Medcalf Hydrogeological and Hydrological Study

Surface Water Assessment

Prepared for

Audalia Resources Limited

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Report Distribution

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EXECUTIVE SUMMARY

Audalia Resources Limited (Audalia) is developing the Medcalf Vanadium/Titanium Project. The site is located in the Bremer Range, some 470 km east of Perth and 100 km south west of Norseman, near Lake Johnson.

This report presents a surface water assessment for the mine site and for a proposed 73 km haul road from the site to the Coolgardie Esperance Highway. The assessment includes concept design advice for haul road crossings of drainage lines, an assessment of potential impacts of the haul road on the environment and a monitoring plan for the mine site. This report will form part of the project's environmental approval documentation.

The topography along the haul road alignment is largely flat, with isolated low granite outcrops and sandy rises. A number of catchments drain across the road, some of which are quite large, however there are few defined stream channels. Most drainage line crossings are low areas with no defined or incised stream channel. They are generally dry and pond water or have shallow flow after rainfall. The most defined drainage line crossing the haul road is a tributary or arm of Lake Medcalf near the mine site. This is a broad, shallow channel that may convey and pond water in wet periods.

A total of 28 locations where the haul road crosses drainage lines were identified. Three types of structures for these crossings are suggested:

- Causeway;
- Floodway; and
- No formal structure.

The only crossing that requires a causeway is at the Lake Medcalf tributary. Floodways are suggested for crossings where there is a defined drainage channel or valley and a moderate or large contributing catchment. No formal structure is suggested for areas where the contributing catchment is small and there is no defined drainage line. Flow or ponding in these areas, if any, is likely to be minor and can be managed with road maintenance after heavy rainfall events.

The main potential impacts of the roadway on the receiving environment are:

- Shadowing of downstream vegetation due to diversion of shallow overland flow along the upstream edge of the road;
- Discharge of sediment as a result of scour at the roadway; and
- Discharge of pollutants from the road surface.

Shadowing is likely to only be an issue in limited areas where there is high runoff potential (steeper hillslopes and rocky outcrops) and can be managed by minimising concentration and diversion of overland flow. Discharge of sediment from the road to the environment can be minimised by appropriate shaping of the road profile, use of table drains and maintenance. The risk of discharge of pollutants from the road surface as a result of entrainment of spilt material by runoff during a rainfall event is low and can be managed by rapid clean up. If saline water is used on the road surface, accumulated salts could be washed off in subsequent rainfall events. These salts can generally be collected in table drains. If salt build up is substantial then small sumps may be required.

Drainage through the area of the mine site is defined by a line of low hills trending in an east-west direction through the Fuji and Vesuvius pits. Drainage from the hills through the site area is generally either toward the north or south. All of the site catchments drain ultimately into Lake Medcalf.

The landscape is characterised by rocky hill tops grading to deeper loamy soils with distance downslope. Runoff from the rocky hill tops is high but most will reinfiltrate in the deeper soils downstream. Defined stream channels form toward the bottom of the catchments. The drainage lines are generally dry, flowing only for a short periods after rainfall.

The catchment water balance for the site is dominated by evapotranspiration, which accounts for 97% of rainfall. This means that most rainfall is taken up by plants and transpired or evaporated from soil, rock and vegetation surfaces. The amount of runoff leaving the catchments via drainage lines is relatively low, 3% for the total area. Total seepage below the root zone, which could recharge groundwater, is low relative to the other components of the water balance. Recharge is likely to be highly episodic, with most occurring during extended wet periods.

There are two main rock holes within the project disturbance footprint. These are small cavities in the surface rock that collect rainfall and local streamflow and pond water for a time after rainfall. The water is lost mainly to evaporation.

A monitoring plan for the mine site is proposed. The plan focusses on confirming that surface water management infrastructure is functioning to design criteria and that water quality downstream of the mine site is not adversely affected by mining activities.

GLOSSARY OF HYDROGEOLOGICAL TERMS

Annual Exceedance Probability (AEP)

The probability of an event being equalled or exceeded within a year. For rainfall, an event is a total accumulated over a given duration. For floods, an event is typically the annual maximum flow rate. The relationships in terminology between AEP and ARI for specific event probabilities are (Ball *et al.* 2016):

Frequency descriptor	AEP %)	ARI (1 in *x*)
Frequent	63.21	1
Frequent	50	1.44
Frequent	20	4.48
Frequent	18.13	5
Rare	10	9.49
Rare	5	20
Rare	2	50
Rare	1	100

Antecedent Soil Moisture

Water present in the soil prior to a rainfall event.

Average Recurrence Interval (ARI)

The average time period between occurrences of an event equalling or exceeding a given value.

Australian Rainfall and Runoff (ARR)

National guideline document, data and software suite that can be used for the estimation of design flood characteristics in Australia. Currently in its 4th edition it is commonly referred to as ARR2016.

Australian Hydrological Geospatial Fabric (AHGF)

The Australian Hydrological Geospatial Fabric (Geofabric) is a specialised Geographic Information System (GIS). It identifies and registers the spatial relationships between important hydrological features such as watercourses, water bodies, canals, aquifers, monitoring points and catchments.

Backwater

Water backed-up or retarded in its course as compared with its normal or natural condition of flow.

Baseflow

The component of streamflow supplied by groundwater discharge.

Basin

A tract of country, generally larger catchment areas, drained by a river and its tributaries.

Catchment

The land area draining to a point of interest, such as a water storage or monitoring site on a watercourse.

Channel

An artificial or constructed waterway designed to convey water. Often described as open channels to distinguish them from pipes.

Control

Physical properties of a cross-section or a reach of an open channel, either natural or artificial, which govern the relation between stage and discharge at a location in the open channel.

Dead Storage

In a water storage, the volume of water stored below the level of the lowest outlet (the minimum supply level). This water cannot be accessed under normal operating conditions.

Discharge

Volume of liquid flowing through a cross-section in a unit time.

Drainage Division

Representation of the catchments of the 12-major surface water drainage systems across Australia, generally comprising a number of river basins.

Endorheic Basin

A closed surface water drainage basin that retains water and has no outflow to the sea.

Environmental Flow

The streamflow required to maintain appropriate environmental conditions in a waterway or water body.

Ephemeral	Something which only lasts for a short time. Typically used to describe rivers, lakes and wetlands that are intermittently dry.
Evapotranspiration (ET)	The sum of evaporation and plant transpiration from the earth's land surface to the atmosphere.
Evaporation	A process that occurs at a liquid surface, resulting in a change of state from liquid to vapour.
Floodplain	Flat or nearly flat land adjacent to a stream or river that experiences occasional or periodic flooding.
Flood Risk	The combination of the probability (likelihood or chance) of a flood event happening and the consequences (impact) if it occurred. Flood risk is dependent on there being a source of flooding, such as a sufficiently large upstream catchment, and something that is affected by the flood, such as a mine pit.
Full Supply Level (FSL)	The normal maximum operating water level of a water storage when not affected by floods. This water level corresponds to 100% capacity.
Generalised Short-Duration Method (GSDM)	Appropriate for estimating probable maximum precipitation for durations up to six hours and for an area of less than 1000 square kilometres.
Generalised Tropical Storm Method – Revised (GTSMR)	Appropriate for estimating probable maximum precipitation in regions of Australia affected by tropical storms.
Intensity-Frequency-Duration (IFD)	Design rainfall intensities (mm/h) or design rainfall depths (mm) corresponding to selected standard probabilities, based on the statistical analysis of historical rainfall.
Minimum Supply Level (MSL)	The lowest water level to which a water storage can be drawn down (0% full) with existing outlet infrastructure; typically, equal to the level of the lowest outlet, the lower limit of accessible storage capacity.
Precipitation	All forms in which water falls on the land surface and open water bodies as rain, sleet, snow, hail, or drizzle.
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation (PMP, and coupled with the worst flood producing catchment conditions.
Probable Maximum Precipitation (PMP)	The theoretically greatest depth of precipitation for a given duration under modern meteorological conditions for a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends.
Rainfall	The total liquid product of precipitation or condensation from the atmosphere, as received and measured in a rain gauge.
Riparian	An area or zone within or along the banks of a stream or adjacent to a watercourse or wetland; relating to a riverbank and its environment, particularly to the vegetation.
Stage	Water level relative to a datum, typically measured at a water monitoring site.
Storage	A pond, lake or basin, whether natural or artificial, for the storage, regulation and control of water.
Surface Runoff	Water from precipitation or other sources that flows over the land surface. Surface runoff is the fraction of precipitation that does not infiltrate at the land surface and may be retained at the surface or result in overland flow toward depressions, streams and other surface water bodies.
Sustainable Yield	The level of water extraction from a particular system that would compromise key environmental assets, or ecosystem functions and the productive base of the resource, if it were exceeded.
Total Suspended Solids (TSS)	The sum of all particulate material suspended (i.e. not dissolved) in water. Usually expressed in terms of milligrams per litre (mg/L). It can be measured by filtering and comparing the filter weight before and after filtration.

Transpiration	Evaporative loss of water from the leaves of plants through the stomata; the flow of water through plants from soil to atmosphere.
Watercourse	A river, creek or other natural watercourse (whether modified or not) in which water is contained or flows (whether permanently or from time to time).
Wind Run	The product of the average wind speed and the period over which that average speed was measured.

Terms referenced are from BoM (2018a).

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1.0 INTRODUCTION

1.1 BACKGROUND

Audalia Resources Limited (Audalia) is proposing to develop their Medcalf Vanadium/Titanium Project. The site is located some 470 km east of Perth and 100 km south west of Norseman in the Bremer Range, near Lake Johnson.

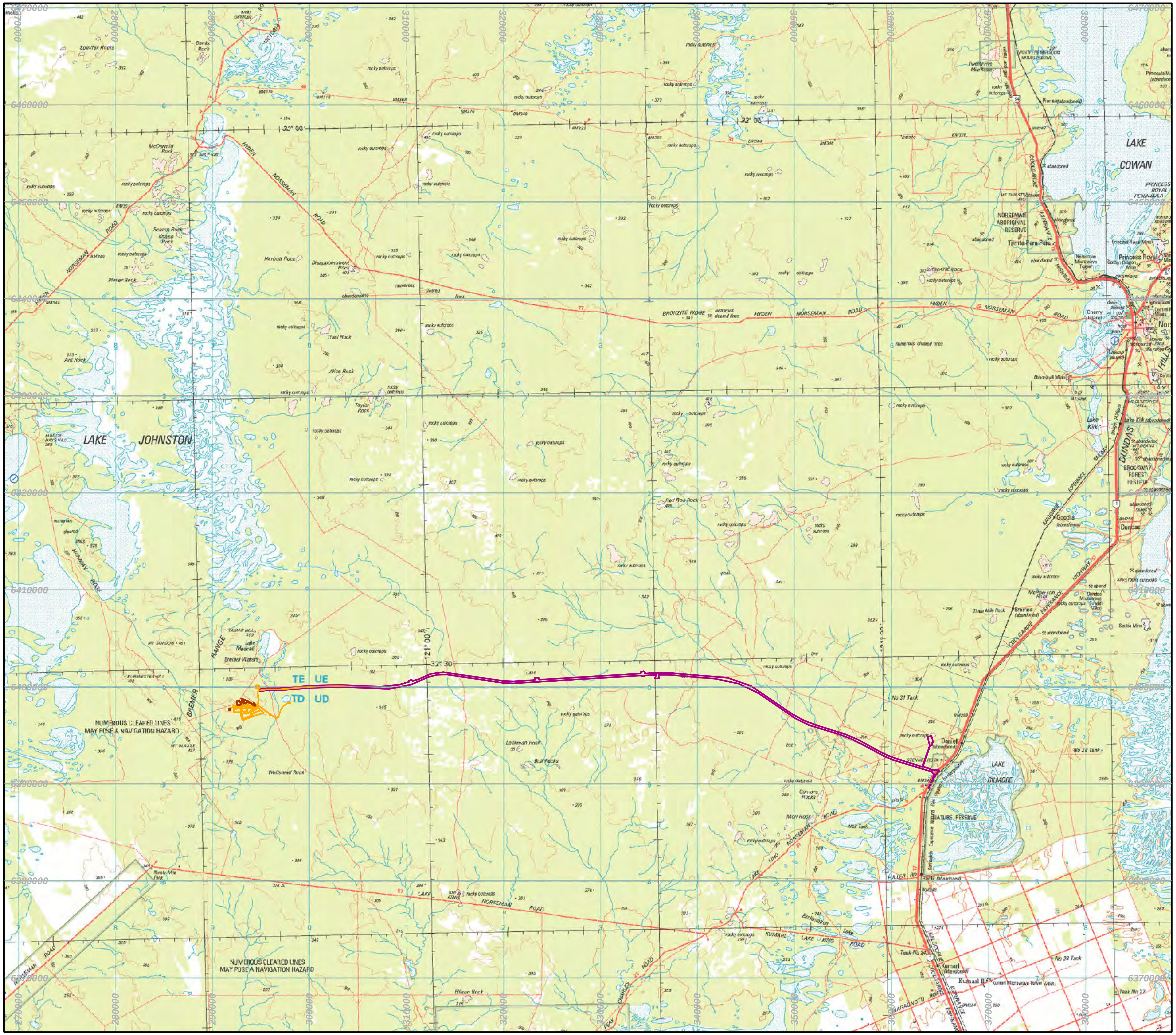
The site location and overall project layout is shown on Figure 1. Details of the proposed mine site layout are given in Figure 2.

Shallow open pit mining for vanadium and titanium is planned from three separate open pits - Vesuvius, Fuji and Egmont. Site infrastructure includes waste rock dumps, tailings storage facility, beneficiation plant, administration and camp. A 73 km haul road will be constructed connecting the site to the Coolgardie Esperance Highway to the east. A transfer depot will be built near the highway.

The ore production rate is likely to be in the order of 1.5 Mtpa over a 19 year life of mine with beneficiation processing at the mine site. The concentrate will be transported by haul trucks along the haul road to the transfer depot. The concentrate will then be transferred to smaller road trains for transport to the Esperance Port.

Audalia has been granted mining lease M63/656, and have submitted an Environmental Protection Authority Scoping Document. Audalia are now undertaking hydrological and hydrogeological assessments for environmental approval.

This report presents a surface water assessment for the site and haul road. The assessment includes a monitoring plan for the site. This report will form part of the project's environmental approval documentation.



Legend

- Pits
- Project Disturbance Footprint
- Transport Development Envelope

Data Sources:
Project Disturbance Footprint, Transport Development Envelope, Pits - Audalia Resources Limited
250K topography - Geoscience Australia

Location

1:100 000 Map Sheet Location

Lake Percy 2934	Diamond Rock 3034	Cave Hill 3134	Cowan 3234
Roundtop 2933	Johnston 3033	Bronzite Ridge 3133	Norseman 3233
Hope 2932	Tay 3032	Peak Charles 3132	Dundas 3232

N
SCALE 1:400,000
0 2.5 5 10 15 20 Km
GDA 1994 MGA Zone 51

Project: Lake Medcalf Hydrogeological and Hydrological Study
Job no: J1843

Figure 1
Project Location

Additional Information

COMPILED: Gaia Resources	DATE: 5/03/2020	LOCN: PERTH	A3	SCALE 1:400,000
GDA 1994 MGA Zone 51	PLAN No: GR604-06_Lake_Medcalf_Fig1.pdf			
DOCUMENT NAME: GR604-06_Lake_Medcalf_Fig1.mxd				

Legend

Pits

Project Disturbance Footprint

Data Sources:
Project Disturbance Footprint, Pits
Imagery - Audalia Resources Limited

Location

1:100 000 Map Sheet Location

Roundtop 2933	Johnston 3033	Bronzite Ridge 3133
Hope 2932	Tay 3032	Peak Charles 3132

N

SCALE 1:25,000

0 0.25 0.5 1 1.5 Km

GDA 1994 MGA Zone 51

audalia resources limited

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Project: Lake Medcalf Hydrogeological and Hydrological Study
Job no: J1843

Figure 2
Site Layout

Additional Information

COMPILED: Gaia Resources	DATE: 7/05/2020	LOCN: PERTH	A3	SCALE 1:25,000
GDA 1994 MGA Zone 51	PLAN No: GR604-06_Lake_Medcalf_Fig2.pdf			
DOCUMENT NAME: GR604-06_Lake_Medcalf_Fig2.mxd				

1.2 Scope of Work

The scope of work was to undertake a surface water assessment for the mine site and haul road. This included:

- Description of the hydrology of the haul road alignment from the Coolgardie Esperance Highway to the site, including definition of key drainage structures and description of potential impacts of the road on the environment;
- Description of the existing hydrology of the mine site with a surface water monitoring plan.

This assessment will form part of the project's environmental approval documentation.

The deliverable is this report.

1.3 Summary of Methodology

The work was undertaken in the following stages:

- Data collation and review;
- Site visit;
- Characterisation of the site and haul road hydrology; and
- Reporting.

1.3.1 Data Review

The data review involved sourcing the available data and undertaking a preliminary review of local catchment conditions.

The following information was used:

- 1 m contour data and high resolution aerial imagery across the site, supplied by Audalia;
- Proposed site layout details, supplied by Audalia;
- Site weather station data (non-complete record for the period 4 April 2014 to 12 June 2018, 0.5 to 1 h rainfall totals), supplied by Audalia;
- Regional topographic and satellite imagery data, supplied by Geoscience Australia;
- Regional weather and design rainfall data, supplied by the Bureau of Meteorology; and
- Reports as referenced throughout the report.

1.3.2 Site Visit

A site visit was undertaken on 29-30 November 2018 by R. Connolly. During the visit the landscape and drainage through the site was inspected. Drainage lines crossing the haul road alignment were inspected.

1.3.3 Characterise Site and Haul Road Hydrology

Aspects of the assessment common to both the haul road and mine site are described together. This covered climate, landforms, soils, vegetation and land use. Assessment of hydrology specific to the two areas was then developed separately.

Haul Road

For the haul road, work included describing characteristics of the alignment and catchments as relevant to surface water drainage and environmental impacts. Key surface water catchments and drainage line crossings along the route were defined and structures required at each location identified at a high level. Areas of the road alignment that might be affected by overland flow were identified by consideration of surface geology mapping and topography. Observations of drainage line crossings made during the site visit were used to inform the haul road assessment. Road drainage design concepts are suggested that aim to minimise potential impacts on overland flows or drainage lines and minimise shadowing of downstream vegetation communities.

Potential impacts of the proposed development on the environment were assessed by considering the spatial location and extent of the road and interaction with overland flow paths, drainage lines and vegetation communities. Suggestions for minimising impacts are incorporated into the drainage design concepts.

Mine site

Drainage through the area of the mine site was defined by interpretation of the detailed topographic data and aerial imagery and was informed by observations made during the site visit. Larger drainage lines and catchments were delineated and general hydrologic processes described. A conceptual model of surface water processes for the site is described.

A preliminary surface water monitoring plan was developed. The intent of the plan is to inform approvals documentation and ongoing management response. As the site has no large streamlines nor permanent water, the focus of the plan was on monitoring and managing operational impacts on surface water, erosion and water quality.

Climate

The climate of the haul road and mine site areas was described using site and regional weather records. Stations recording long term weather in the area are sparse, so it is difficult to determine reliable averages at the site. Also, the site weather station data is not a continuous record. Accordingly the data used for analysis of the climate were derived from a number of sources and should be considered to be indicative.

Daily weather data was generated using the Bureau of Meteorology's Data Drill (Queensland Government 2018) and used to describe the general climate of the area. Data Drill data for a number of locations was tested and compared with station data published by the Bureau of Meteorology. It was found that data generated at the location of the BoM Salmon Gums Station, located some 90 km to the southeast of the mine site, gave the best overall representation of weather at the site. Accordingly, these data were used in the general climate description.

The site rainfall data covered the period 2014-2018 with a 0.5 or 1 h time step but is not complete. These data were used to characterise individual rainfall events, including antecedent soil wetness.

Design rainfall was derived for the site using the Bureau of Meteorology's online data tool (BoM 2018b). This was used for general description of site climate and to estimate the magnitude of rainfall events measured using the site weather station.

Topography

Surface water catchments and drainage lines were defined using the available topographic data. For the site, this was 1 m contour data. For the haul road, a one second SRTM digital elevation model, supplied by Geoscience Australia (GA 2018) was used. This is a nation-wide ground surface model with a spatial resolution of approximately 30 m and a vertical accuracy of up to 7.6 m.

1.4 Limitations

This report has been prepared by Groundwater Resource Management Pty Ltd (GRM) for Audalia and may only be used and relied on by Audalia for the purpose agreed between GRM and Audalia as set out in Section 1.2 of this report.

GRM otherwise disclaims responsibility to any person other than Audalia arising in connection with this report. GRM also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GRM in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GRM has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GRM described in this report (refer Section 1.3 of this report). GRM disclaims liability arising from any of the assumptions being incorrect.

GRM has prepared this report on the basis of information provided by Audalia and others who provided information to GRM (including Government authorities), which GRM has not independently verified or checked beyond the agreed scope of work. GRM does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

2.0 CLIMATE, LANDFORM AND VEGETATION

2.1 INTRODUCTION

This section presents information relevant to both the site and haul road. A description of regional and local climate, land systems, soils, vegetation and land use is given and used to form the haul road and mine site assessments.

A description of the hydrology of the haul road is given in Section 3.0. Mine site hydrology is described in Section 4.0.

2.2 CLIMATE

The site and haul road are located in an arid area with low and variable rainfall year round and with high evaporation. The climate is classified by the modified Köppen system (BoM 2018c) as Grassland, warm (persistently dry). Summers are warm to hot and winters mild. There is a tendency for more rain to be received over winter, but rain occurs all year round.

Key aspects of the climate that affect site infrastructure are rainfall and evaporation. The timing and intensity of rainfall affects infiltration of rainfall into the soil and rates of runoff. Runoff needs to be controlled when interacting with mine infrastructure, to prevent or reduce impacts on the environment and on mine operations. Evaporation is important because it affects the rate that the soil dries out, which can affect rates of runoff. Evaporation also affects the rate of loss of water from ponded areas, such as water and tailings storages.

A summary of rainfall statistics derived for the site is given in Figure 3. A summary of larger events observed at site is given in Table 1.

One estimate of annual rainfall (using data from the BoM station at Salmon Gums) is 357 mm/year. A number of daily events exceeding 120 mm (the 1% AEP) have been recorded in the 86 years of record at Salmon Gums. This indicates that rainfall is variable and large rainfall events can occur at the site. Rainfall occurs all year round, but more tends to be received, on average, during winter (May to September). Large events tend to occur in summer, mainly January to March. However significant events have occurred in September to December and in June.

Rainfall in the period before large events is variable. Table 1 shows data for the 10 days prior, with totals tending to vary from almost no rain to around 30 mm, but sometimes much more.

Rainfall at the site occurs generally as a result of regional rain-bearing depressions in winter, or in summer from thunderstorms and occasionally as a result of tropical cyclones that track far enough south (BoM 2018d). The influence of cyclones, though, is weak and generally results in only small rainfall events.

Mean annual pan evaporation is some 1,500 mm/year. Mean monthly evaporation exceeds mean rainfall in every month of the year. Evaporation rates are much lower in winter than in summer. This pattern of variation in evaporation combined with rainfall distributed during the year in variable falls suggests that the soil profile prior to larger events is likely to be relatively dry in summer but could be moist to saturated in winter.

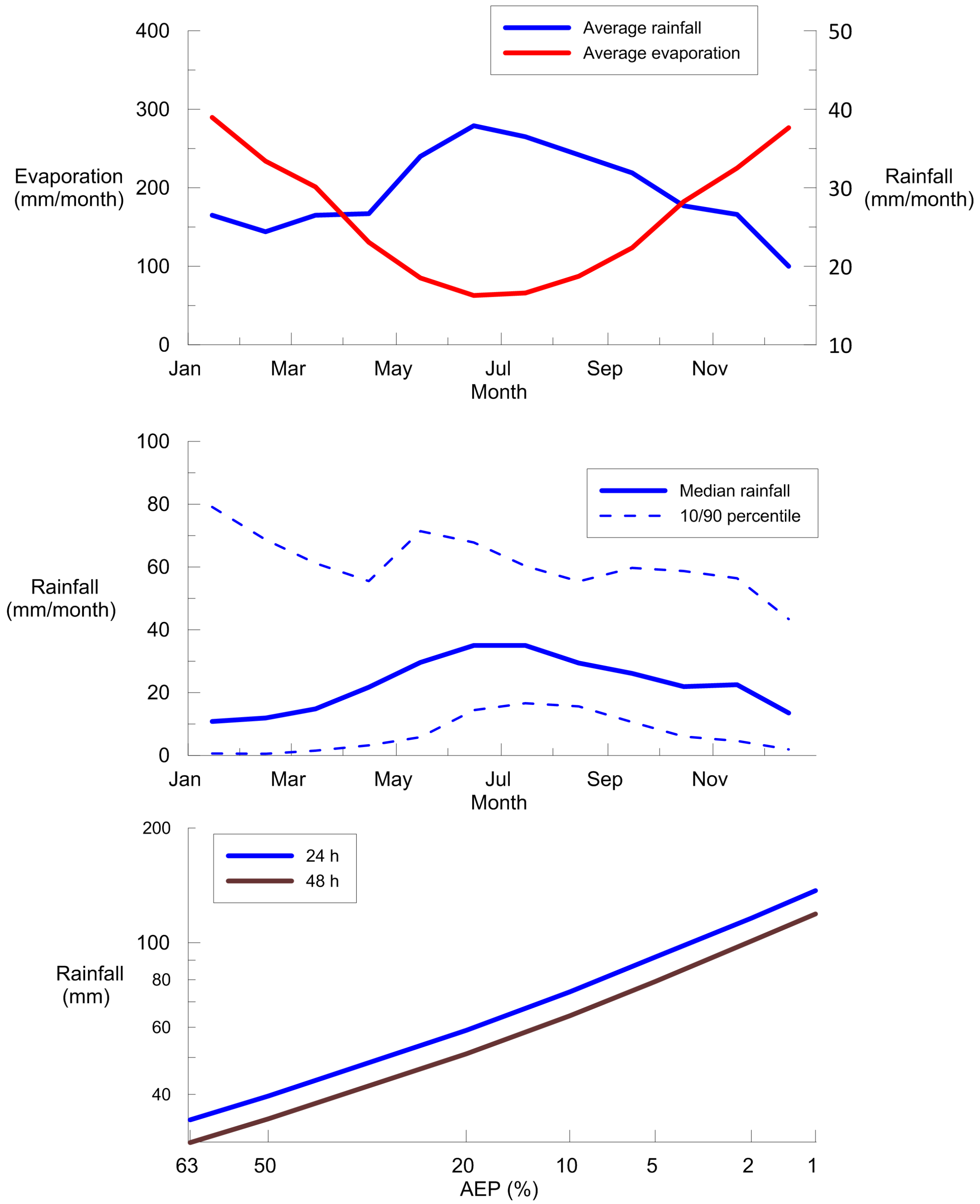


Figure 3 Site Climate Details

Table 1 Site Rainfall Events

Date	Duration (h)	Rain (mm)	Rain in previous 10 days (mm)	AEP
21/09/2017	9.5	97.5	1.2	1 in 200
7-8/02/2017	10.0	78.3	24.6	2%
26/10/2017	6.0	59.4	9.9	2%
10/06/2018	5.0	49.2	5.1	5%
18/12/2017	5.0	24.9	31.2	50%
18/02/2018	1.0	23.1	11.4	10%

Data are observed at the mine site, 0.5 or 1 h time step. AEP is approximate.

2.3 LAND SYSTEMS AND SOILS

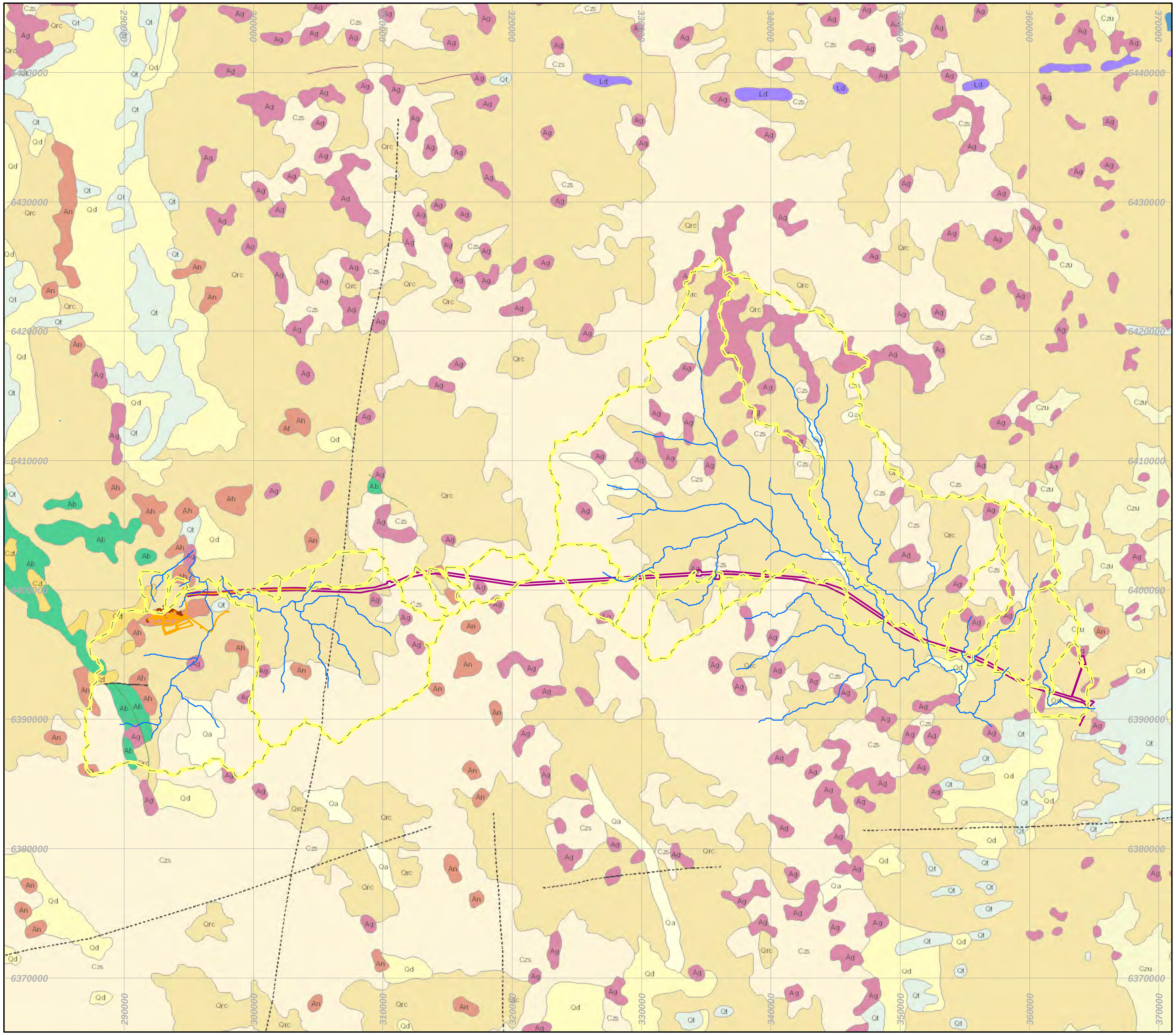
Land systems, soils and geology through the project area have been mapped by a number of agencies. Most though, are at regional scales, which are hard to interpret at the scale of the project footprint. One dataset, surface geology (GA 2018), has sufficient resolution to provide some background to the soils and landscape that occurs through the mine site and along the haul road. The surface geology for the area including the haul road and mine site is mapped in Figure 4. This data set is supplemented by observations made on site.

Through the mine site area, the surface geology mapping shows a band of rock corresponding to the low hills and mine resource areas. Off the hills to the north and south is mapped as colluvium. Observations made during the site visit support this mapping. A line of low hills running east-west shows rocky outcrops with pebbles and little topsoil. With distance downslope the depth of soil increases into the colluvial zone. Soils tend to be yellow sandy and loamy earths or red loamy earths.

The haul road crosses two main types of surface geology – colluvium and sandplain. Colluvium lies on the eastern and western end of the haul road. Soils tend to be clay loams (Botanica 2017) and will produce some runoff, at least in intense rainfall events and some drainage lines cross the road.

The sandy area lies in the middle of the road alignment. Soils here are sandy loams (Botanica 2017). This area is undulating and probably produces little runoff.

The road crosses occasional granite outcrops. The eastern end of the road crosses part of a lunette dune system associated with Lake Gilmore. Though not mapped in the surface geology dataset, the road also crosses a tributary of Lake Medcalf.



Legend

- Drainage Lines
- Pits
- Project Disturbance Footprint
- Catchments
- Transport Development Envelope

Surface Geology

QUATERNARY
- Qa
- Qd
- Qrc
- Qt

CENOZOIC
- Cza
- Czk
- Czl
- Czs
- Czz

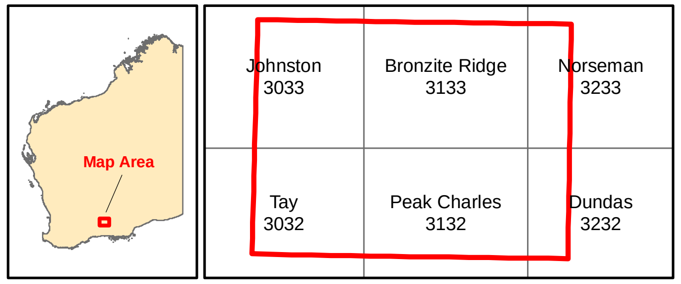
PROTEROZOIC
- -Ps

PALEOPROTEROZOIC
- Lc
- Ls

ARCHEAN
- Aa
- Ab
- Ad
- Ae
- Af
- Ag
- An
- As
- At
- Au
- Av
- Aw
- Ay

Data Sources:
Project Disturbance Footprint, Transport Development Envelope, Pits - Audalia Resources Limited
Catchments, Drainage Lines - GRM
Geology of Australia - Geoscience Australia

Location | 1:100 000 Map Sheet Location



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0 1.5 3 6 9 12 Km
GDA 1994 MGA Zone 51

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Project: Lake Medcalf Hydrogeological and Hydrological Study
Job no: J1843

Figure 4
Surface Geology

Additional Information

COMPILED: Gaia Resources	DATE: 6/03/2020	LOCN: PERTH	A3	SCALE 1:300,000
GDA 1994 MGA Zone 51	PLAN No: GR604-06_Lake_Medcalf_Fig4_R2.pdf			
DOCUMENT NAME: GR604-06_Lake_Medcalf_Fig4_R2.mxd				

2.4 VEGETATION AND LAND USE

Vegetation through the mine site and along the haul road is generally classified as Eucalypt and Mallee woodlands and shrublands (Botanica 2017).

Vegetation across the area is variably affected by fire. At any one time, the forest will include areas in various stages of regrowth and with variable litter and fallen dead material. This affects the hydrological characteristics of the landscape. Areas with little vegetation and ground cover (i.e. freshly burnt) will have higher rates of runoff and increased turbidity compared with heavily vegetated areas.

Land use is unallocated crown land overlain with mining act tenements. There is native vegetation through most of the mine site and haul road alignment. Access tracks cross the area. The eastern end of the haul road joins the Coolgardie Esperance Highway.

3.0 HAUL ROAD HYDROLOGY

3.1 INTRODUCTION

This section presents a description of drainage along the alignment of the proposed haul road. The proposed alignment is shown in Figure 1.

The haul road alignment currently has an incomplete access track. When completed, it is understood that the road will be a graded, two lane, dirt or gravel surfaced road constructed generally on the ground surface (i.e. not built up). Low earth banks may form on the sides of the road as a result of grading or may be constructed as safety berms. The road in places may have table drains on one or both sides of the roadway with turnout drains discharging stormwater to the environment.

Indicative locations of drainage line crossings and concept design guidance on the nature of crossings and drainage along the road in general is given. This information is indicative and needs to be updated as part of detailed road design. Some crossings, such as of the Lake Medcalf channel near the mine site, may need more hydrologic and hydraulic assessment to inform engineering design.

A review of potential impacts to the environment associated with the road is given. Management of these impacts is incorporated into the design guidance.

3.2 DRAINAGE

The topography along the haul road alignment is largely flat, with isolated low granite outcrops and sandy rises. Catchments for drainage lines crossing the alignment and potential crossing locations are delineated in Figure 5. Catchment characteristics are summarised in Table 2.

There are a number of catchments that drain across the road, some of which are quite large, however there are few defined stream channels. Most drainage line crossings are low areas with ponded water or shallow flow.

The most defined drainage line crossing the haul road is a tributary or arm of Lake Medcalf near the mine site. The actual crossing point could not be accessed during the site visit but the channel downstream was inspected. Aerial imagery of the crossing point shows a broad, shallow channel that may flow and pond water in wet periods. Photo 1 shows the channel further downstream, where it is larger and more saline.

Many of the other crossings are topographic valleys with no defined channel. Photo 2, taken at Crossing 11, is an example of this type. The existing access track is shown in Photos 2 to 5.

In other areas the crossing has more definition and may convey water in larger events. However, there is still no defined or incised stream channel. Flow in these locations probably occurs as shallow flow. Ponding could occur for some time. Photo 3 shows Crossing 8, which has a small catchment but more topographic definition. Photo 4 shows Crossing 21, which has a large catchment but still a diffuse drainage line. Photo 5 shows Crossing 26, which is the drainage line for a small playa about 1.5 km downstream.

Photo 1 Lake Medcalf Channel Downstream of Crossing 1

Photo 2 Crossing 11

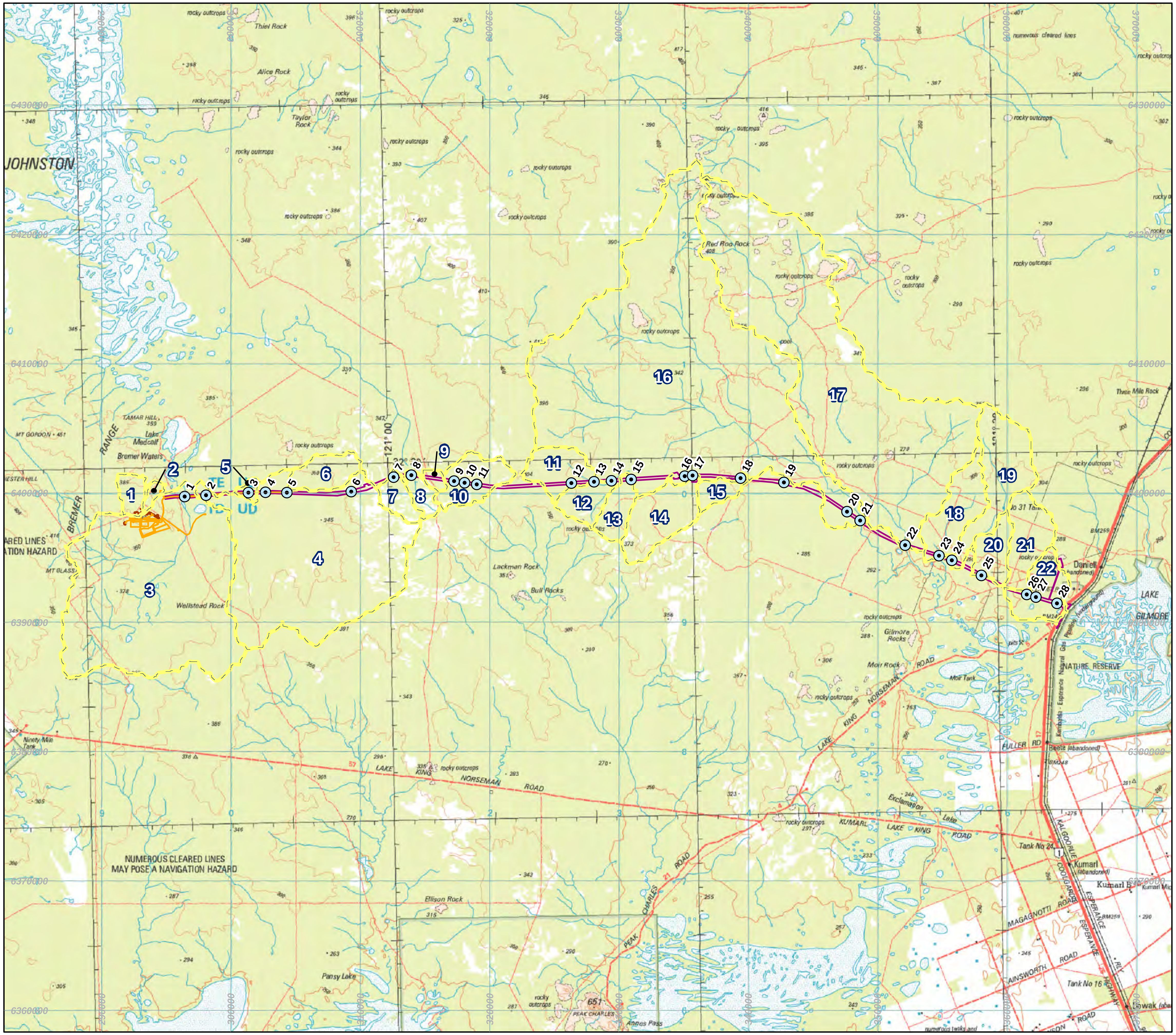
Photo 3 Crossing 8

Photo 4 Crossing 21

Photo 5 Crossing 26

Table 2 Haul Road Catchments

Name	Area (km^2)	Description
1	5.9	Drains the north western portion of the mine site. Discharges toward L Medcalf.
2	2.0	Drains the north eastern portion of the mine site. Discharges toward L Medcalf.
3	162.6	Drains the southern portion of the mine site. Drained by a tributary of L Medcalf that crosses the haul road just east of the mine site at Crossing 1.
4	148.0	Large catchment. Drains toward L Medcalf. Includes a number of internally drained areas discharging to small playas. A diffuse drainage line crosses the haul road at Crossing 2.
5	2.0	Small catchment with no defined drainage line at the haul road.
6	12.0	Small catchment with a diffuse drainage line at the haul road.
7	7.5	Small catchment with no defined drainage line at the haul road.
8	5.6	Small catchment with a diffuse drainage line at the haul road. Drainage line is the upper reaches of a stream discharging to L Medcalf.
9	2.2	Small catchment with no defined drainage line at the haul road.
10	15.7	Small catchment with a diffuse drainage across the haul road. Topographic data indicates a number of potential drainage valleys or low points (Crossings 9, 10 and 11).
11	15.0	Small catchment with a diffuse drainage line at the haul road. Several potential crossings or low points at the haul road (Crossings 12 and 13).
12	9.8	Small catchment with a diffuse drainage line at the haul road.
13	10.0	Small catchment with no defined drainage line at the haul road.
14	23.8	Moderate sized catchment with no defined drainage line at the haul road.
15	6.1	Small catchment with no defined drainage line at the haul road.
16	316.5	Large catchment with a drainage valley at the haul road but ill-defined stream channel. Number of crossings in this area. The main drainage line is at Crossing 21.
17	230.7	Large catchment with a diffuse drainage line at the haul road.
18	22.4	Moderate sized catchment with a diffuse drainage line at the haul road.
19	31.9	Moderate sized catchment with a diffuse drainage line at the haul road.
20	11.2	Small catchment with no defined drainage line at the haul road.
21	19.2	Small catchment with a drainage valley or upper reaches of a playa at the haul road. Drainage line crosses the road alignment at Crossing 26.
22	16.6	Small catchment with a number of ill-defined crossings of the haul road (27 and 28). Receives streamflow from Catchment 21 and includes a number of playas in the lower reaches. Any discharge from the playas is across the Coolgardie Esperance Highway to L Gilmore.



Legend

- Crossings
- Pits
- Project Disturbance Footprint
- Catchments
- Transport Development Envelope

Data Sources:
Project Disturbance Footprint, Transport Development Envelope, Pits - Audalia Resources Limited
Crossings, Catchments - GRM
250K topography - Geoscience Australia

Location

1:100 000 Map Sheet Location

Roundtop 2933	Johnston 3033	Bronzite Ridge 3133	Norseman 3233
Hope 2932	Tay 3032	Peak Charles 3132	Dundas 3232

N

SCALE 1:300,000

0 1.5 3 6 9 12 Km

GDA 1994 MGA Zone 51

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Project: Lake Medcalf Hydrogeological and Hydrological Study
Job no: J1843

Figure 5
Haul Road Catchments and Drainage Line Crossings

Additional Information

COMPILED: Gaia Resources	DATE: 5/03/2020	LOCN: PERTH	A3	SCALE 1:300,000
GDA 1994 MGA Zone 51	PLAN No: GR604-06_Lake_Medcalf_Fig5_R2.pdf			
DOCUMENT NAME: GR604-06_Lake_Medcalf_Fig5_R2.mxd				

3.3 Road Drainage Structures

Indicative crossing locations for the haul road are shown in Figure 5 and described in Table 3. A total of 28 crossing locations were identified, based on interpretation of regional topographic data.

Three types of structures for drainage lines crossing the haul road are suggested:

- Causeway;
- Floodway; and
- No formal structure.

The only crossing that requires a causeway is Crossing 1, which is a large, defined streamline and tributary or arm of Lake Medcalf. It is likely that water flows in the channel toward Lake Medcalf during and after rainfall events. As the lake fills, water could pond at the crossing location for some time, gradually dissipating to infiltration and evaporation.

A causeway could be an appropriate structure for this location as it caters for both flowing and ponded water. The structure could take the form of an elevated roadway with low-flow culverts. The roadway could be designed as a floodway for larger events. Smaller events and movement of ponded water across the road alignment could be conveyed in culverts. Flow concentration should be minimised to reduce impact on the downstream hydrologic regime and to minimise scour. More detailed hydrologic and hydraulic modelling should be undertaken to design this structure.

Floodways are suggested for crossings where there is a defined drainage channel or valley and a moderate or large contributing catchment. The floodway could take the form of a protected road surface and free drainage to the floodway upstream and downstream. Roadside berms should be discontinued through the floodway. Floodways should be constructed so as to not unduly concentrate flows. Culverts or an elevated roadway may not be required unless there is persistent ponding or interference to road operation.

No formal structure is suggested for areas where the contributing catchment is small and there is no defined drainage line. These areas are, however, topographic low points and may convey or pond water after heavy rainfall. Accordingly, the design of the roadway and maintenance regime in these areas should account for the possibility of flow and ponding. Maintenance may involve repair of minor damage to the road surface or edge banks resulting from ponding or scour.

Shallow overland flow could occur in areas along the road alignment. Indicative areas where overland flow may occur along the road alignment are shown in Figure 6. In these areas the road formation could intercept and divert overland flow so consideration should be given to management of concentrated or diverted overland flow along the upstream edge of the roadway. Edge banks or safety berms could impede natural drainage flow paths in areas where there is overland flow. This is most likely on steeper hillslopes and on high runoff areas (such as rocky outcrops). Provision should be made to allow overland flow to cross the roadway without substantial accumulation or diversion. This is to maintain natural flow paths and to minimise impacts on downstream vegetation and as management of smaller flows across the roadway is easier than larger flows.

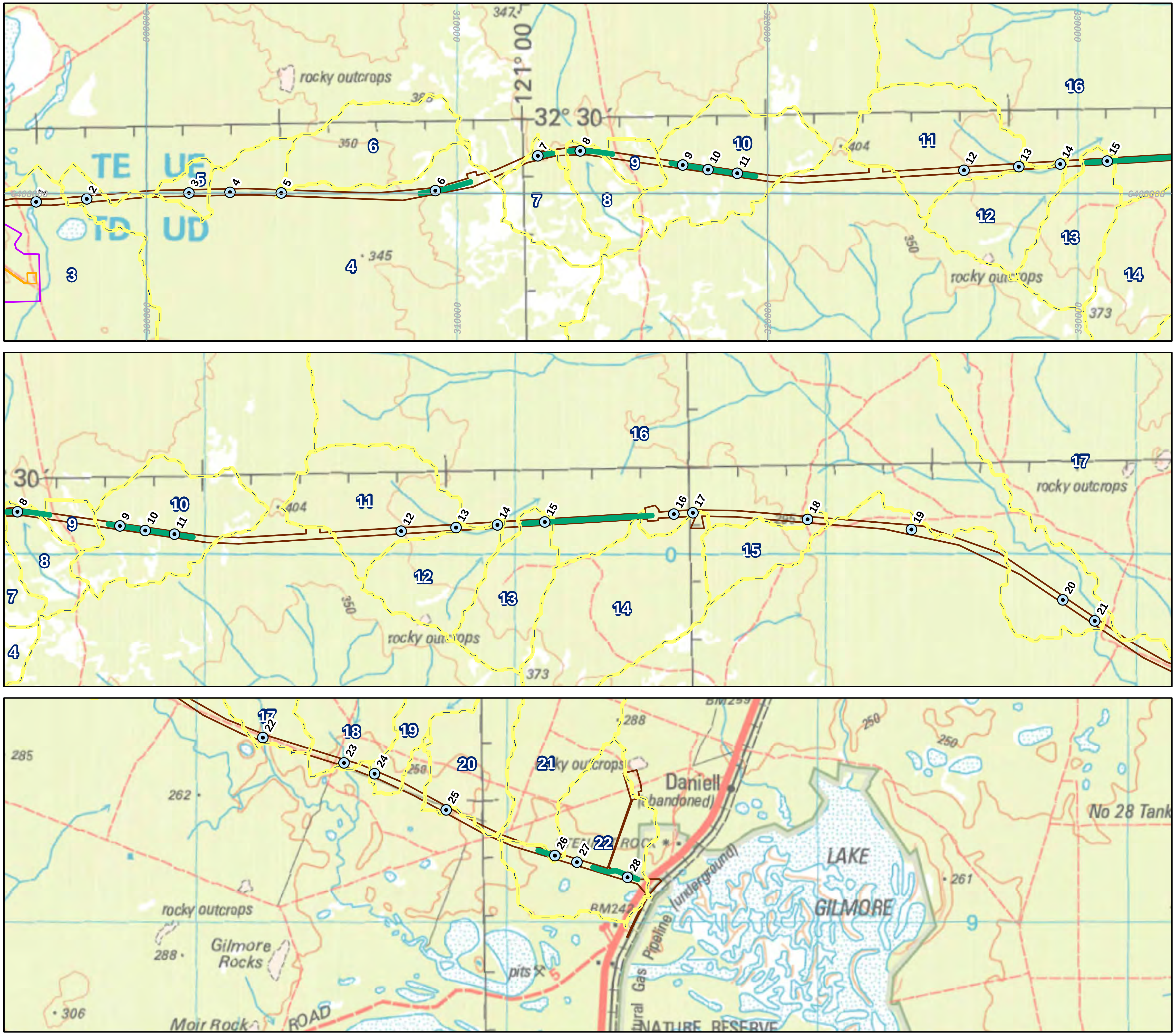
Appropriate shaping of the road surface may be required to prevent uncontrolled linear flow and scour of the road surface. This may involve forming cross-grade on the road surface and use of table drains. Table drains should aim to collect any sediment and discharge to the environment at non-erosive velocities.

Note that this is a preliminary assessment and more detail will be required as part of the road design. Monitoring during mine operation may also inform the nature of some crossings, which may need to be upgraded or modified to better suit site conditions.

Table 3 Haul Road Crossings

Name	Indicative Crossing Type	Description
1	Causeway	L Medcalf tributary. Defined channel with likely flowing and ponded water.
2	Floodway	Diffuse drainage line but a large catchment. Allow for shallow overland flow and/or ponding.
3	No formal structure	Diffuse drainage line and a small catchment. No structure may be viable, but may need road maintenance after rainfall events.
4	No formal structure	Diffuse drainage line and a small catchment. No structure may be viable, but may need road maintenance after rainfall events.
5	No formal structure	Diffuse drainage line and a small catchment. No structure may be viable, but may need road maintenance after rainfall events.
6	No formal structure	Diffuse drainage line and a small catchment. No structure may be viable, but may need road maintenance after rainfall events.
7	No formal structure	Diffuse drainage line and a small catchment. No structure may be viable, but may need road maintenance after rainfall events.
8	Floodway	Diffuse drainage line and a small catchment. Allow for shallow overland flow and/or ponding.
9	No formal structure	Diffuse drainage line and a small catchment. No structure may be viable, but may need road maintenance after rainfall events.
10	No formal structure	Diffuse drainage line and a small catchment. No structure may be viable, but may need road maintenance after rainfall events.
11	No formal structure	Diffuse drainage line and a small catchment. No structure may be viable, but may need road maintenance after rainfall events.
12	No formal structure	Diffuse drainage line and a small catchment. No structure may be viable, but may need road maintenance after rainfall events.
13	Floodway	Diffuse drainage line. Allow for shallow overland flow and/or ponding.
14	Floodway	Diffuse drainage line, continuation of drainage line from Crossing 13. Allow for shallow overland flow and/or ponding.
15	No formal structure	Diffuse drainage line and a small catchment. No structure may be viable, but may need road maintenance after rainfall events.
16	No formal structure	Diffuse drainage line and a small catchment. No structure may be viable, but may need road maintenance after rainfall events.
17	Floodway	Ill-defined drainage line but a moderate sized catchment. Allow for shallow overland flow and/or ponding.
18	No formal structure	Diffuse drainage line and a small catchment. No structure may be viable, but may need road maintenance after rainfall events.
19	No formal structure	Diffuse drainage line and a small catchment. No structure may be viable, but may need road maintenance after rainfall events.
20	No formal structure	Diffuse drainage line and a small catchment. No structure may be viable, but may need road maintenance after rainfall events.
21	Floodway	Diffuse drainage line. Allow for shallow overland flow and/or ponding.
22	Floodway	Diffuse drainage line but a large catchment. Allow for shallow overland flow and/or ponding. Possibly larger flows in bigger events.

Name	Indicative Crossing Type	Description
23	Floodway	Diffuse drainage line and a moderate-sized catchment. Allow for shallow overland flow and/or ponding.
24	Floodway	Diffuse drainage line and a moderate-sized catchment. Allow for shallow overland flow and/or ponding.
25	No formal structure	Diffuse drainage line and a small catchment. No structure may be viable, but may need road maintenance after rainfall events.
26	Floodway	Diffuse drainage line, possibly the upper reaches of a playa. Allow for shallow overland flow and/or ponding.
27	No formal structure	Diffuse drainage line and a small catchment. No structure may be viable, but may need road maintenance after rainfall events.
28	No formal structure	Diffuse drainage line and a small catchment. No structure may be viable, but may need road maintenance after rainfall events.



Legend

- Crossings
- Indicative overland flow areas
- Catchments
- Project Disturbance Footprint
- Mine Development Envelope
- Transport Development Envelope

Data Sources:
Mine development envelope, project disturbance footprint and transport development envelope - Audalia Resources Limited
Crossings, catchments, indicative overland flow areas - GRM 250K topography - Geoscience Australia

Location

1:100 000 Map Sheet Location

Roundtop 2933	Johnston 3033	Bronzite Ridge 3133	Norseman 3233
Hope 2932	Tay 3032	Peak Charles 3132	Dundas 3232

N

SCALE 1:125,000

0 2 4 6 Km

GDA 1994 MGA Zone 51

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Project: Lake Medcalf Hydrogeological and Hydrological Study
Job no: J1843

Figure 6
Indicative overland flow areas

Additional Information

COMPILED: Gaia Resources	DATE: 20/4/2020	LOCN: PERTH	A3	SCALE 1:125,000
GDA 1994 MGA Zone 51	PLAN No: GR604-06_Lake_Medcalf_Fig6_R2.pdf			
DOCUMENT NAME: GR604-06_Lake_Medcalf_Fig6_R2.mxd				

3.4 Potential Impacts on Hydrological Regimes

There are three hydrologic regimes that the haul road alignment intersects:

1. Overland flow areas;
2. Diffuse drainage lines; and
3. Lakes and associated drainage lines.

Overland flow can occur all along the alignment but the amount and frequency of flow is heavily influenced by soil types, surface cover and land surface grade. Steeper, rocky areas will have the highest runoff rates and overland flow may occur during relatively small rainfall events. Colluvium or higher clay soils will produce more runoff than sandy soils. Bare areas (such as after a fire) will produce more runoff than heavily covered areas. Areas with high runoff tend to be isolated in the landscape. Higher infiltration areas downstream tend to absorb runoff from upslope. Characteristics of the soils and landscape are discussed in more detail in Section 2.3.

A number of diffuse drainage lines cross the alignment. These are largely topographic lows with little or no evidence of concentrated stormwater flow. They may infrequently carry stormwater as shallow overland flow. These areas are identified and discussed in Section 3.3.

In some places playas or lakes lie relatively close to the alignment – within about 1 km. Most appear to be hydraulically disconnected from flows crossing the roadway, so should be unaffected by the proposed road. Two lakes/lake systems on the far eastern end of the alignment have a diffuse defined drainage line that could provide a hydraulic connection in flow events after heavy rainfall. The drainage line at the road is less well defined than the Lake Medcalf channel so the connection to activities on the roadway are likely to be less direct.

The only lake that is connected to the road alignment via a well-defined stream channel is Lake Medcalf. Lake Medcalf proper is within about 4 km of the alignment via a tributary channel. Here the channel is probably in direct contact during runoff events and possibly when Lake Medcalf holds water. Accordingly, the channel could be a possible pollutant pathway for the lake.

The main potential impacts of the roadway on the receiving environment are:

- Shadowing of downstream vegetation due to diversion of overland flow along the upstream edge of the road;
- Discharge of sediment as a result of scour at the roadway; and
- Discharge of pollutants from the road surface.

Shadowing can be managed by minimising concentration and diversion of overland flow through road design. Regular overland flow is likely to occur in limited areas where there is high runoff potential (steeper hillslopes and rocky outcrops). The landscape along much of the alignment has low runoff and is unlikely to generate much overland flow except in very large events. In areas with high overland flow potential, the roadway should be designed to minimise flow concentration and diversion and to allow flow to cross the road at regular intervals.

Floodways in diffuse drainage lines and the crossing over the Lake Medcalf tributary should also not unduly concentrate flows. This will minimise the chance of concentrated flows causing scouring and will reduce downstream shadowing.

Scour of the roadway can be minimised by appropriate shaping of the road profile and use of table drains to manage runoff and scour from the road surface. Maintenance of any scour that occurs after rainfall events may also be required.

Discharge of pollutants from the road surface could occur as a result of entrainment of spilt material by runoff during a rainfall event. This risk is low due to the nature of the material transported on the road and the intermittent nature of rainfall events. The risk can be readily managed by rapid clean up.

If saline water is used on the road surface, accumulated salts could be washed off in subsequent rainfall events. These salts can be collected in table drains. If salt build up is substantial then small sumps may be required.

Design guidance is given in Section 3.3.

4.0 MINE SITE HYDROLOGY

4.1 INTRODUCTION

This section describes the existing hydrology and drainage of the mine site area. This includes a conceptual model of the site catchment water balance. A surface water monitoring plan is presented. This section is informed by the description of climate, landform and vegetation given in Section 2.0.

The mine site is the area inside the mine development envelope (Figure 2). Proposed infrastructure that will be located inside the development envelope includes pits, processing areas, waste dumps, tailings storage facility, camp and roads.

4.2 DRAINAGE AND TOPOGRAPHY

Topography, drainage lines and catchments for the mine site area are shown in Figure 7. Drainage through the area of the mine site is defined by a line of low hills trending in an east-west direction through the Fuji and Vesuvius pits. Drainage from the hills through the site area is generally either toward the north or south.

The northern catchments cover parts of the Fuji and Vesuvius pits, some access and internal haul roads and the western end of the haul road to the Coolgardie Esperance Highway. Runoff from these catchments drains into Lake Medcalf (Figure 5).

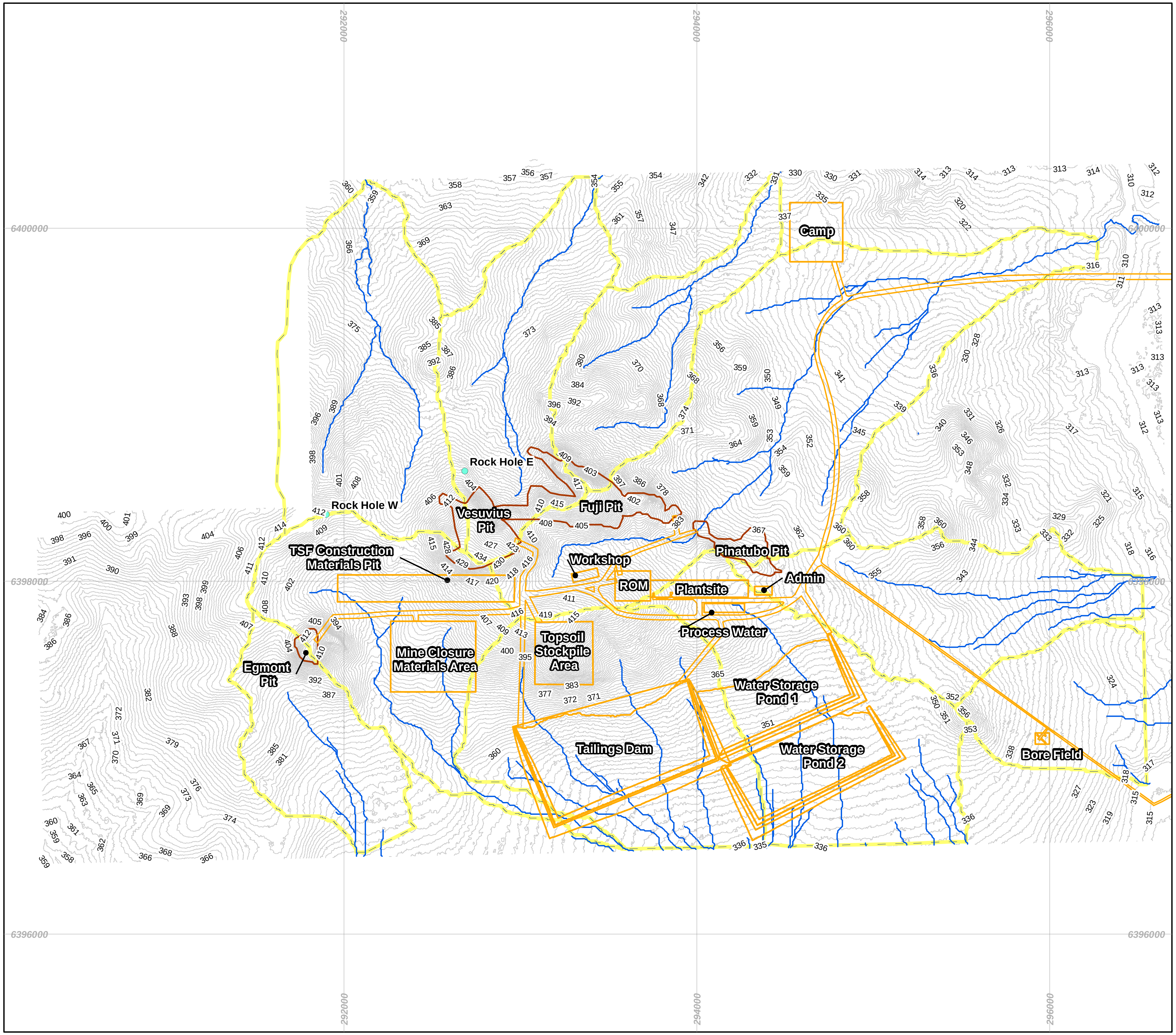
The southern catchments cover the Egmount pit, parts of the Fuji and Vesuvius pits, waste rock dump, tailings storage facility, plant area and camp. These catchments drain toward a tributary of Lake Medcalf. This tributary crosses the haul road before joining Lake Medcalf from the south.

The landscape is characterised by rocky hill tops grading to deeper loamy soils with distance downslope. Rock is generally exposed on the top of the hills and there is little vegetation in contact with the ground surface. These areas are high runoff zones. Runoff from even small rainfall events will likely move off these areas as overland flow. In smaller events, most runoff will reinfiltrate in areas downstream with a deeper soil profile.

Moving downslope, a soil profile gradually forms, either as yellow sandy and loamy earths or red loamy earths. The soil profile increases in depth with distance downstream. Occasional small erosion gullies tend to form about mid-slope and then dissipate.

Defined streamlines form toward the bottom of the catchments. Runoff from the deeper soil areas will occur in more intense events and move as overland flow concentrating into drainage lines then defined streams as flow rates increase with distance downstream. Vegetation density increases as the soil profile increases and in proximity to drainage lines. The larger drainage lines tend to have heavy grass and scrub growth. The drainage lines are generally dry, flowing only for a short period after rainfall.

There are two main rock holes within the project disturbance footprint. These are small cavities in the surface rock that collect rainfall and local streamflow and pond water for a time after rainfall. The water is lost mainly to evaporation.



Legend

- Rock Holes
- Pits
- Project Disturbance Footprint
- Drainage Lines
- Contours (1m)
- Catchments

Data Sources:
Project Disturbance Footprint,
Pits - Audalia Resources Limited
Rock Holes, Drainage Lines, Catchments,
Contours - GRM

1:100 000 Map Sheet Location

Roundtop 2933	Johnston 3033	Bronzite Ridge 3133
Hope 2932	Tay 3032	Peak Charles 3132

N

SCALE 1:22,000

0 0.125 0.25 0.5 0.75 1 Km

GDA 1994 MGA Zone 51

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Project: Lake Medcalf Hydrogeological and Hydrological Study
Job no: J1843

Figure 7
Site Drainage and Topography

Additional Information

COMPILED: Gaia Resources	DATE: 7/05/2020	LOCN: PERTH	A3	SCALE 1:22,000
GDA 1994 MGA Zone 51	PLAN No: GR604-06_Lake_Medcalf_Fig7_R2.pdf			
DOCUMENT NAME: GR604-06_Lake_Medcalf_Fig7_R2.mxd				

4.3 Conceptual Site Catchment Water Balance

Catchment water balance modelling presenting in GRM (2019) was used to help characterise the water balance for the mine site. The results of this modelling are summarised here.

A predicted water balance for the site for the period 2014-2017 is given in Table 4. Average rainfall over this period was 390 mm/year. The water balance is dominated by evapotranspiration, which accounts for 97% of rainfall. This means that most rainfall is taken up by plants and transpired or evaporated from soil, rock and vegetation surfaces.

The amount of runoff leaving the catchments via drainage lines is relatively low, 3% for the total area. While runoff from upper rocky areas can be high, much of this is infiltrated in the colluvial zone downstream.

Total seepage below the root zone, which could recharge groundwater, is low relative to the other components of the water balance. Recharge is likely to be highly episodic, with much occurring during extended wet periods. Accordingly, wetter periods than observed during the simulation period (2014-2017) may have higher seepage rates.

Table 4 Predicted Catchment Water Balance

Catchment	Rainfall (mm/year)	Water balance (mm/year)			Water balance (% of rainfall)		
		Evapo-transpiration	Runoff leaving the catchment	Seepage below the root zone	Evapo-transpiration	Runoff leaving the catchment	Seepage below the root zone
Site	390	379	13	0	97%	3%	0%

Taken from GRM (2019). Water balance is presented for the unsaturated zone (root zone). Simulation period – 2014-2017. Rainfall and evaporation data are for the location of the BoM Salmon Gums station, derived using BoM data drill. Catchments are shown on Figure 5.

4.4 Monitoring Plan

The monitoring plan is developed assuming that if surface water management infrastructure is properly designed, constructed and maintained, there will be little impact on the surrounding environment. Due to limitations on access and the extremely variable nature of runoff, it is not practical to sample streamflow through the site area or downstream in smaller drainage lines. Lake Medcalf and tributaries are also generally dry.

Most potential impacts on the environment will arise in association with failure of surface water management infrastructure. This is most likely to occur in disturbed areas, around outfalls from diversion drains where they discharge into the environment and at road crossings. Regular visual monitoring of the performance of surface water management infrastructure is a simple and effective means of identifying failure of infrastructure and triggering rectification action.

The two rock holes hold water after rainfall events. It is proposed that levels in these rock holes be monitored, to better understand the dynamics of the water balance for the rock holes. The rock holes have little interaction with the wider site hydrology, so more intensive sampling is not proposed.

Accordingly, the objectives of the monitoring plan are to:

- Confirm that surface water management infrastructure is functioning to design criteria;
- Trigger rectification action if required; and
- Confirm that water quality downstream of the mine site is not adversely affected by mining activities.

A monitoring plan is summarised in Table 5. Sampling locations are shown in Figure 8.

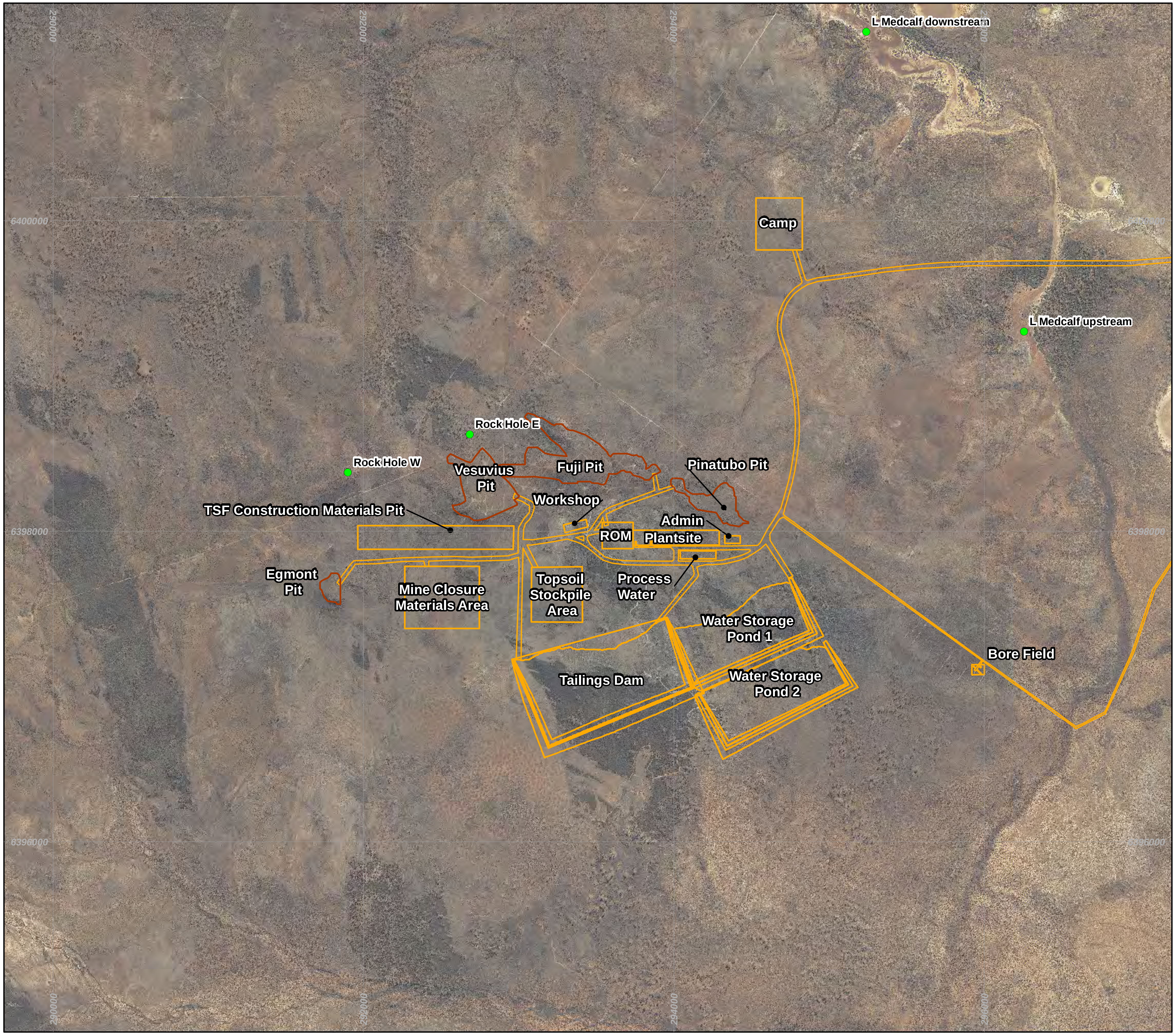
Sampling of Lake Medcalf pools is intended to provide baseline water quality and inundation period information as well as quantify impacts from site operation. However, sampling locations, timing and analysis suites in Lake Medcalf are indicative and may need to be moved for access or operational reasons. It may be appropriate, for example, to undertake visual monitoring of sedimentation at more locations. More detailed water quality sampling may be required if a spill occurs.

Monitoring is based mainly around visual observation of operational assets. Sampling in Lake Medcalf is proposed only when the lake holds water.

Table 5 Summary of the Surface Water Monitoring Program

Area to be monitored	**Monitoring type**	**Analysis suite**	**Frequency**
L Medcalf pools	Water level Water quality sample	Water level, water quality suite*	After significant rainfall events when the lake holds water. Six monthly as the lake dries.
Rock holes	Water level	Water level, visual observation, photos.	After significant rainfall events when the holes hold water. Weekly as the holes dry.
Mine site drains	Visual	Observation of scour, deposition or failure of drainage infrastructure.	After runoff events.
Road culverts and flood ways	Visual	Observation of scour.	After runoff events.
Water management ponds	Visual	Observation of freeboard.	During large runoff events or periods of low water reuse/discharge.
Sediment ponds	Visual	Observation of sediment build up.	After larger runoff events.
Site	Weather	Standard weather parameters, including rainfall intensity,	Ongoing.

* The standard water quality suite is: pH, total suspended solids, total dissolved solids, total alkalinity, ions and metals.



Legend

- Sampling Locations
- Pits
- Project Disturbance Footprint

Data Sources:
Project Disturbance Footprin,
Imagery, Pits - Audalia Resources Limited
Sampling Locations - GRM

Location

1:100 000 Map Sheet Location

Roundtop 2933	Johnston 3033	Bronzite Ridge 3133
Hope 2932	Tay 3032	Peak Charles 3132

N
SCALE 1:25,000
0 0.25 0.5 1 1.5 Km
GDA 1994 MGA Zone 51

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Figure 8
Surface Water Monitoring Sites

Additional Information

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GDA 1994 MGA Zone 51	PLAN No: GR604-06_Lake_Medcalf_Fig8_R2.pdf			
DOCUMENT NAME: GR604-06_Lake_Medcalf_Fig8_R2.mxd				

5.0 REFERENCES

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