT:	Lake Medcalf

COMMENCED:	Sep-19	EASTING:	296,078	INCLINATION:	90 degrees
COMPLETED:	Sep-19	NORTHING:	6,399,750	AZIMUTH:	NA degrees
DRILLED BY:	Harrington	ELEVATION:	NA	SWL (date):	9.45 mbtoc (27-Sep-19)
LOGGED BY:	RFT	GRID SYSTEM:	MGA, Zn 51		

Depth (m bgl) | Graphic + Stratigraphy | Lithological Description | Field Notes | Bore Construction



Lithological Description	Field Notes
CLAY: brown - grey damp dense plastic	
CLAY: light brown , dense plastic	
CLAY: pale brown, damp	
SAPROLITE: blue - dark grey, weathered	
ULTRAMAFIC: dark blue - grey, fractured 41-44, minor gw	41m Groundwater intersect
ULTRAMAFIC: dark blue - grey	42m: Flow 0L/s, EC 89.75mS/cm, pH 7.4, temp 25.1°C
GRANODIORITE: pink - grey, fractured gw zone	50m: Flow 0L/s, EC 89.75mS/cm, pH 7.61, temp 25.4°C
GRANODIORITE: dark blue - grey - pink,56m & 62m fractured, gw significant increase	62m: Flow 13L/s, EC 197.45mS/cm, pH 7.4, temp 25.4°C
ULTRAMAFIC: dark blue - grey	66m: Flow 14L/s, EC 268.8mS/cm, pH 7.4, temp 25.6°C
ULTRAMAFIC: dark blue - grey	



+0.2 - 6m 50mm ND class 9 uPVC casing

0-30m 8" diameter air rotary hammer drill-hole

0 - 30m annular seal

+0.3 - 30m 8" PVC collar

6 - 66m 50mm ND class 9 uPVC slotted casing (1mm slots)

66m end cap

30-102m 5.25" percussion drill-hole

GROUNDWATER
RESOURCE MANAGEMENT

PO Box 244 Bayswater WA 6933
15 Harborne Street
Wembley WA 6014
Ph: +61 8 9433 2222 Fx: +61 8 9433 2322
Email: water@g-r-m.com.au

ID: **MWH010 (D201)**

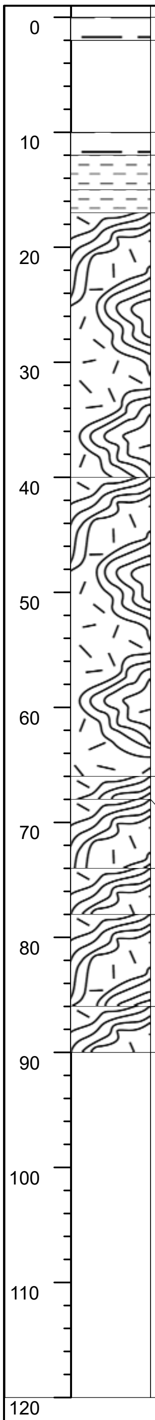
JOB NUMBER: J1843

CLIENT: Audalia Resources Limited

PROJECT: Lake Medcalf

COMMENCED:	Sep-19	EASTING:	291,930	INCLINATION:	90 degrees
COMPLETED:	Sep-19	NORTHING:	6,398,230	AZIMUTH:	NA degrees
DRILLED BY:	Harrington	ELEVATION:	NA	SWL (date):	>66 mbtoc (26-Sep-19)
LOGGED BY:	RFT	GRID SYSTEM:	MGA, Zn 51		

Depth (m bgl)	Graphic + Stratigraphy	Lithological Description	Field Notes	Bore Construction



CLAY: brown - grey damp dense plastic

CLAY: light brown , dense plastic

SAPROLITE: brown

SAPROCK: blue - grey weathered

ULTRAMAFIC: dark blue - grey, fractured

ULTRAMAFIC: dark blue - grey, fractured

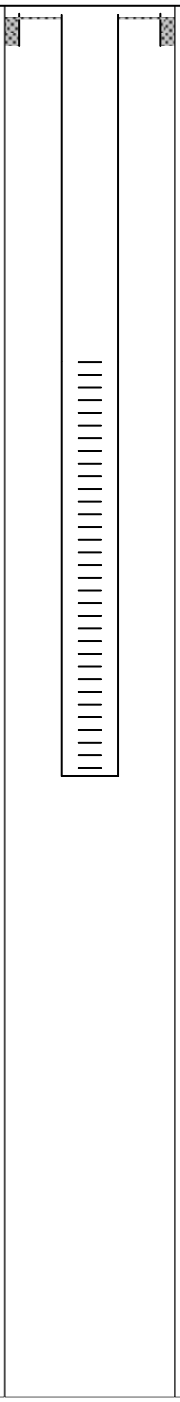
ULTRAMAFIC: dark blue - grey, fractured, quartz veins, porphyry

ULTRAMAFIC: dark blue - grey, fractured, mottled

ULTRAMAFIC: dark blue - grey, feldspar-quartz veins

ULTRAMAFIC: black, mottled

ULTRAMAFIC: black, unoxidised



0-2.5m 8" diameter air rotary hammer drill-hole
0 - 2.5m annular seal
+0.3 - 2.5m 8" PVC collar

+0.2 - 30m 50mm ND class 9 uPVC casing

30 - 66m 50mm ND class 9 uPVC slotted casing (1mm slots)

66m end cap

2.5-90m 5.25" percussion drill-hole

GROUNDWATER
RESOURCE MANAGEMENT

PO Box 244 Bayswater WA 6933
15 Harborne Street
Wembley WA 6014
Ph: +61 8 9433 2222 Fx: +61 8 9433 2322
Email: water@g-r-m.com.au

ID: **MWH011 (D401)**

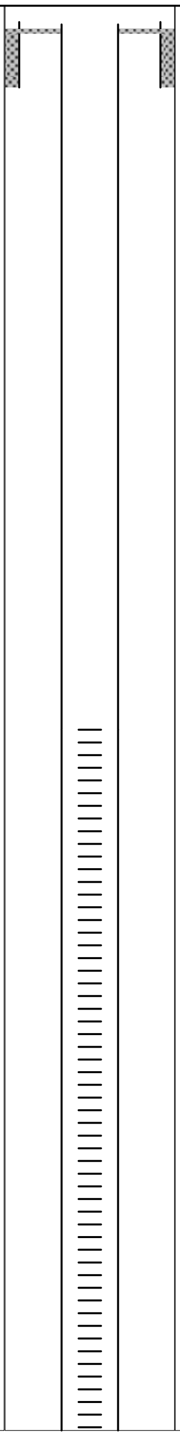
JOB NUMBER: J1843

CLIENT: Audalia Resources Limited

PROJECT: Lake Medcalf

COMMENCED:	Sep-19	EASTING:	295,211	INCLINATION:	90 degrees
COMPLETED:	Sep-19	NORTHING:	6,398,236	AZIMUTH:	NA degrees
DRILLED BY:	Harrington	ELEVATION:	NA	SWL (date):	45 mbtoc (27-Sep-19)
LOGGED BY:	RFT	GRID SYSTEM:	MGA, Zn 51		

Depth (m bgl)	Graphic + Stratigraphy	Lithological Description	Field Notes	Bore Construction
0		CLAY: brown - grey damp dense plastic		0-2.5m 8" diameter air rotary hammer drill-hole 0 - 2.5m annular seal +0.3 - 2.5m 8" PVC collar
4				
8				
		CLAY: light brown , dense plastic		
12		CLAY: brown, damp		
		SAPROCK: blue - grey weathered		
16				
20				+0.2 - 30m 50mm ND class 9 uPVC casing
24				
28				
32				
36		ULTRAMAFIC: dark blue - grey, fractured, minor gw		
40				
44				30 - 66m 50mm ND class 9 uPVC slotted casing (1mm slots)
48				
52				
56				
60				

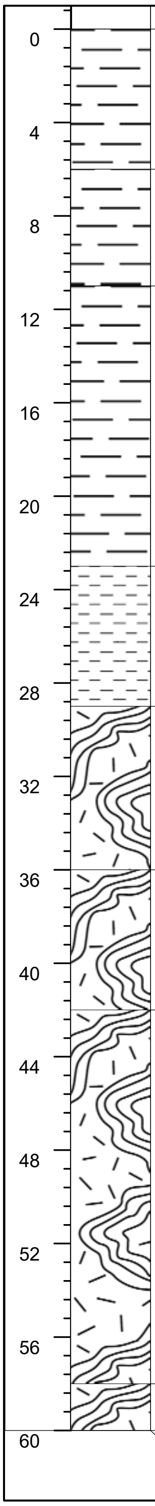


GROUNDWATER
RESOURCE MANAGEMENT

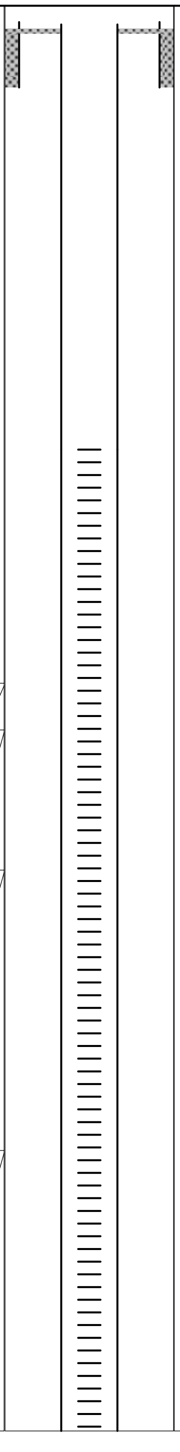
PO Box 244 Bayswater WA 6933
15 Harborne Street
Wembley WA 6014
Ph: +61 8 9433 2222 Fx: +61 8 9433 2322
Email: water@g-r-m.com.au

ID:	**MWH012 (DB03)**	JOB NUMBER:	J1843
CLIENT:	Audalia Resources Limited	PROJECT:	Lake Medcalf

COMMENCED:	Sep-19	EASTING:	295,975	INCLINATION:	90 degrees
COMPLETED:	Sep-19	NORTHING:	6,397,085	AZIMUTH:	NA degrees
DRILLED BY:	Harrington	ELEVATION:	NA	SWL (date):	23.48 mbtoc (27-Sep-19)
LOGGED BY:	RFT	GRID SYSTEM:	MGA, Zn 51		



Lithological Description	Field Notes	Bore Construction
CLAY: brown - grey damp dense plastic		0-6m 8" diameter air rotary hammer drill-hole 0 - 6m annular seal +0.3 - 6m 8" PVC collar
CLAY: light brown , dense plastic		
CLAY: brown, damp		+0.2 - 18m 50mm ND class 9 uPVC casing
SAPROCK: khaki, blue - grey weathered, fractured 29m aquifer		
ULTRAMAFIC: porphyry textures dark blue - grey, fractured, major fractured aquifer	29m Groundwater intersect 29m: Flow 2L/s, EC 53.85mS/cm, pH 8.18, temp 22.1°C	
ULTRAMAFIC: pale green, Serpeninite, porphyry textures dark blue - grey, fractured, major fractured aquifer	36m: Flow 5L/s, EC 48.09mS/cm, pH 8.41, temp 23.1°C	18 - 54m 50mm ND class 9 uPVC slotted casing (1mm slots)
ULTRAMAFIC: grey, porphyry textures dark blue - grey, fractured, major fractured aquifer	48m: Flow 8L/s, EC 55.92mS/cm, pH 8.12, temp 23.5°C	54m end cap
ULTRAMAFIC: dark grey, porphyry textures dark blue - grey, fractured, major fractured aquifer, SULPHIDES, Ni, SERPENTINISATION		



GROUNDWATER
RESOURCE MANAGEMENT

PO Box 244 Bayswater WA 6933
15 Harborne Street
Wembley WA 6014
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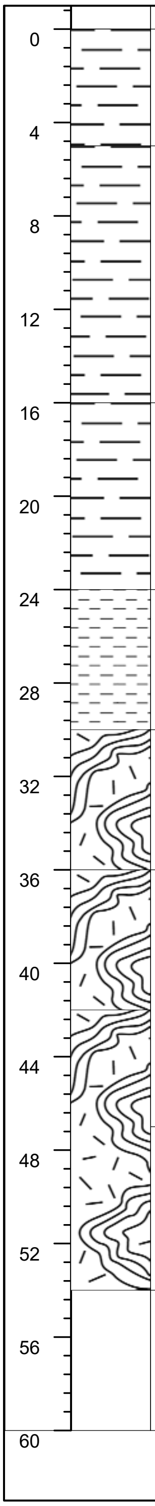
Email: water@g-r-m.com.au

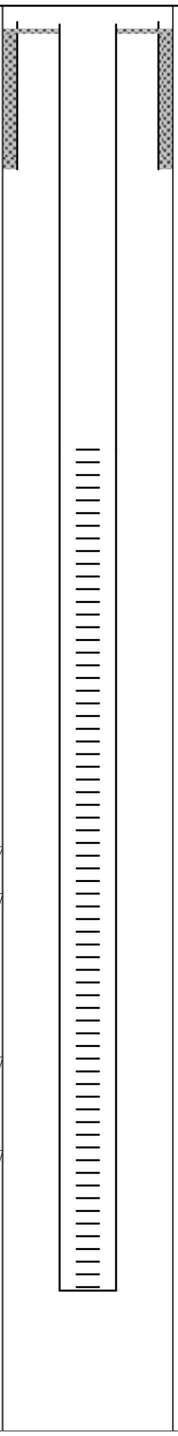
ID:	**MWH013 (DB04)**	JOB NUMBER:	J1843
CLIENT:	Audalia Resources Limited	PROJECT:	Lake Medcalf

COMMENCED:	Oct-19	EASTING:	295,935	INCLINATION:	90 degrees
COMPLETED:	Oct-19	NORTHING:	6,397,125	AZIMUTH:	NA degrees
DRILLED BY:	Harrington	ELEVATION:	NA	SWL (date):	mbtoc ( )
LOGGED BY:	RFT	GRID SYSTEM:	MGA, Zn 51		

Depth (m bgl)	Graphic + Stratigraphy	Lithological Description	Field Notes	Bore Construction



CLAY: brown - grey damp dense plastic		0-6m 8" diameter air rotary hammer drill-hole 0 - 6m annular seal +0.3 - 6m 8" PVC collar
CLAY: light brown , dense plastic		
CLAY: brown - khaki, damp		+0.2 - 18m 50mm ND class 9 uPVC casing
SAPROCK: khaki, blue - grey weathered, fractured 29m aquifer		
ULTRAMAFIC: pyroxenite, dark blue - grey	36m Groundwater intersect	
ULTRAMAFIC: pyroxenite, dark grey, Pyrrhotite, Magnetite, dark - grey, fractured, major fractured aquifer	36m: Flow 4L/s, EC 48.45mS/cm, pH 8.05, temp 22°C 44m: Flow 6L/s, EC 51.15mS/cm, pH 8.03, temp 22.1°C	18 - 54m 50mm ND class 9 uPVC slotted casing (1mm slots)
ULTRAMAFIC: pyroxenite, dark grey, Pyrrhotite, Magnetite, dark - grey, fractured, major fractured aquifer	48m: Flow 6L/s, EC 49.68mS/cm, pH 7.8, temp 22°C	6-54m 5.25" percussion drill-hole
		54m end cap



GROUNDWATER
RESOURCE MANAGEMENT

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15 Harborne Street
Wembley WA 6014
Ph: +61 8 9433 2222 Fx: +61 8 9433 2322
Email: water@g-r-m.com.au

ID: **MWH014 (DB01)**

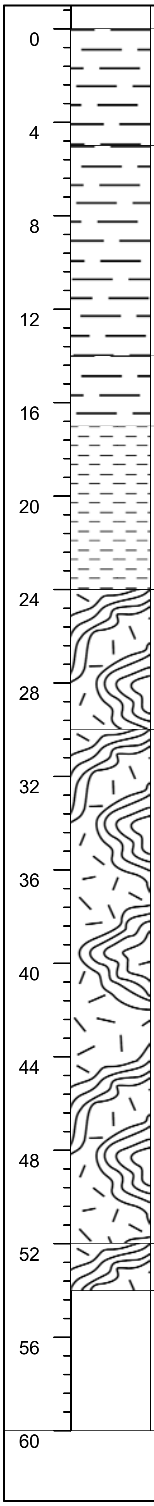
JOB NUMBER: J1843

CLIENT: Audalia Resources Limited

PROJECT: Lake Medcalf

COMMENCED:	Oct-19	EASTING:	295,975	INCLINATION:	90 degrees
COMPLETED:	Oct-19	NORTHING:	6,397,125	AZIMUTH:	NA degrees
DRILLED BY:	Harrington	ELEVATION:	NA	SWL (date):	mbtoc ( )
LOGGED BY:	RFT	GRID SYSTEM:	MGA, Zn 51		

Depth (m bgl)	Graphic + Stratigraphy	Lithological Description	Field Notes	Bore Construction



CLAY: brown - grey damp dense plastic

CLAY: light brown , dense plastic

CLAY: brown - khaki, damp

SAPROCK: khaki, blue - grey weathered, fractured
29m aquifer

ULTRAMAFIC: pyroxenite, dark blue - grey, fractured, fractured aquifer

ULTRAMAFIC: pyroxenite, dark grey, Pyrrhotite, Magnetite, dark - grey, fractured, major fractured aquifer

ULTRAMAFIC: grey, porphyry textures dark blue - grey, fractured, major fractured aquifer

30m Groundwater intersect

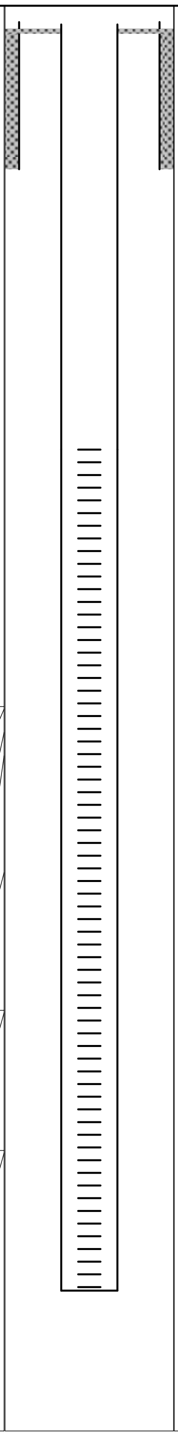
30m: Flow 0.3L/s, EC 51.6mS/cm, pH 8.3, temp 19.6°C

31m: Flow 2.5L/s, EC 49.53mS/cm, pH 8.52, temp 19.3°C

36m: Flow 4L/s, EC 53.1mS/cm, pH 8.27, temp 20.2°C

42m: Flow 7L/s, EC 51.78mS/cm, pH 8.24, temp 19.2°C

48m: Flow 7L/s, EC 55.35mS/cm, pH 8.62, temp 19.6C



0-6m 8" diameter air rotary hammer drill-hole
0 - 6m annular seal
+0.3 - 6m 8" PVC collar

+0.2 - 18m 50mm ND class 9 uPVC casing

18 - 54m 50mm ND class 9 uPVC slotted casing (1mm slots)

6-54m 5.25" percussion drill-hole

54m end cap

SIEVE ANALYSIS RESULTS

ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS

Contact	Kathy McDougall
Client	Groundwater Resource Management
Address	PO Box 8110 Fremantle High Street, Fremantle, WA, 6160 23 Parry Street Fremantle 6160 KARDINYA WA
Telephone	9433 2222
Facsimile	9433 2322
Email	kathy@g-r-m.com.au
Project	**Audalia Lake Medcalf**
Order Number	**J1843**
Samples	1

LABORATORY DETAILS

Manager	Marjana Siljanoska
Laboratory	SGS Perth Environmental
Address	28 Reid Rd Perth Airport WA 6105
Telephone	(08) 9373 3500
Facsimile	(08) 9373 3556
Email	au.environmental.perth@sgs.com
SGS Reference	**PE138252A R0**
Date Received	01 Oct 2019
Date Reported	15 Oct 2019

COMMENTS

Accredited for compliance with ISO/IEC 17025 - Testing. NATA accredited laboratory 2562(898/20210).

SIGNATORIES

Tommy CHENG
ICP Chemist

		Sample Number	PE138252A.007
		Sample Matrix	Soil
		Sample Date	13 Sep 2019
		Sample Name	PC06 22-28m
Parameter	Units	LOR	

Particle sizing of soils by sieving Method: AN005 Tested: 11/10/2019

Passing 9.5mm	%w/w	1	98
Retained 9.5mm	%w/w	1	2
Passing 4.75mm	%w/w	1	97
Retained 4.75mm	%w/w	1	3
Passing 2.36mm	%w/w	1	94
Retained 2.36mm	%w/w	1	6
Passing 1.18mm	%w/w	1	81
Retained 1.18mm	%w/w	1	19
Passing 710µm	%w/w	1	58
Retained 710µm	%w/w	1	42
Passing 600µm	%w/w	1	50
Retained 600µm	%w/w	1	50
Passing 425µm	%w/w	1	35
Retained 425µm	%w/w	1	65
Passing 300µm	%w/w	1	23
Retained 300µm	%w/w	1	77
Passing 150µm	%w/w	1	6
Retained 150µm	%w/w	1	94
Passing 75µm	%w/w	1	<1
Retained 75µm	%w/w	1	100

QC SUMMARY

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage.* Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

No QC samples were reported for this job.

METHOD SUMMARY

METHOD	METHODOLOGY SUMMARY
AN005	The particle size distribution of a soil is determined by wet sieving, using a maximum of 900 mL of deionised water to sieve all fractions down to 75 µm. Referenced to AS1289.3.6.1 and AS1141.11.

FOOTNOTES

IS	Insufficient sample for analysis.	LOR	Limit of Reporting
LNR	Sample listed, but not received.	↑↓	Raised or Lowered Limit of Reporting
*	NATA accreditation does not cover the performance of this service.	QFH	QC result is above the upper tolerance
**	Indicative data, theoretical holding time exceeded.	QFL	QC result is below the lower tolerance
		-	The sample was not analysed for this analyte
		NVL	Not Validated

Unless it is reported that sampling has been performed by SGS, the samples have been analysed as received.
Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calcuated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the " Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

Results reported for samples tested under test methods with codes starting with ARS-SOP, radionuclide or gross radioactivity concentrations are expressed in becquerel (Bq) per unit of mass or volume or per wipe as stated on the report. Becquerel is the SI unit for activity and equals one nuclear transformation per second.
Note that in terms of units of radioactivity:
a. 1 Bq is equivalent to 27 pCi
b. 37 MBq is equivalent to 1 mCi

For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

The QC and MU criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here: www.sgs.com.au.pv.sgsvr/en-gb/environment.

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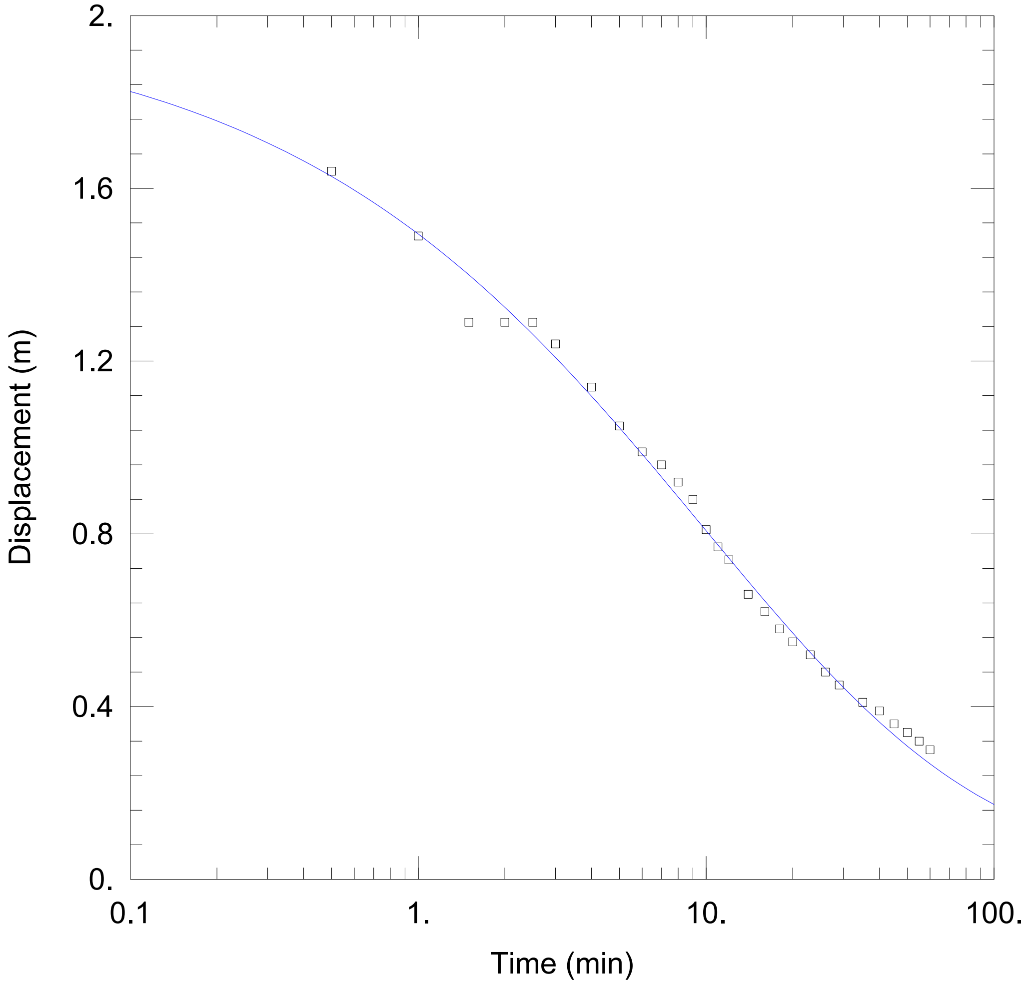
SLUG TEST ANALYSIS



PC02

Data Set: E:\...\PC02 coop.aqt
Date: 11/10/19 Time: 09:40:44

PROJECT INFORMATION

Company: GRM
Client: Audalia Resources Limited
Project: J1843
Location: Lake Medcalf
Test Well: PC02
Test Date: 12 Oct 2019

AQUIFER DATA

Saturated Thickness: 44.65 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (PC02)

Initial Displacement: 2. m
Static Water Column Height: 44.65 m
Total Well Penetration Depth: 44.65 m
Screen Length: 44.65 m
Casing Radius: 0.025 m
Well Radius: 0.0609 m

SOLUTION

Aquifer Model: Confined
Solution Method: Cooper-Bredehoeft-Papadopulos

T = 0.02496 m^2/day
S = 0.1

APPENDIX H

LABORATORY ANALYSIS

ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS

Contact	Kathy McDougall
Client	Groundwater Resource Management
Address	PO Box 8110 Fremantle High Street, Fremantle, WA, 6160 23 Parry Street Fremantle 6160 KARDINYA WA
Telephone	9433 2222
Facsimile	9433 2322
Email	kathy@g-r-m.com.au
Project	**Audalia Lake Medcalf**
Order Number	**J1843**
Samples	6

LABORATORY DETAILS

Manager	Marjana Siljanoska
Laboratory	SGS Perth Environmental
Address	28 Reid Rd Perth Airport WA 6105
Telephone	(08) 9373 3500
Facsimile	(08) 9373 3556
Email	au.environmental.perth@sgs.com
SGS Reference	**PE138252 R0**
Date Received	01 Oct 2019
Date Reported	09 Oct 2019

COMMENTS

Accredited for compliance with ISO/IEC 17025 - Testing. NATA accredited laboratory 2562(898/20210).

Metals: The over range results on ICPMS Method AN318 were reported using ICPOES method AN320.

The upper limit for Conductivity in Water is 100,000 uS/cm. Any result above this is an estimate. This will also cause the TDS on EC ratio to bias high.

SIGNATORIES

Hue Thanh LY
Metals Team Leader

LouiseHope

Louise HOPE
Laboratory Technician

Mary Ann OLA-A
Inorganics Team Leader

Murray O'NEILL
Lab Technician-Nutrients Signatory

Ohmar DAVID
Metals Chemist

Parameter	Units	LOR	PE138252.001 Water 13 Sep 2019 PC06 top	PE138252.002 Water 13 Sep 2019 PC06 bottom	PE138252.003 Water 10 Sep 2019 D501	PE138252.004 Water 23 Sep 2019 D801

Sample Number / Sample Matrix / Sample Date / Sample Name

pH in water Method: AN101 Tested: 1/10/2019

pH**	pH Units	0.1	3.7	3.8	7.2	7.0

Conductivity and TDS by Calculation - Water Method: AN106 Tested: 1/10/2019

Conductivity @ 25 C	µS/cm	2	100000	110000	140000	170000

Total Dissolved Solids (TDS) in water Method: AN113 Tested: 3/10/2019

Total Dissolved Solids Dried at 175-185°C	mg/L	10	76000	85000	120000	160000

Alkalinity Method: AN135 Tested: 1/10/2019

Total Alkalinity as CaCO3	mg/L	5	<5	<5	150	96
Carbonate Alkalinity as CO3	mg/L	1	<1	<1	<1	<1
Bicarbonate Alkalinity as HCO3	mg/L	5	<5	<5	180	120

Chloride by Discrete Analyser in Water Method: AN274 Tested: 7/10/2019

Chloride, Cl	mg/L	1	39000	45000	63000	90000

Sulfate in water Method: AN275 Tested: 7/10/2019

Sulfate, SO4	mg/L	1	8900	11000	12000	15000

		Sample Number	PE138252.001	PE138252.002	PE138252.003	PE138252.004
		Sample Matrix	Water	Water	Water	Water
		Sample Date	13 Sep 2019	13 Sep 2019	10 Sep 2019	23 Sep 2019
		Sample Name	PC06 top	PC06 bottom	D501	D801
Parameter	**Units**	**LOR**				
Metals in Water (Dissolved) by ICPOES Method: AN320 Tested: 3/10/2019						
Calcium, Ca	mg/L	0.2	240	290	450	700
Magnesium, Mg	mg/L	0.1	3400	4000	4700	6600
Potassium, K	mg/L	0.1	260	230	340	540
Soluble Silicon as Silica, SiO2	mg/L	0.05	87	64	9.8	19
Sodium, Na	mg/L	0.5	18000	22000	34000	44000
Total Hardness by Calculation	mg CaCO3/L	1	14000	17000	20000	29000
Trace Metals (Dissolved) in Water by ICPMS Method: AN318 Tested: 3/10/2019						
Aluminium, Al	μg/L	5	63000	16000	<250↑	<500↑
Iron, Fe	μg/L	5	54000	86000	<250↑	3400
Manganese, Mn	μg/L	1	1400	2000	2100	2600
Nitrate Nitrogen and Nitrite Nitrogen (NOx) by FIA Method: AN258 Tested: 4/10/2019						
Nitrate, NO_3 as NO_3	mg/L	0.2	<0.2	<0.2	0.4	0.3

Parameter	Units	LOR	PE138252.005 Water 25 Sep 2019 DB03	PE138252.006 Water 05 Sep 2019 KJC34
Sample Number			PE138252.005	PE138252.006
Sample Matrix			Water	Water
Sample Date			25 Sep 2019	05 Sep 2019
Sample Name			DB03	KJC34

pH in water Method: AN101 Tested: 1/10/2019

pH**	pH Units	0.1	7.6	7.7

Conductivity and TDS by Calculation - Water Method: AN106 Tested: 1/10/2019

Conductivity @ 25 C	µS/cm	2	89000	54000

Total Dissolved Solids (TDS) in water Method: AN113 Tested: 3/10/2019

Total Dissolved Solids Dried at 175-185°C	mg/L	10	62000	36000

Alkalinity Method: AN135 Tested: 1/10/2019

Total Alkalinity as CaCO3	mg/L	5	420	630
Carbonate Alkalinity as CO3	mg/L	1	<1	<1
Bicarbonate Alkalinity as HCO3	mg/L	5	520	760

Chloride by Discrete Analyser in Water Method: AN274 Tested: 7/10/2019

Chloride, Cl	mg/L	1	36000	19000

Sulfate in water Method: AN275 Tested: 7/10/2019

Sulfate, SO4	mg/L	1	5700	4200

		Sample Number	PE138252.005	PE138252.006
		Sample Matrix	Water	Water
		Sample Date	25 Sep 2019	05 Sep 2019
		Sample Name	DB03	KJC34
Parameter	Units	LOR		

Metals in Water (Dissolved) by ICPOES Method: AN320 Tested: 3/10/2019

Calcium, Ca	mg/L	0.2	**980**	**570**
Magnesium, Mg	mg/L	0.1	**2900**	**1700**
Potassium, K	mg/L	0.1	**200**	**110**
Soluble Silicon as Silica, SiO2	mg/L	0.05	**31**	**40**
Sodium, Na	mg/L	0.5	**17000**	**9400**
Total Hardness by Calculation	mg CaCO3/L	1	**14000**	**8300**

Trace Metals (Dissolved) in Water by ICPMS Method: AN318 Tested: 3/10/2019

Aluminium, Al	µg/L	5	<250↑	<100↑
Iron, Fe	µg/L	5	<250↑	<100↑
Manganese, Mn	µg/L	1	**1100**	**700**

Nitrate Nitrogen and Nitrite Nitrogen (NOx) by FIA Method: AN258 Tested: 4/10/2019

Nitrate, NO_3 as NO_3	mg/L	0.2	**0.3**	<0.2

QC SUMMARY

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage.* Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Alkalinity Method: ME-(AU)-[ENV]AN135

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Total Alkalinity as CaCO3	LB164465	mg/L	5	<5	0 - 1%	103 - 104%
Carbonate Alkalinity as CO3	LB164465	mg/L	1	<1		
Bicarbonate Alkalinity as HCO3	LB164465	mg/L	5	<5		

Chloride by Discrete Analyser in Water Method: ME-(AU)-[ENV]AN274

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Chloride, Cl	LB164618	mg/L	1	<1	0 - 5%	104%	107 - 112%

Conductivity and TDS by Calculation - Water Method: ME-(AU)-[ENV]AN106

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Conductivity @ 25 C	LB164479	µS/cm	2	<2	0%	98%

Metals in Water (Dissolved) by ICPOES Method: ME-(AU)-[ENV]AN320

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Calcium, Ca	LB164502	mg/L	0.2	<0.2	2%	93%	90%
Magnesium, Mg	LB164502	mg/L	0.1	<0.1	2%	93%	93%
Potassium, K	LB164502	mg/L	0.1	<0.1	1%	88%	85%
Soluble Silicon as Silica, SiO2	LB164502	mg/L	0.05	<0.05			
Sodium, Na	LB164502	mg/L	0.5	<0.5	5%	95%	95%
Total Hardness by Calculation	LB164502	mg CaCO3/L	1	<1			

pH in water Method: ME-(AU)-[ENV]AN101

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
pH**	LB164479	pH Units	0.1	5.7 - 5.8	0%	101%

QC SUMMARY

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage.* Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Sulfate in water Method: ME-(AU)-[ENV]AN275

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Sulfate, SO4	LB164618	mg/L	1	<1	0 - 1%	103 - 107%	103 - 113%

Total Dissolved Solids (TDS) in water Method: ME-(AU)-[ENV]AN113

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery	MSD %RPD
Total Dissolved Solids Dried at 175-185°C	LB164547	mg/L	10	<10	1%	103%	107%	4%

Trace Metals (Dissolved) in Water by ICPMS Method: ME-(AU)-[ENV]AN318

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Aluminium, Al	LB164496	µg/L	5	<5	2%	120%	NA
Iron, Fe	LB164496	µg/L	5	<5	1%	115%	NA
Manganese, Mn	LB164496	µg/L	1	<1	5%	104%	-336%

METHOD SUMMARY

METHOD	METHODOLOGY SUMMARY
	Nitrate and Nitrite by FIA: In an acidic medium, nitrate is reduced quantitatively to nitrite by cadmium metal. This nitrite plus any original nitrite is determined as an intense red-pink azo dye at 540 nm following diazotisation with sulphanilamide and subsequent coupling with N-(1-naphthyl) ethylenediamine dihydrochloride. Without the cadmium reduction only the original nitrite is determined. Reference APHA 4500-NO3- F.
AN101	pH in Soil Sludge Sediment and Water: pH is measured electrometrically using a combination electrode (glass plus reference electrode) and is calibrated against 3 buffers purchased commercially. For soils, an extract with water is made at a ratio of 1:5 and the pH determined and reported on the extract. Reference APHA 4500-H+.
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AN106	Salinity may be calculated in terms of NaCl from the sample conductivity. This assumes all soluble salts present, measured by the conductivity, are present as NaCl.
AN113	Total Dissolved Solids: A well-mixed filtered sample of known volume is evaporated to dryness at 180°C and the residue weighed. Approximate methods for correlating chemical analysis with dissolved solids are available. Reference APHA 2540 C.
AN113	The Total Dissolved Solids residue may also be ignited at 550 C and volatile TDS (Organic TDS) and non-volatile TDS (Inorganic) can be determined.
AN135	Alkalinity (and forms of) by Titration: The sample is titrated with standard acid to pH 8.3 (P titre) and pH 4.5 (T titre) and permanent and/or total alkalinity calculated. The results are expressed as equivalents of calcium carbonate or recalculated as bicarbonate, carbonate and hydroxide. Reference APHA 2320. Internal Reference AN135
AN274	Chloride by Aquakem DA: Chloride reacts with mercuric thiocyanate forming a mercuric chloride complex. In the presence of ferric iron, highly coloured ferric thiocyanate is formed which is proportional to the chloride concentration. Reference APHA 4500Cl-
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AN320	Metals by ICP-OES: Samples are preserved with 10% nitric acid for a wide range of metals and some non-metals. This solution is measured by Inductively Coupled Plasma. Solutions are aspirated into an argon plasma at 8000-10000K and emit characteristic energy or light as a result of electron transitions through unique energy levels. The emitted light is focused onto a diffraction grating where it is separated into components .
AN320	Photomultipliers or CCDs are used to measure the light intensity at specific wavelengths. This intensity is directly proportional to concentration. Corrections are required to compensate for spectral overlap between elements. Reference APHA 3120 B.
Calculation	Free and Total Carbon Dioxide may be calculated using alkalinity forms only when the samples TDS is <500mg/L. If TDS is >500mg/L free or total carbon dioxide cannot be reported. APHA4500CO2 D.

FOOTNOTES

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*	NATA accreditation does not cover the performance of this service.	QFH	QC result is above the upper tolerance
		QFL	QC result is below the lower tolerance
**	Indicative data, theoretical holding time exceeded.	-	The sample was not analysed for this analyte
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Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calcuated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the " Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

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Note that in terms of units of radioactivity:

a. 1 Bq is equivalent to 27 pCi
b. 37 MBq is equivalent to 1 mCi

For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

The QC and MU criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here: www.sgs.com.au.pv.sgsvr/en-gb/environment.

ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS		LABORATORY DETAILS	
Contact	Kathy McDougall	Manager	Marjana Siljanoska
Client	Groundwater Resource Management	Laboratory	SGS Perth Environmental
Address	PO Box 8110 Fremantle High Street, Fremantle, WA, 6160 23 Parry Street Fremantle 6160 KARDINYA WA	Address	28 Reid Rd Perth Airport WA 6105
Telephone	9433 2222	Telephone	(08) 9373 3500
Facsimile	9433 2322	Facsimile	(08) 9373 3556
Email	kathy@g-r-m.com.au	Email	au.environmental.perth@sgs.com
Project	**Audalia Lake Medcalf**	SGS Reference	**PE138652 R0**
Order Number	**J1843**	Date Received	16 Oct 2019
Samples	2	Date Reported	25 Oct 2019

COMMENTS

Accredited for compliance with ISO/IEC 17025 - Testing. NATA accredited laboratory 2562(898/20210).

Metals: Dissolved Fe: Spike recovery failed acceptance criteria due to the presence of significant concentration of analyte (i.e. the concentration of analyte exceeds the spike level).

SIGNATORIES

Hue Thanh LY
Metals Team Leader

LouiseHope

Louise HOPE
Laboratory Technician

Mary Ann OLA-A
Inorganics Team Leader

Murray O'NEILL
Lab Technician-Nutrients Signatory

Ohmar DAVID
Metals Chemist

Parameter	Units	LOR	Sample Number Sample Matrix Sample Date Sample Name	PE138652.001 Water 13 Oct 2019 DB01	PE138652.002 Water 11 Oct 2019 DB04

pH in water Method: AN101 Tested: 17/10/2019

pH**	pH Units	0.1	7.6	7.9

Conductivity and TDS by Calculation - Water Method: AN106 Tested: 17/10/2019

Conductivity @ 25 C	µS/cm	2	56000	55000

Total Dissolved Solids (TDS) in water Method: AN113 Tested: 22/10/2019

Total Dissolved Solids Dried at 175-185°C	mg/L	10	42000	41000

Alkalinity Method: AN135 Tested: 17/10/2019

Total Alkalinity as CaCO3	mg/L	5	580	560
Carbonate Alkalinity as CO3	mg/L	1	<1	<1
Bicarbonate Alkalinity as HCO3	mg/L	5	710	680

Chloride by Discrete Analyser in Water Method: AN274 Tested: 23/10/2019

Chloride, Cl	mg/L	1	21000	20000

Sulfate in water Method: AN275 Tested: 23/10/2019

Sulfate, SO4	mg/L	1	4300	4300

		Sample Number	PE138652.001	PE138652.002
		Sample Matrix	Water	Water
		Sample Date	13 Oct 2019	11 Oct 2019
		Sample Name	DB01	DB04
Parameter	Units	LOR		

Low Level Nitrate Nitrogen and Nitrite Nitrogen (NOx) by FIA Method: AN258 Tested: 18/10/2019

Nitrate, NO_3 as NO_3	mg/L	0.05	**0.82**	**0.85**

Metals in Water (Dissolved) by ICPOES Method: AN320 Tested: 21/10/2019

Calcium, Ca	mg/L	0.2	**610**	**610**
Magnesium, Mg	mg/L	0.1	**1700**	**1700**
Potassium, K	mg/L	0.1	**120**	**120**
Soluble Silicon as Silica, SiO2	mg/L	0.05	**40**	**37**
Sodium, Na	mg/L	0.5	**9900**	**10000**
Total Hardness by Calculation	mg CaCO3/L	1	**8300**	**8600**

Trace Metals (Dissolved) in Water by ICPMS Method: AN318 Tested: 21/10/2019

Aluminium, Al	µg/L	5	<100↑	<100↑
Iron, Fe	µg/L	5	<100↑	<100↑
Manganese, Mn	µg/L	1	**700**	**630**

QC SUMMARY

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage.* Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Alkalinity **Method: ME-(AU)-[ENV]AN135**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Total Alkalinity as CaCO3	LB165170	mg/L	5	<5	0 - 4%	100%
Carbonate Alkalinity as CO3	LB165170	mg/L	1	<1		
Bicarbonate Alkalinity as HCO3	LB165170	mg/L	5	<5		

Chloride by Discrete Analyser in Water **Method: ME-(AU)-[ENV]AN274**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Chloride, Cl	LB165167	mg/L	1	<1	0 - 2%	105%	98 - 101%

Conductivity and TDS by Calculation - Water **Method: ME-(AU)-[ENV]AN106**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Conductivity @ 25 C	LB165197	µS/cm	2	<2	0%	99 - 100%

Low Level Nitrate Nitrogen and Nitrite Nitrogen (NOx) by FIA **Method: ME-(AU)-[ENV]AN258**

Parameter	QC Reference	Units	LOR	MB
Nitrate, NO_3 as NO_3	LB165066	mg/L	0.05	<0.05

Metals in Water (Dissolved) by ICPOES **Method: ME-(AU)-[ENV]AN320**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Calcium, Ca	LB165101	mg/L	0.2	<0.2	0 - 3%	97%	94%
Magnesium, Mg	LB165101	mg/L	0.1	<0.1	0 - 1%	97%	93%
Potassium, K	LB165101	mg/L	0.1	<0.1	1 - 2%	97%	
Soluble Silicon as Silica, SiO2	LB165101	mg/L	0.05	<0.05			
Sodium, Na	LB165101	mg/L	0.5	<0.5	0 - 1%	102%	94%
Total Hardness by Calculation	LB165101	mg CaCO3/L	1	<1			

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pH in water Method: ME-(AU)-[ENV]AN101

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
pH**	LB165197	pH Units	0.1	5.7 - 5.9	0%	99 - 101%

Sulfate in water Method: ME-(AU)-[ENV]AN275

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Sulfate, SO4	LB165167	mg/L	1	<1	0 - 8%	101 - 104%	98 - 100%

Total Dissolved Solids (TDS) in water Method: ME-(AU)-[ENV]AN113

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery	MSD %RPD
Total Dissolved Solids Dried at 175-185°C	LB165173	mg/L	10	<10	1 - 2%	96%	70%	32%

Trace Metals (Dissolved) in Water by ICPMS Method: ME-(AU)-[ENV]AN318

Parameter	QC Reference	Units	LOR	MB	LCS %Recovery	MS %Recovery
Aluminium, Al	LB165096	µg/L	5	<5	114%	
Iron, Fe	LB165096	µg/L	5	<5	112%	-105%
Manganese, Mn	LB165096	µg/L	1	<1	120%	125%

METHOD SUMMARY

METHOD	METHODOLOGY SUMMARY
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GRAVITY SURVEY

Atlas Geophysics Memorandum M2019125

Lake Medcalf Gravity Survey

AUDALIA RESOURCES LIMITED

Memo completed by:

Richard Allpike
Geophysicist

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ABN 68 123 110 243

17th October 2019

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APPENDICES

1.0 Project Brief

Project P2019125 involved the acquisition and processing of **564** new gravity stations for Audalia Resources Limited over an area near Lake Medcalf, situated about 95km west-south-west of Norseman in Western Australia (Figure 1).

Atlas Geophysics completed the acquisition of the dataset with one, two-person crew utilising foot-borne gravity methods. Stations were acquired in a 200m x 50m rectangular grid configuration.

Acquisition commenced on the 8th of October 2019 and was completed on the 11th of October 2019. Final data was delivered shortly after project completion.

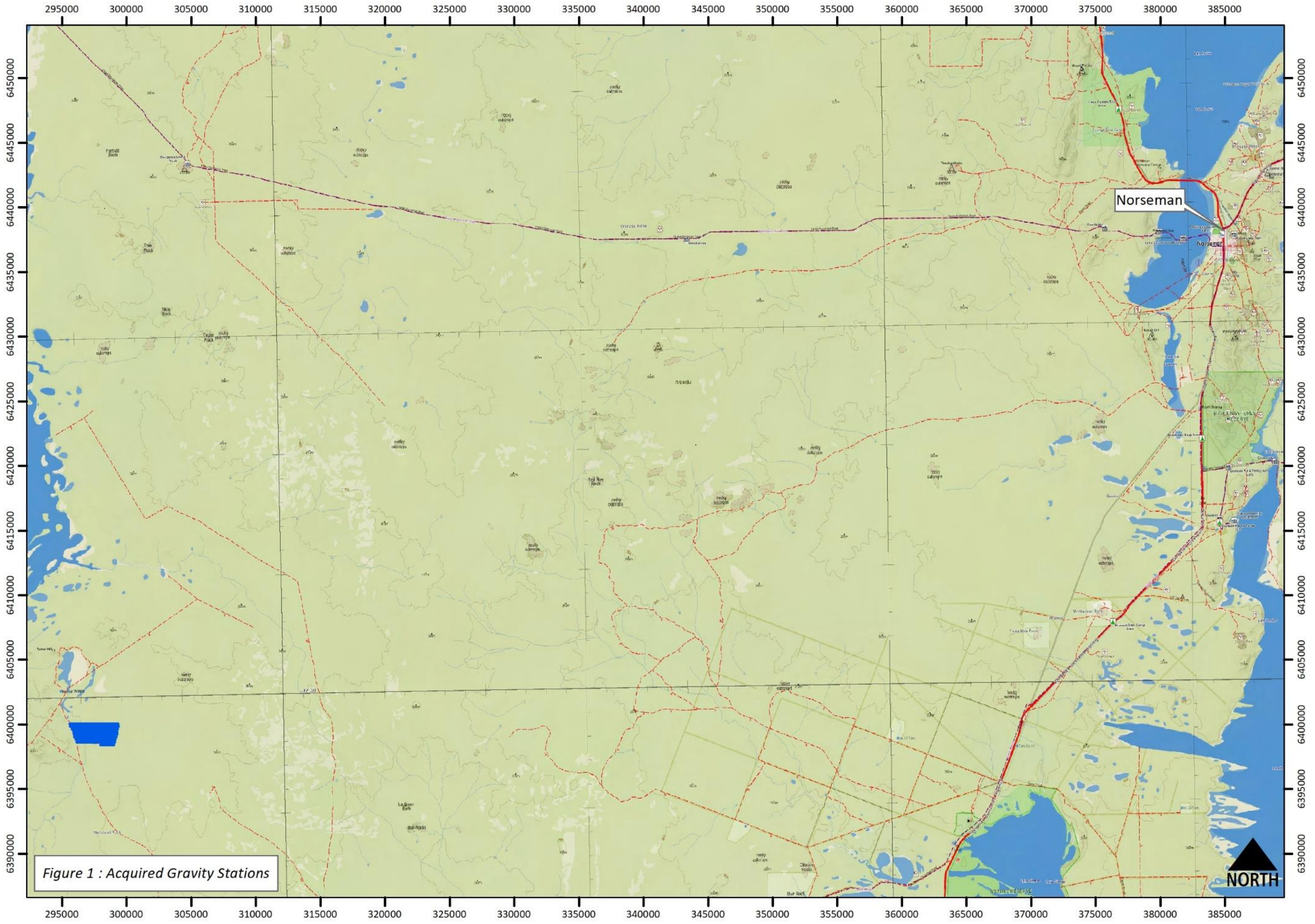


Figure 1 : Acquired Gravity Stations

2.0 Equipment and Instrumentation

The following instrumentation was used for acquisition of the gravity data:

- One Scintrex CG-5 Autograv Gravity Meter (Serial Number: 276, SF: 1.00000)
- One CHC Nav i70+ GNSS Rover Receiver
- One CHC Nav i70+ GNSS Base Receiver

Ancillary equipment included:

- One HP Laptop computer for data download and processing
- Garmin autonomous GPS receivers for navigation
- InReach personal satellite tracking units
- Iridium satellite phones for long distance communications
- Personal Protective Equipment for all personnel
- Batteries, battery chargers, solar cells, UPS System
- Survey consumables
- Tools, engineering and maintenance equipment for vehicle servicing
- First aid and survival kits
- Tyres and recovery equipment

3.0 Calibration and Control

The gravity meter used for the survey had been recently calibrated on the Guildford Cemetery – Helena Valley Primary School calibration range (2010990117 - 2010990217) in Western Australia. The calibration process validated the gravity meter's scale factor to ensure reduction of the survey data produces correct Observed Gravities from measured dial reading values.

One new Atlas Geophysics Gravity/GNSS control station; 201912500001 "Lake Medcalf Camp" was used to control all field observations throughout the survey.

GNSS control was established by submitting three 10-hour sessions of static data to Geoscience Australia's AUSPOS processing system, producing first-order geodetic coordinates. These coordinates are accurate to better than 10mm for the x, y and z observables.

Gravity control was established at 201912500001 via multiple ABA tie loops with the project gravity meter to existing Atlas Geophysics control station 201505600001 "Lake Medcalf". Standard deviation of the gravity ties is 0.001 mGal.

4.0 GNSS-Gravity Acquisition

Gravity data were acquired concurrently with GNSS data using one Scintrex CG-5 gravity meter. Data were acquired in single shifts of up to 12 hours duration, with each shift consisting of a single loop controlled by observations at the gravity control station. Each loop contained a minimum of two repeated readings so that an interlocking network of closed loops was formed. A total of **22** repeat readings representing **3.90%** of the survey were acquired for quality control purposes. Repeat readings were evenly distributed, where possible, on a time-basis throughout each of the gravity loops.

GNSS data were acquired with the rover receiver operating in post-process kinematic (PPK) mode with the GNSS sensor mounted to a fixed 2.000m walking pole. Static data were logged at the control station with a base receiver operating in post-process static (PPS) mode with the GNSS sensor mounted on a fixed 2.000m pole.

5.0 GNSS Processing and QC

The acquired GNSS raw data were processed nightly in the field using Novatel Waypoint GrafNav v8.80 post-processing software.

GrafNav was used to transform the GNSS-derived WGS84 coordinates to GDA94 coordinates for each gravity station location. MGA coordinates were then derived by projecting the GDA94 geodetic coordinates with a Universal Transverse Mercator (UTM) transform using the appropriate zone. It should be noted that WGS84 and GDA94 coordinates (x, y, and z) are no longer roughly equivalent, with a difference in horizontal coordinates of greater than 1.0m and a difference in elevation of 90-100mm. GrafNav produced GDA94 ellipsoidal heights for each gravity station location; and elevations above the Australian Height Datum (AHD) were modelled using the AUSGEOID09 geoid model, with separations (N values) added to GDA94 ellipsoidal heights.

The resulting GrafNav data (output in Atlas Geophysics PPK standard format) were then imported into Atlas Geophysics Reduction and Interpretation Software (AGRIS) for QC and used in the reduction of the gravity data. A module built into AGRIS allows the user to examine data quality factors such as station repeatability between multiple control stations, coordinate velocity, dilution of precision, coordinate quality factor and standard error for each gravity station location. The procedure is carried out before merging the positional data with gravity data for final reduction to Bouguer Anomaly. Comprehensive statistics, repeatability analysis and histogram plotting are also performed.

QC procedures were applied to the GNSS data on a daily basis and any gravity stations not conforming to the quoted specifications were repeated by the company at no cost to the client.

6.0 Gravity Processing and QC

The acquired gravity data were processed using the company's in-house gravity pre-processing and reduction software, AGRIS. This software allows for full data pre-processing, reduction to Bouguer Anomaly, repeatability and statistical analysis, as well as full quality control of the output dataset.

Once downloaded from the gravity meter, the data were analysed for consistency and preliminary QC was performed to confirm that observations meet specification for standard deviation, reading rejection, temperature and tilt values. Once the data were verified the software averaged the multiple gravity readings and performed a merge with the previously QC-passed GNSS data. The software then applies a linear drift correction and earth tide correction. Any gravity stations not conforming to the quoted specifications were repeated by the company at no cost to the client.

The following corrections were further applied to the dataset to produce Spherical Cap Bouguer Anomalies on the GDA94 transform of the GRS80 ellipsoid and AAGD07 gravity datum. For legacy reasons, Geoidal Bouguer Anomalies on the Australian Height Datum (AHD) and ISOGAL84 gravity datum have also been calculated.

The formulae below produce data in μms^{-2} or gravity units (GU). To convert to mGal, divide by a factor of 10.

Instrument scale factor: This correction is used to correct a gravity reading (in dial units) to a relative gravity unit value based on the meter calibration.

$$r_c = 10 \cdot (r \cdot S(r))$$

where,

r_c	corrected reading in gravity units
r	gravity meter reading in dial units
$S(r)$	scale factor (dial units/milliGal)

Earth Tide Correction: The earth is subject to variations in gravity due to the gravitational attraction of the Sun and the Moon. These background variations can be corrected for using a predictive formula which utilises the gravity observation position and time of observation. The Scintrex CG-5 gravity meter automatically calculates ETC but uses only an approximate position for the gravity observation so is not entirely accurate. For this reason, the Scintrex ETC is subtracted from the reading and a new correction calculated within AGRIS software.

$$r_t = r_c + g_{tide}$$

where,

r_t	tide corrected reading in gravity units
r_c	scale factor corrected reading in gravity units
g_{tide}	Earth Tide Correction (ETC) in gravity units

Instrument Drift Correction: Since all gravity meters are mechanical, they are all prone to instrument drift. Drift can be caused by mechanical stresses and strains in the spring mechanism as the meter is moved, knocked, reset, subjected to temperature extremes, subjected to vibration, unclamped etc. The most common cause of instrument drift is due to extension of the sensor spring with changes in temperature (obeying Hooke's law). To calculate and correct for daily instrument drift, the difference between the gravity control station readings (closure error) is used to assume the drift and a linear correction is applied.

$$ID = \frac{r_{cs2} - r_{cs1}}{t_{cs2} - t_{cs1}}$$

where,

ID	Instrument Drift in gu/hour
r_{cs2}	control station 2nd reading in gravity units
r_{cs1}	control station 1st reading in gravity units
t_{cs2}	control station 2 time
t_{cs1}	control station 1 time

Observed Gravity: The preceding corrections are applied to the raw gravity reading to calculate the earth's absolute gravitational attraction at each gravity station. The corrections produced Observed Gravities on the AAGD07 and ISOGAL84 datums.

$$G_o = g_{cs1} + (r_t - r_{cs1}) - (t - t_{cs1}) \cdot ID$$

where,

G_o	Observed Gravity in gravity units (ISOGAL84 or AAGD07)
g_{cs1}	control station 1 known Observed Gravity in gravity units
r_t	tide corrected reading in gravity units
r_{cs1}	control station 1 reading in gravity units
t	reading time
t_{cs1}	control station 1 time
ID	instrument drift in gravity units/hour

Theoretical Gravity 1980: The theoretical (or normal) gravity value at each gravity station is calculated based on the assumption that the Earth is a homogeneous ellipsoid. The closed form of the 1980 International Gravity Formula is used to approximate the theoretical gravity at each station location and essentially produce a latitude correction. Gravity values vary with latitude as the earth is not a perfect sphere and the polar radius is much smaller than the equatorial radius. The effect of centrifugal acceleration is also different at the poles versus the equator.

$$G_{t80} = 9780326.7715((1 + 0.001931851353(sin^2 l)/(SQRT(1 - 0.0066943800229(sin^2 l)))$$

where,

G_{t80}	Theoretical Gravity 1980 in gravity units
l	GDA94 latitude at the gravity station in decimal degrees

Theoretical Gravity 1967: The theoretical (or normal) gravity value at each gravity station is calculated based on the assumption that the Earth is a homogeneous ellipsoid. The 1967 variant of the International Gravity Formula is used to approximate the theoretical gravity at each station location and essentially produce a latitude correction. Gravity values vary with latitude as the earth is not a perfect sphere and the polar radius is much smaller than the equatorial radius. The effect of centrifugal acceleration is also different at the poles versus the equator.

$$G_{t67} = (9780318.456 \cdot \left(1 + 0.005278895 \cdot sin^2(l) + 0.000023462 \cdot sin^4(l)\right))$$

where,

G_{t67} Theoretical Gravity 1967 in gravity units

l GDA94 latitude at the gravity station in decimal degrees

Atmospheric Correction: The gravity effect of the atmosphere above the ellipsoid can be calculated with an atmospheric model and is subtracted from the theoretical gravity.

$$AC = 8.74 – 0.00099 \cdot h \ + \ 0.0000000356 \cdot h^2$$

where,

AC Atmospheric Correction in gravity units

h elevation above the GDA94 transformed GRS80 ellipsoid in metres

Ellipsoidal Free Air Correction: Since the gravity field varies inversely with the square of distance, it is necessary to correct for elevation changes from the reference ellipsoid (GDA94 transformed GRS80). Gravitational attraction decreases as the elevation above the reference ellipsoid increases.

$$EFAC = -(3.087691 – 0.004398 \, sin^2 l) \cdot h \ + \ 7.2125 \cdot 10^{-7} \cdot h^2$$

where,

$EFAC$ Ellipsoidal Free Air Correction in gravity units

l GDA94 latitude at the gravity station in decimal degrees

h elevation above the GDA94 transformed GRS80 ellipsoid in metres

Geoidal Free Air Correction: Since the gravity field varies inversely with the square of distance, it is necessary to correct for elevation changes from the reference geoid (AHD). Gravitational attraction decreases as the elevation above the reference geoid increases.

$$GFAC = \left(3.08768 - 0.00440 sin^2(l)\right) \cdot h - 0.000001442 \cdot h^2$$

where,

$GFAC$ Free Air Correction in gravity units

l GDA94 latitude at the gravity station in decimal degrees

h elevation above the reference geoid (AHD) in metres

Spherical Cap Bouguer Correction: If a gravity observation is made above the reference ellipsoid, the effect of rock material between the observation and the ellipsoid must be taken into account. The mass of rock makes a positive contribution to the gravity value. The correction is calculated using the closed form equation for the gravity effect of a spherical cap of radius 166.7km, based on a spherical Earth with a mean radius of 6,371.0087714km, height relative the ellipsoid and rock densities of 2.67, 2.40 and 2.20 tm^{-3} (gm/cc).

$$SCBC = 2\pi G\rho((1+\mu)\cdot h - \lambda R)$$

where,

$SCBC$	Spherical Cap Bouguer Correction in gravity units
G	gravitational constant = 6.67428·10^{-11}m^{3}kg^{-1}s^{-2}
ρ	rock density (2.67, 2.40 and 2.20 tm^{-3})
h	elevation above the GDA94 transformed GRS80 ellipsoid in metres
R	$(R_o + h)$ the radius of the earth at the station
R_o	mean radius of the earth = 6,371.0087714 km (on the GDA94 transformed GRS80 ellipsoid)
μ & λ	are dimensionless coefficients defined by:

$$\mu = ((1/3)\cdot \eta^2 - \eta)$$

where,

η	h/R

$$\lambda = (1/3)\{(d + f\delta + \delta^2)[(f - \delta)^2 + k]^{\frac{1}{2}} + p + m \cdot ln(n/(f - \delta + [(f - \delta)^2 + k]^{\frac{1}{2}})\}$$

where,

d	$3 \cdot cos^2\alpha - 2$
f	$cos\alpha$
k	$sin^2\alpha$
p	$-6 \cdot cos^2\alpha \cdot \sin(\alpha/2) + 4 \cdot sin^3(\alpha/2)$
δ	(R_o/R)
m	$-3 \cdot k \cdot f$
n	$2 \cdot [sin\ (\alpha/2) - sin^2(\alpha/2)]$
α	S/R_o with S = Bullard B Surface radius = 166.735 km

Geoidal Bouguer Correction: If a gravity observation is made above the reference geoid, the effect of rock material between the observation and the ellipsoid must be taken into account. The mass of rock makes a positive contribution to the gravity value. The slab of rock makes a positive contribution to the gravity value. Rock densities of 2.67, 2.40 and 2.20 t/m^{-3} (gm/cc) were used in the correction.

$$GBC = 0.4191 \cdot \rho \cdot h$$

where,

GBC	Geoidal Bouguer Correction in gravity units
ρ	rock density (2.67, 2.40 and 2.20 tm^{-3})
h	elevation above the reference geoid (AHD) in m

Ellipsoidal Free Air Anomaly: The Ellipsoidal Free Air Anomaly is the difference between the observed gravity and theoretical gravity that has been computed for latitude and corrected for the elevation of the gravity station above or below the reference ellipsoid.

$$EFAA\ = G_{oAAGD07} - (G_{t80} - AC) - EFAC$$

where,

$EFAA$	Ellipsoidal Free Air Anomaly in gravity units
G_o	Observed Gravity on the AAGD07 datum in gravity units
G_{t80}	Theoretical Gravity 1980 in gravity units
AC	Atmospheric Correction in gravity units
$EFAC$	Ellipsoidal Free Air Correction in gravity units

Geoidal Free Air Anomaly: The Geoidal Free Air Anomaly is the difference between the observed gravity and theoretical gravity that has been computed for latitude and corrected for the elevation of the gravity station above or below the reference geoid.

$$GFAA\ = G_{oISOGAL84}\ - G_{t67} + GFAC$$

where,

$GFAA$	Free Air Anomaly in gravity units
G_o	Observed Gravity on the ISOGAL84 datum in gravity units
G_{t67}	Theoretical Gravity 1967 in gravity units
$GFAC$	Geoidal Free Air Correction in gravity units

Spherical Cap Bouguer Anomaly: The Spherical Cap Bouguer Anomaly is computed from the Ellipsoidal Free Air Anomaly above by removing the attraction of the spherical cap calculated by the Spherical Cap Bouguer Correction.

$$SCBA\ = EFAA - SCBC$$

where,

$SCBA$	Spherical Cap Bouguer Anomaly in gravity units
$EFAA$	Ellipsoidal Free Air Anomaly in gravity units
$SCBC$	Bouguer Correction in gravity units

Geoidal Bouguer Anomaly: The Geoidal Bouguer Anomaly is computed from the Geoidal Free Air Anomaly above by removing the attraction of the slab calculated by the Geoidal Bouguer Correction.

$$GBA\ = GFAA - GBC$$

where,

GBA	Geoidal Bouguer Anomaly in gravity units
$GFAA$	Geoidal Free Air Anomaly in gravity units
GBC	Geoidal Bouguer Correction in gravity units

7.0 Gravity Results

The gravity survey was completed in **4** days of acquisition. An average acquisition rate of around **141** stations per day of production was achieved for the survey. The survey progressed well with no major delays.

Final data have met and exceeded quoted project specifications. Repeatability of the data was excellent, with the standard deviation of the elevation repeats at **0.018m** and the standard deviation of the gravity repeats at **0.018mGal**. The production report contains summary statistics and histograms for repeatability.

8.0 Data Formats and Deliverables

Final reduced ASCII data for the project have been delivered in ASEG-GDF2 and standard Atlas format. Table 2 overleaf details the format of the final gravity database supplied. All fields are comma delimited.

Appendix B contains a plot of final station locations, images of GNSS Derived Elevation (GDA94 transformed GRS80), Spherical Cap Bouguer Anomaly and first vertical derivative of Spherical Cap Bouguer Anomaly.

All data, both raw and processed, have been supplied with this memorandum using a cloud-based service. Table 1 below summarises the deliverables. Should the reader require further copies of the deliverables, please contact Atlas Perth Operations.

Final Delivered Data	Format	Data
Gravity Database	Comma Space Delimited .csv	•
Gravity Database	Point located data ASEG-GDF2	•
Raw Positional Data	AGRIS format, comma delimited	•
Raw Gravity Data	Scintrex CG-5 format	•
Final Grids	ER Mapper Grids .ers	•
Final Images	GIS compatible Geotiff .tif	•
Acquisition Memo	PDF .pdf	•

Table 1: Final Deliverables

Field Header	Field Description	Format	Units
PROJECT	Atlas Geophysics Project Number	A9	None
STATION	Unique Station ID	I8	None
STATIONCODE	Unique Station Code	A13	None
LINE	Line ID	I8	None
TYPE	Observation Type : Base, Field or Repeat	A8	None
EASTING	Coordinate Easting UTM projection of the Geographic coordinates	F11.3	M
NORTHING	Coordinate Northing UTM projection of the Geographic coordinates	F12.3	M
ZONE	UTM Zone Number	F8.0	NA
LATITUDE	Coordinate Latitude (Refer DATUM column for Geographic Datum)	F15.10	DD
LONGITUDE	Coordinate Longitude (Refer DATUM column for Geographic Datum)	F15.10	DD
ORTHOHTM	Coordinate Elevation Orthometric (Refer GEOID column for Geoid used)	F9.3	M
ELLIPHTM	Coordinate Elevation Ellipsoidal	F9.3	M
N	Geoid Separation (Refer GEOID column for Geoid used)	F8.3	M
DATE	Observation Date	I8	None
TIME	Observation Time	I8	None
DIALMGAL	Gravity Dial Reading	F9.3	mGal
ETCMGAL	Earth Tide Correction (Longman)	F8.3	mGal
SCALE	Scale Factor Applied to Dial Reading	F9.6	None
OBSG84MGAL	Observed Gravity ISOGAL84	F11.3	mGal
OBSG84GU	Observed Gravity ISOGAL84	F11.2	Gu
OBSGAAGD07GU	Observed Gravity AAGD07	F13.2	Gu
OBSGAAGD07MGAL	Observed Gravity AAGD07	F16.3	mGal
DRIFTMGAL	Drift Applied to Dial Readings	F10.3	mGal
TGRAV67GU	Theoretical Gravity 1967	F11.2	Gu
TGRAV67MGAL	Theoretical Gravity 1967	F12.3	mGal
TGRAV80GU	Theoretical Gravity 1980	F11.2	Gu
GFACGU	Geoidal Free Air Correction	F8.2	Gu
GFACMGAL	Geoidal Free Air Correction	F9.3	mGal
GFAAGU	Geoidal Free Air Anomaly	F8.2	Gu
GFAAMGAL	Geoidal Free Air Anomaly	F9.3	mGal
GBC267GU	Geoidal Bouguer Correction 2.67 tm^-3	F9.2	Gu
GBC240GU	Geoidal Bouguer Correction 2.40 tm^-3	F9.2	Gu
GBC220GU	Geoidal Bouguer Correction 2.20 tm^-3	F9.2	Gu
GBC267MGAL	Geoidal Bouguer Correction 2.67 tm^-3	F11.3	mGal
GBC240MGAL	Geoidal Bouguer Correction 2.40 tm^-3	F11.3	mGal
GBC220MGAL	Geoidal Bouguer Correction 2.20 tm^-3	F11.3	mGal
GBA267GU	Geoidal Bouguer Anomaly 2.67 tm^-3	F9.2	gu
GBA240GU	Geoidal Bouguer Anomaly 2.40 tm^-3	F9.2	gu
GBA220GU	Geoidal Bouguer Anomaly 2.20 tm^-3	F9.2	gu
GBA267MGAL	Geoidal Bouguer Anomaly 2.67 tm^-3	F11.3	mGal
GBA240MGAL	Geoidal Bouguer Anomaly 2.40 tm^-3	F11.3	mGal
GBA220MGAL	Geoidal Bouguer Anomaly 2.20 tm^-3	F11.3	mGal
TGRAV80ACGU	Theoretical Gravity 1980 Atmospheric Corrected	F11.2	gu
EFACGU	Ellipsoidal Free Air Correction	F9.2	gu
EFAAGU	Ellipsoidal Free Air Anomaly	F8.2	gu
SCBC267GU	Spherical Cap Bouguer Correction 2.67 tm^-3	F10.2	gu
SCBC240GU	Spherical Cap Bouguer Correction 2.40 tm^-3	F10.2	gu
SCBC220GU	Spherical Cap Bouguer Correction 2.20 tm^-3	F10.2	gu
SCBA267GU	Spherical Cap Bouguer Anomaly 2.67 tm^-3	F10.2	gu
SCBA240GU	Spherical Cap Bouguer Anomaly 2.40 tm^-3	F10.2	gu
SCBA220GU	Spherical Cap Bouguer Anomaly 2.20 tm^-3	F10.2	gu
SCBA267MGAL	Spherical Cap Bouguer Anomaly 2.67 tm^-3	F12.3	mGal
SCBA240MGAL	Spherical Cap Bouguer Anomaly 2.40 tm^-3	F12.3	mGal
SCBA220MGAL	Spherical Cap Bouguer Anomaly 2.20 tm^-3	F12.3	mGal
TCINNERGU	Inner Terrain Correction	F8.2	gu
TCINNERMGAL	Inner Terrain Correction	F8.3	mGal
QFINNER	Quality Factor Inner TC	I2	None
TCOUTERGU	Outer Terrain Correction	F8.2	gu
TCOUTERMGAL	Outer Terrain Correction	F8.3	mGal
QFOUTER	Quality Factor Outer TC	F2	None
TCTOTALGU	Total Terrain Correction	F8.2	gu
TCTOTALMGAL	Total Terrain Correction	F8.3	mGal
CGBA267GU	Complete Geoidal Bouguer Anomaly 2.67 tm^-3	F11.3	gu
CGBA267MGAL	Complete Geoidal Bouguer Anomaly 2.67 tm^-3	F11.3	mGal
CSCBA267GU	Complete Spherical Cap Bouguer Anomaly 2.67 tm^-3	F12.2	gu
CSCBA267MGAL	Complete Spherical Cap Bouguer Anomaly 2.67 tm^-3	F12.2	mGal
DIFFEASTM	Repeat Error for Easting Observation	F8.3	m
DIFFNORTHM	Repeat Error for Northing Observation	F8.3	m
DIFFHTM	Repeat Error for Elevation Observation	F8.3	m
DIFFOBSGMGAL	Repeat Error for Observed Gravity	F8.3	mGal
DIFFOBSGGU	Repeat Error for Observed Gravity	F8.2	gu
METERSN	Serial Number of Gravity Instrument	I8	None
CLOSUREGU	Loop Closure in gu	F8.2	gu
CLOSUREMGAL	Loop Closure in mGal	F8.3	mGal
HDIFF	Horizontal Difference between Acquired and Proposed Station	F7.3	m
GRVBASE	Gravity Base	A11	None
GNSSBASE	GNSS Base	A11	None
DATUM	Geographic Datum	A10	None
GEOID	Geoid Model	A10	None
GRAVDATUM	Gravity Datum	A10	None

Table 2: Final Gravity Database Format

9.0 Project Safety

Prior to survey commencement, a Hazard Identification and Risk Assessment (HIRA) was carried out for all new tasks not covered under Atlas Geophysics Standard Operating Procedures (SOP's) or the company's Health Safety Environment (HSE) field manual.

APPENDIX A

Control Station Descriptions

201912500001 – Lake Medcalf Camp

GEODETIC COORDS GDA94		GRID COORDINATES MGA Z51	
Latitude (DD MM SS)	32° 31' 23.47622"S	**Easting**	292,989.638
Longitude (DD MM SS)	120° 47' 45.60500"E	**Northing**	6,399,429.198
Ellipsoidal Height	344.636	**Orthometric Height (AUSGEOID09)**	371.072

OBSERVED GRAVITY

Established: 08/10/2019

gu AAGD07	9794101.68

Occupation Method/Location Details

The GNSS control point consists of a steel star picket driven into the ground to a height of 15cm above ground level. This control station is witnessed by a star picket with a plaque. The gravity control point is located within 0.5m of the small picket.

Gravity Control was established via multiple ABA tie loops with the project meter to existing gravity control station 201505600001 “Lake Medcalf”. Standard deviation of the gravity ties is 0.001mGal.

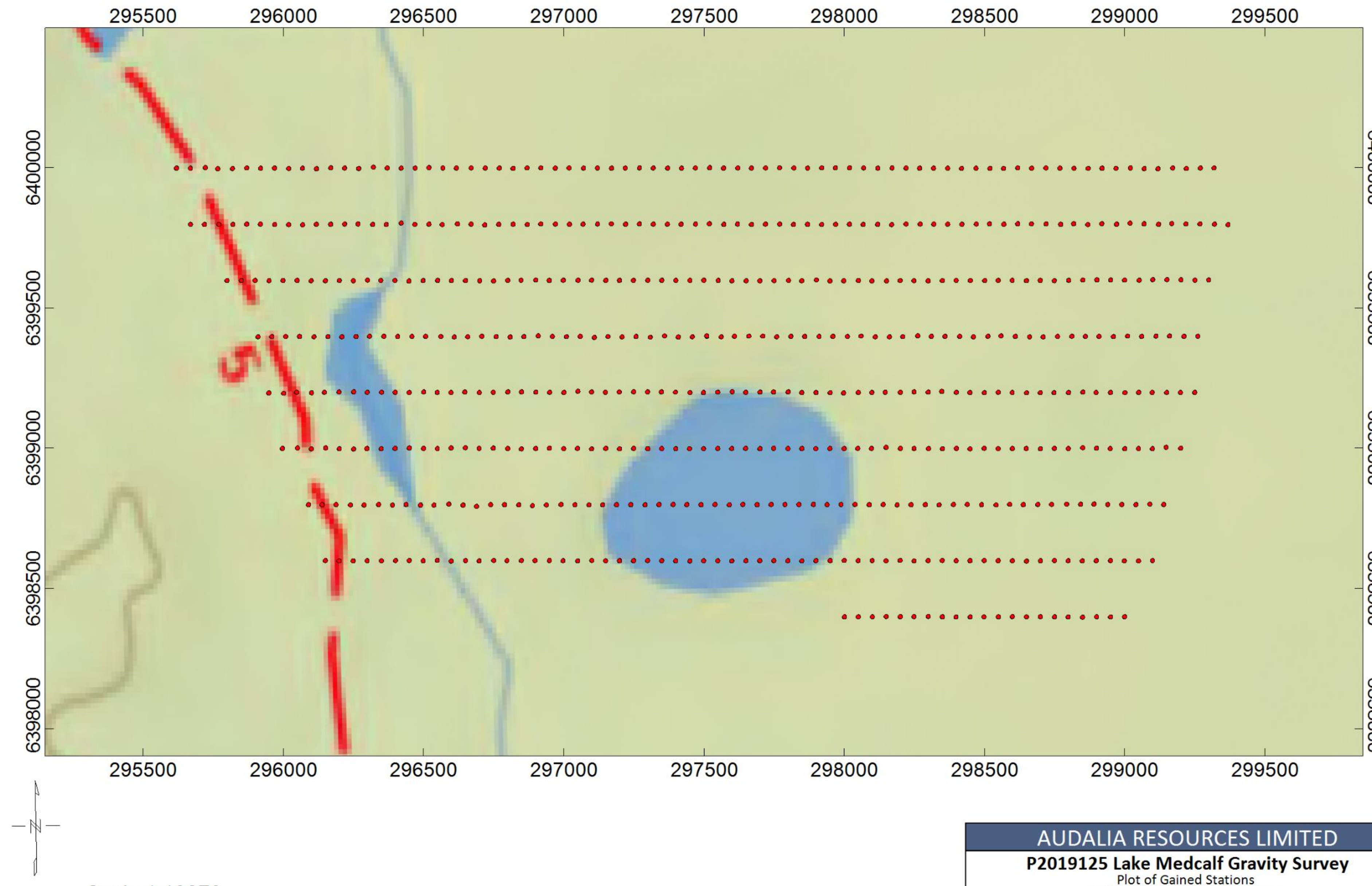
GNSS Control was established using AUSPOS. Three 10-hour sessions were submitted to Geoscience Australia’s online processing system, AUSPOS. Returned coordinates were accurate to better than 0.01m.

The control station can be located via the following directions from Norseman. Travel south for 73km and turn right onto Kumarl-Lake King Road. Follow this road for 21km and then turn left on to the Lake King-Norseman Road and follow it for 25km. The control station will then be on the right between two drill track lines.

Photograph of Control Station 201912500001 and surrounds

APPENDIX B

Plots and Imagery



Scale 1:19870

GDA94 / MGA zone 51

AUDALIA RESOURCES LIMITED

P2019125 Lake Medcalf Gravity Survey

Plot of Gained Stations

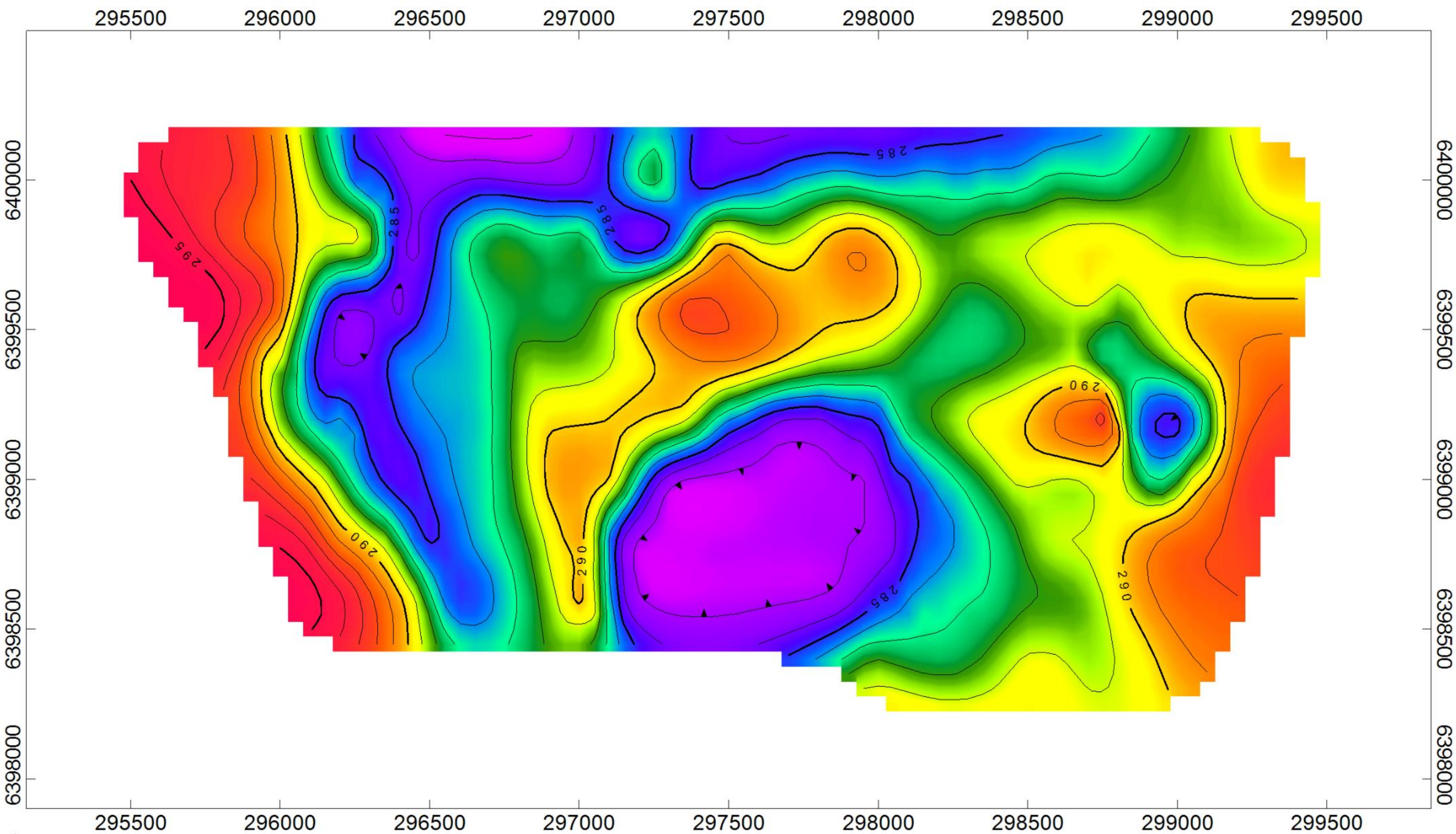
200m x 50m Grid Configuration

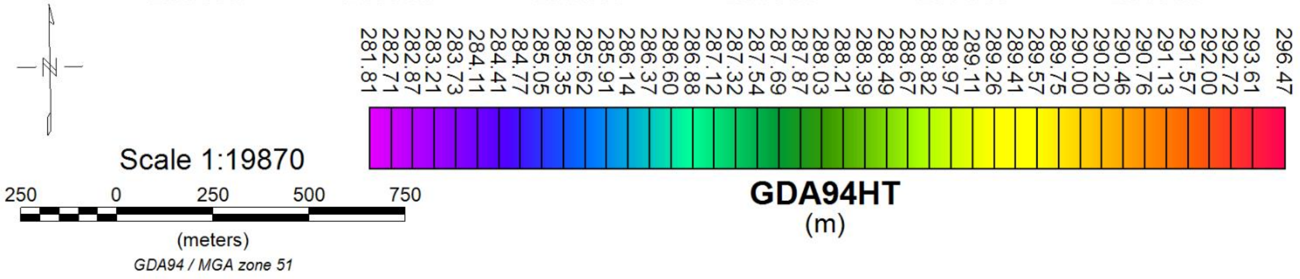
ATLAS GEOPHYSICS PTY LTD

FINAL DATA

www.atlasgeo.com.au

drawn by : RNA





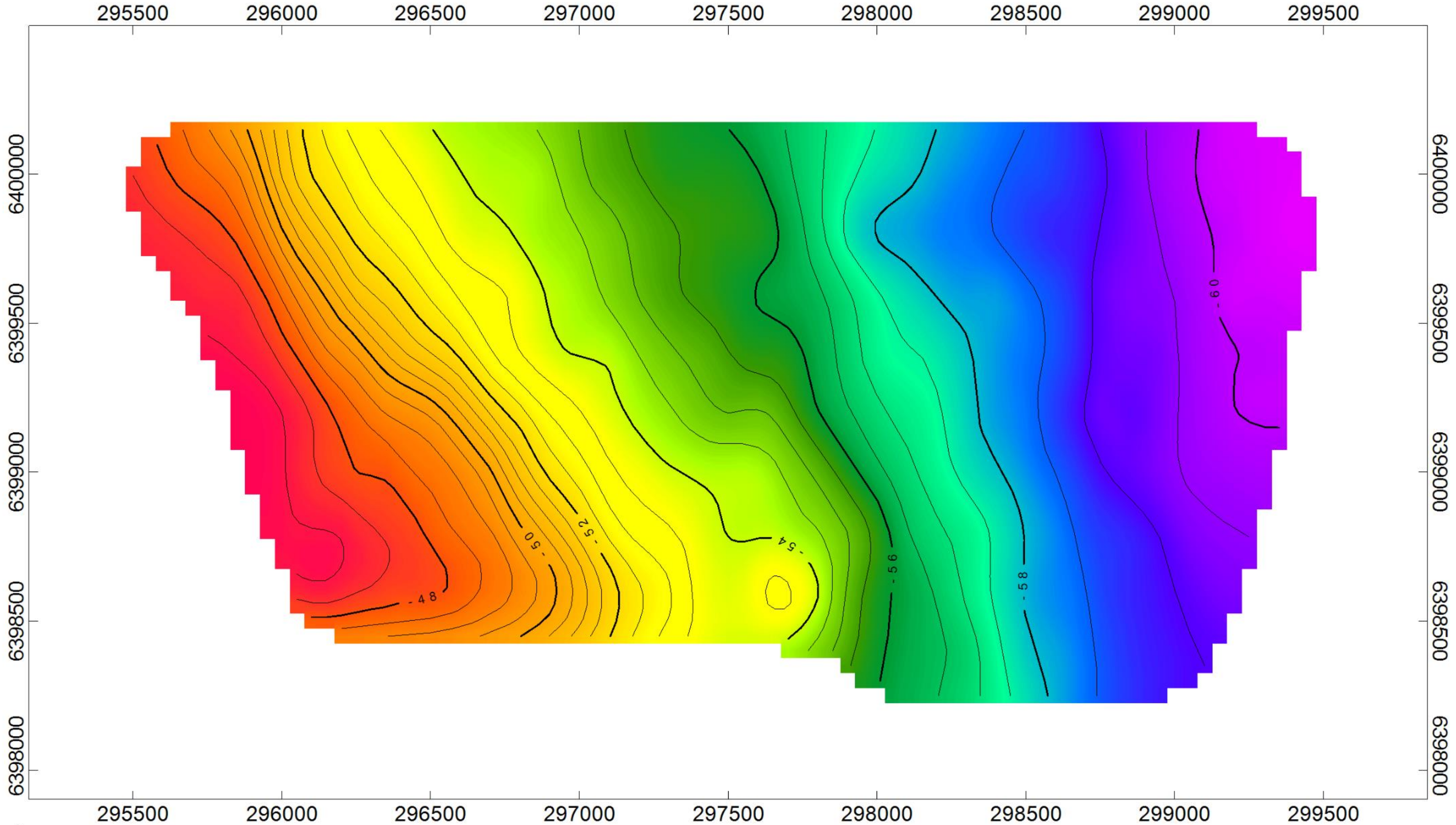
AUDALIA RESOURCES LIMITED

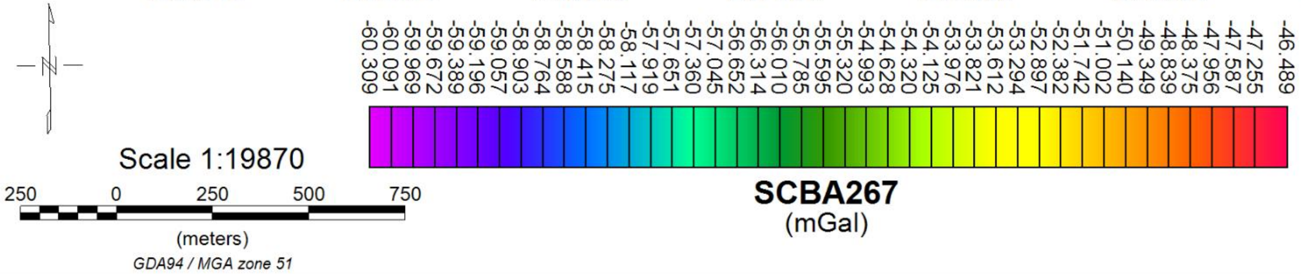
P2019125 Lake Medcalf Gravity Survey

Pseudocoloured Image of GNSS Derived Elevation (GDA94HT)
Shade = None, Contours = 1.0m, Histo = Equalised

ATLAS GEOPHYSICS PTY LTD
FINAL DATA
www.atlasgeo.com.au

drawn by : RNA



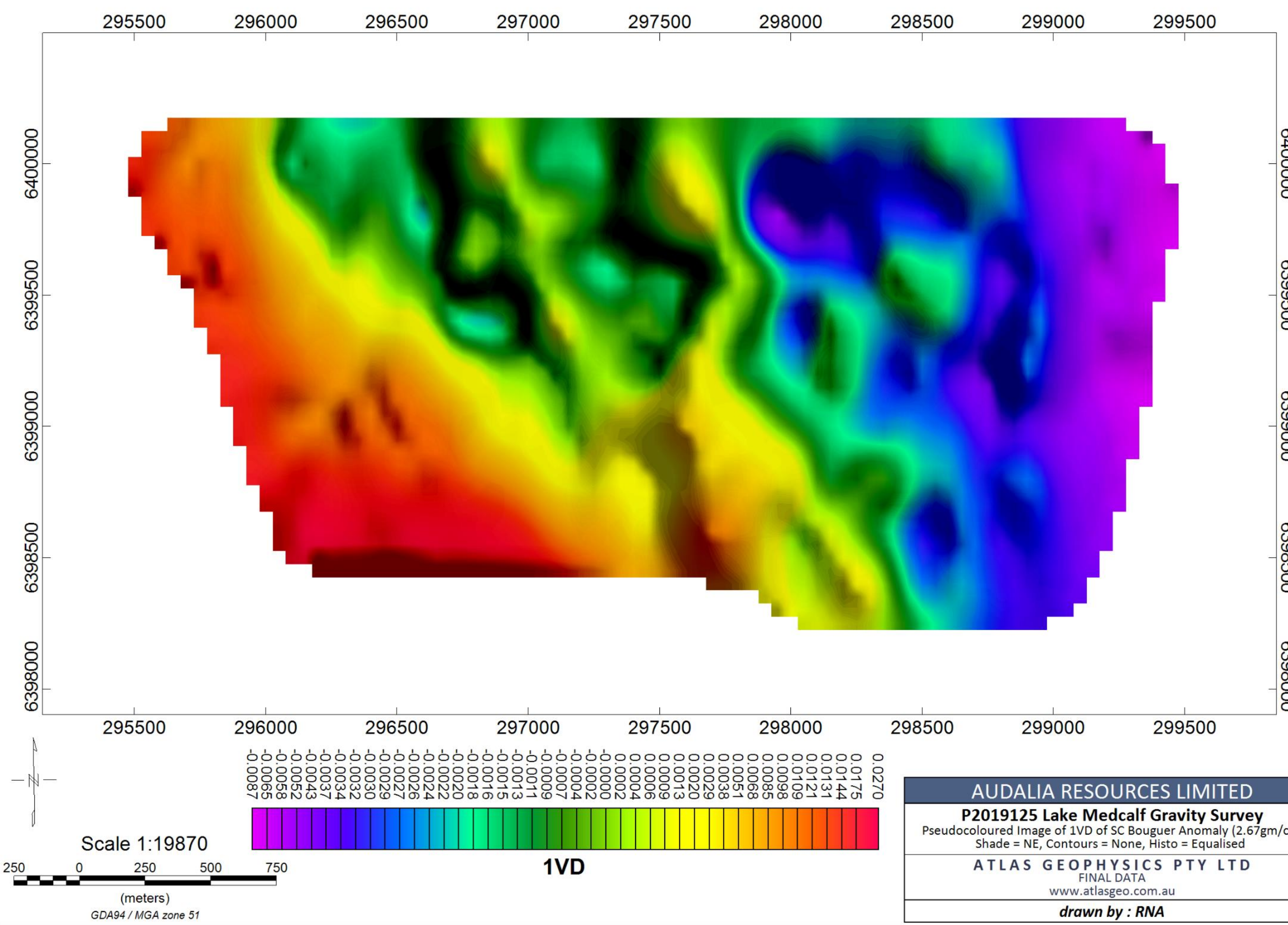


AUDALIA RESOURCES LIMITED

P2019125 Lake Medcalf Gravity Survey
Pseudocoloured Image of SC Bouguer Anomaly (2.67gm/cc)
Shade = None, Contours = 0.5mGal, Histo = Equalised

ATLAS GEOPHYSICS PTY LTD
FINAL DATA
www.atlasgeo.com.au

drawn by : RNA



AUDALIA RESOURCES LIMITED

P2019125 Lake Medcalf Gravity Survey

Pseudocoloured Image of 1VD of SC Bouguer Anomaly (2.67gm/cc)
Shade = NE, Contours = None, Histo = Equalised

ATLAS GEOPHYSICS PTY LTD
FINAL DATA
www.atlasgeo.com.au

drawn by : RNA

APPENDIX C
GNSS Control Information

201912500001 Lake Medcalf Camp

```
0001 -32 31 23.47625 120 47 45.60505 344.636 371.072 GDA94
0001 -32 31 23.47612 120 47 45.60493 344.635 371.071 GDA94
0001 -32 31 23.47625 120 47 45.60501 344.638 371.074 GDA94

GDA94AVE
-32 31 23.47621
120 47 45.60500

-32.52318784
120.79600139

GDA94HT
344.636

AHDHT
371.072

N
-26.436

MGA51
292989.638
6399429.198

AMG51
292853.762
6399272.965
```

NEWEXCO
GEOLOGY GEOPHYSICS DISCOVERY

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P +61 8 9227 1266
E hrh@newexco.com.au
W www.newexco.com.au

Memorandum

TO:	Kathy McDougal	**CLIENT:**	GRM
FROM:	Bill Amann	**PROJ / PROS:**	Medcalf
Cc:		**DAT / PROJ:**	GDA 94 Z51
DATE:	14/11/2019	**MEMO #:**	
SUBJECT:	Medcalf Gravity		

At your request I have had a brief look at the Medcalf paleo channel gravity survey as carried out by Atlas see Figure 1 and make comment regarding channel interpretation.

Data were loaded into geosoft data base and sorted into line and direction to run FFT1D filters to remove the steep regional gradient along line. Numerous attempts were made but failed. A 2 D approach was then adopted as shown on Figure 2. This utilised a 9X9 filter run in oasis. Similar results to that of the 1VD shown were obtained. The spherical cap bouguer anomaly for a density of 2.67 g/cc was used.

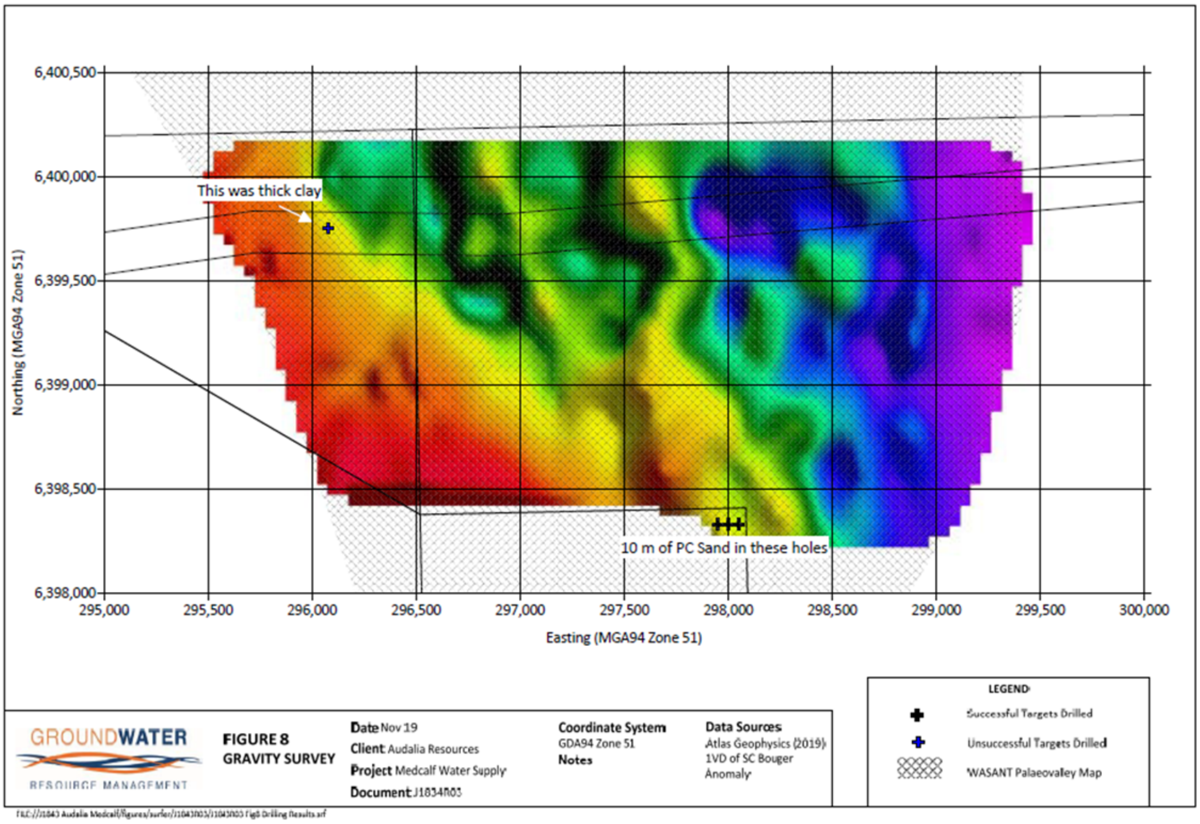

Figure 1 1VD of SC (after Atlas)

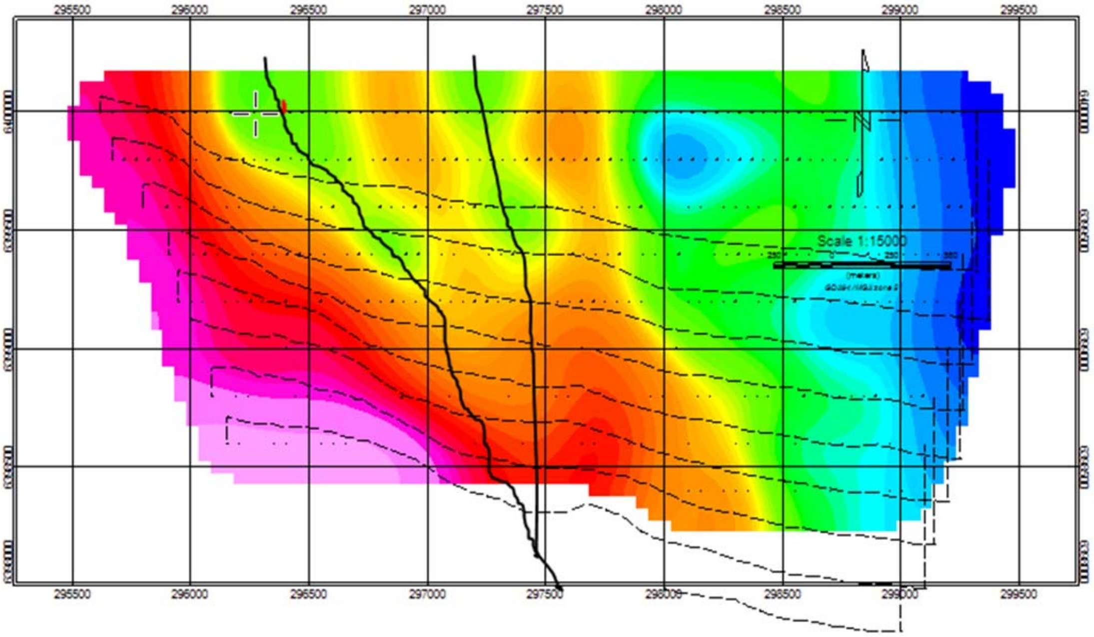

Figure 2 Stacked profiles S C Bouguer anomaly at 2.67 over 9X9 grid filter linear colour. showing lows in green

Interpretation of profile data of the scba2.67 shows a steep gradient of around 10mGal from west to east with a subtle inflection of around 1mGal central to the survey running nne ssw as indicated by a black line on Figure 2.

Please note the presence of a sand aquifer cannot be implied from these data although could be assumed to be in the interpreted deeper portion of the interpreted channel.

Also note that the (my) interpreted channel runs some distance to the west of the southern (successful) water bores.

It is recommended to check the aeromagnetic data /images in this area for proto dykes and possible impediments to drilling. In areas of steep gravity gradients, such as this, we may recommended the use of EM over the interpreted paleo channels to identify central position of most conductivity (assuming salt water in the Lefroy paleo channel)