
Hydrological (Surface Water) Assessment

Calingiri Copper Project Caravel Minerals

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Report

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Executive Summary

Scope of Works

Pendragon Environmental Solutions was requested by Caravel Minerals to undertake a desk study assessment of the surface water hydrology at their Calingiri Copper Project.

Objectives

This document details the hydrological assessment pertaining to the potential for impacts by mining on environmental factors including Terrestrial Environmental Quality, Hydrological Processes, Inland Waters Environmental Quality and Rehabilitation and Decommissioning (EPA, 2015). The primary objectives are to ensure that the quality of land, soils, sediment and surface and ground water is maintained to protect environmental values and existing and potential future uses and to facilitate decommissioning and closure in an ecologically sustainable manner.

The scope of works for the hydrological desk study assessment included preliminary level identification and delineation of catchments, rainfall and runoff, conceptual drainage with considerations of impacts to beneficial use and environmental values coupled with a review of all relevant regional, publically available datasets for hydrological data and reports to guide further investigations and assessments.

Salient Findings

The Calingiri Project falls within the Mortlock River North Catchment, a tributary of the Avon River. The Mortlock River system discharges significant flow, salt and nutrients, particularly total phosphorus to the Avon River west of Northam. There are a range of minor creek and perched water bodies across the Project Area; the creeks systems remain dry for the majority of the year these drains may generate groundwater flow, they are ineffective for returning land to agricultural production (Cox, 2010).

Topographic elevations vary between 240mAH (Opie Open Pit and WRD) and 240mAH to 255mAH (Bindi Open Pit, WRD, TSF and Plant) and 300mAH (Dasher Open Pit and WRD). Whilst locally undulating, topographic gradients are generally small at between 0.01 and 0.10. The Bindi infrastructure drains predominantly in a northerly direction towards Lake Ninan which discharges into the Mortlock River. The Dasher Open Pit and WRD drain in a south easterly direction whilst the Opie Open Pit and WRD drain in a north-easterly direction (Figure 2.3) towards the Mortlock River between 3km and 5km away.

With the current layout of mine infrastructure and provided that construction employs best practice, it seems unlikely that mining and processing at the Calingiri Copper Project will impact any GDE's and subterranean fauna seems to be absent.

The hydrological desk study assessments concluded that the primary impacts of mining and processing pertain to:

- The potential for impacts to soils, sediment and surface water resources (erosion and sedimentation).
- Potential seepage, runoff and/or discharge from mine impoundments such as ROM pads, stockpiles and plant water infrastructure, WRDs and the TSF impacting surface water quality.

Whilst the potential impacts appear to be negligible and manageable, appropriate best practice (during design, construction and operations) and site specific management of mining, waste rock and tailings disposal will be required to ensure that there is no impact on the receiving environment.

Recommendations

Consideration should be given to:

- Undertake a census of all available surface water sources within the mine tenements.
- Baseline sampling of surface waters upstream and downstream of the proposed mine infrastructure.
- Employ best practice during design, construction and operation of the proposed mine infrastructure including diversion of clean water and containment of dirty water.

1. Introduction

1.1 Scope of Work

Pendragon Environmental Solutions was requested by Caravel Minerals to undertake a desk study assessment of the surface water hydrology at their Calingiri Copper Project (Figure 1.1).

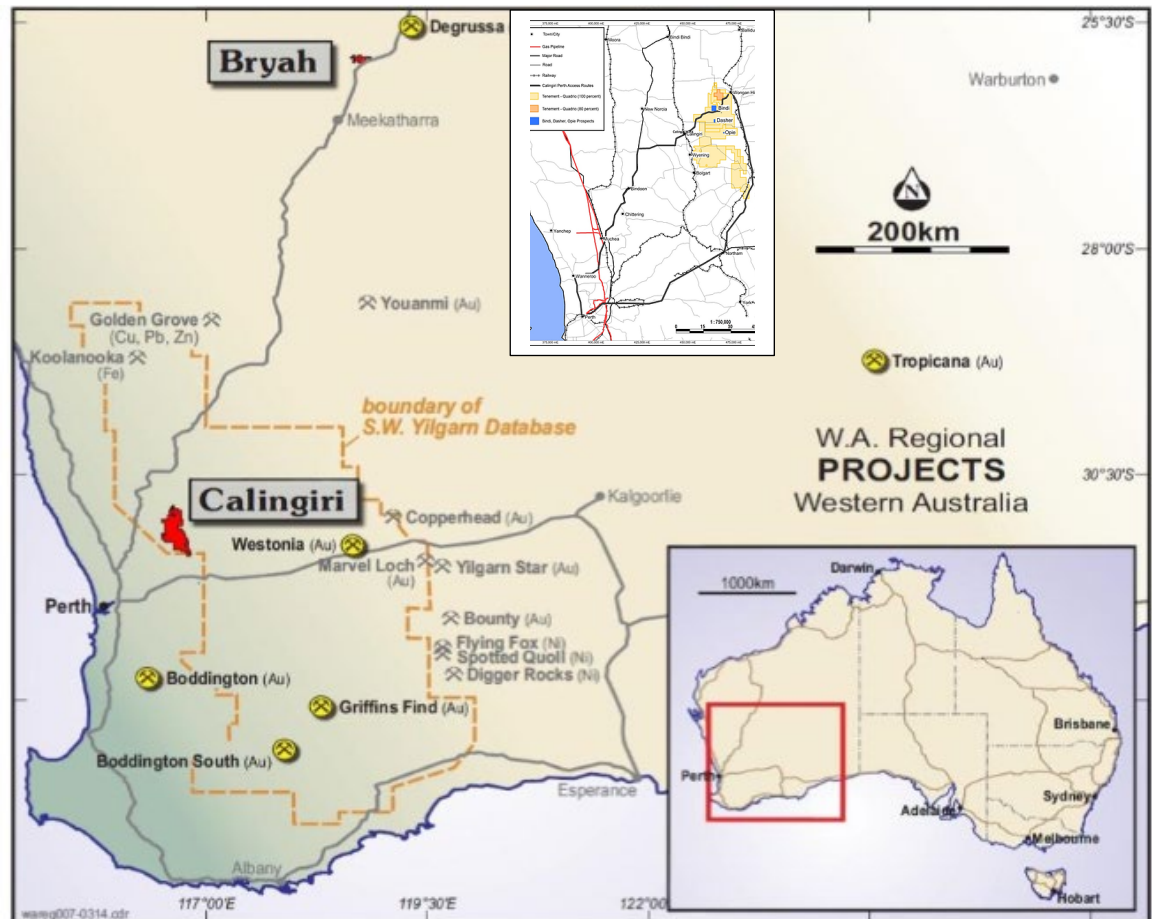


Figure 1.1: Location of the Calingiri Copper Project.

The scope of works for the hydrological desk study assessment included:

- Preliminary level identification and delineation of catchments, rainfall and runoff (AR&R) if possible, conceptual drainage plan with considerations of impacts to beneficial use and environmental values.
- Assessment of all relevant regional, publically available datasets for hydrological data and reports to develop a conceptual model to guide further investigations and assessments aiming at:
 - Assess regional surface water catchments (catchment delineation using publically available topographical datasets) and drainage, rainfall, runoff and water quality.
 - Preliminary assessment of the requirements for mining and processing i.e. mine catchment delineation, pit water accumulation/storage/controlled discharge and stormwater/flood water diversion requirements.
- Identify and assess potential risks associated with mining and processing.
- Provide a report detailing the above including recommendations with regard to data gaps.

1.2 Objectives

This document details the hydrological assessment pertaining to the potential for impacts by mining on environmental factors including Terrestrial Environmental Quality, Hydrological Processes, Inland Waters Environmental Quality and Rehabilitation and Decommissioning (EPA, 2015). The primary objectives are to ensure that the quality of land, soils, sediment and surface and ground water is maintained to protect environmental values and existing and potential future uses and to facilitate decommissioning and closure in an ecologically sustainable manner.

1.3 Project Description

The proposed Calingiri Copper Project is located some 120km north-east of Perth, 13km south-west of the township of Wongan Hills and some 3km south-west of Lake Ninan in the northern Wheatbelt of Western Australia. Lake Ninan, at the head of the Mortlock River (North), covers an area of almost 700ha of reserve land.



Lake Ninan (view from south to north).



Calingiri-Wongan Hills Road crossing Mortlock River east of Lake Ninan.

The Department of Parks and Wildlife (DPAW) manages the 259ha A Class Reserve for the conservation of fauna and flora (vested 1963) and the Recreation Reserve (245ha) is managed by the Shire of Wongan-Ballidu. The lake, along with many wetlands in Western Australia, was impacted by water logging and increased salinity. It is affected by the activities in the catchment which extends north as far as Bindi Bindi and consequently, the water in the lake can be up to six times more saltier than the sea, fish species once found are no longer consistently present and the numbers and variety of bird species are reduced due to the absence of food in the lake. There are no other potential ground water dependent ecosystems within the mining area.

Access to the Calingiri Copper Project is via the Calingiri-Wongan Hills road or the Great Eastern Highway and Goomalling Road. The project is accessible year round via the sealed road network with local access via gazetted gravel roads. Rail infrastructure, used for grain, provides access to the ports of Fremantle and Kwinana.

The project, currently the subject of a feasibility study, is considered *a world class copper resource having a large resource (844kt Copper and 17kt Molybdenum, Caravel Minerals March 2018) and low (1:1) strip ratio with processing by means of conventional flotation. Environmental, social, tenure and infrastructure are low risk with low technical risk and no native title issues.* Caravel Minerals intends employing an advanced bulk ore sorting technology to optimise mill feed grades with lower plant throughput and consequently markedly lower power and water consumption and tailings requirements.

The project has an initial life of 21 years at 15Mtpa.

The Calingiri Project is located in the south-western corner of the Archaen Yilgarn craton comprising granitic, volcanic and sedimentary rocks. The Calingiri mineralised trend extends south of the Wongan Hills Greenstone Belt (host to the Ninan mineralisation) into an area dominated by granite and granite-gneiss (hosts to the Bindi, Dasher and Opie deposits). The mineralised zones at Dasher and Opie dip moderately to the east and north respectively, while the Bindi mineralisation appears to be folded resulting in the Bindi West (west dipping) and Bindi East (dip currently uncertain) components. Drilling identified lenses of amphibolite at all prospects and some post-mineralisation granite and pegmatite intrusions. Post-mineralisation dykes of dolerite are common.

Conventional opencast mining will take place at three locations: Bindi, Dasher and Opie (Figure 1.2); these deposits all contain Copper (Cu), Molybdenum (Mo), Silver (Ag) and Gold (Au). Processing will be by means of crushing (with ore stockpiling), grinding and flotation to yield a concentrate for metal recovery. Waste rock will be placed in rock dumps near the open pits.

The Calingiri mineralisation is characterised by a relatively simple mineralogy of a common style and comprises chalcopyrite, pyrite, Molybdenite and magnetite, disseminated within coarse-grained quartz-feldspar-garnet-biotite gneiss of granitic origin. The garnet-biotite gneiss and associated mineralisation typically forms tabular zones in the order of 50m to 150m thick, up to 200m, through the core of the main prospects. The sulphide mineralisation is developed in fresh bedrock generally at depths between 5m and 50m beneath a regolith cover of in situ saprolitic clays blanketed by a variable 1m to 10m layer of sand and gravel beneath a thin soil horizon. All the copper is in the form of chalcopyrite with pyrite the only other significant sulphide (cpy: py variable 3:1 to 1:1). All sulphides, including molybdenite, are relatively coarse grained. The gangue is dominantly silicates (quartz, feldspar, epidote, chlorite and garnet) with minor magnetite. There is a saprolitic weathering layer between 5m and 50m thick (at Bindi and 45m and 35m respectively at Dasher and Opie), immediately below which the mineralisation is developed. All of the reported resources relate to sulphide mineralisation which is developed within a very consistent gneissic unit.

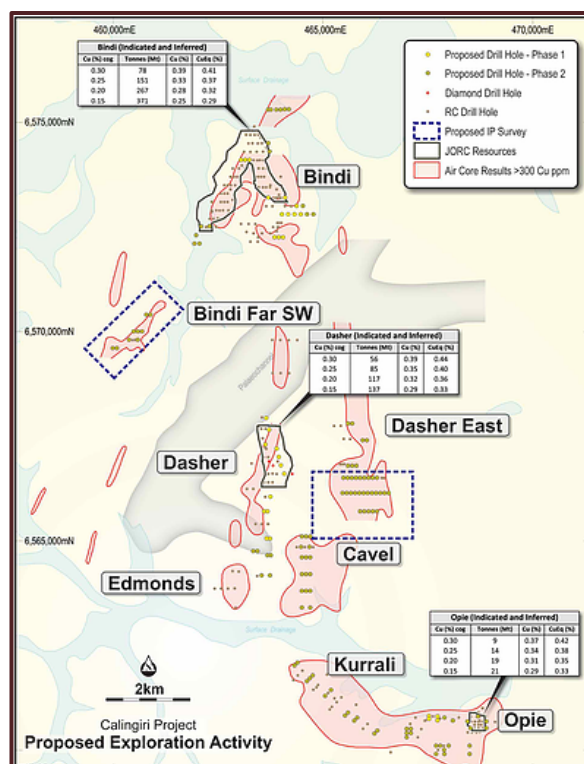


Figure 1.2: Location of the Bindi, Dasher and Opie Prospects and Open Pits.

The Tailings Storage Facility (TSF) at Bindi, adjacent to the processing plant, will be progressively developed over the life of mine with conventional sub areal deposition forming long beaches with water returned to the process plant for reuse from a central decant. The final TSF will have 4 cells of 300ha each, each cell having a diameter of around 1,950m i.e. the final TSF will cover an area of 1,200ha, 3.9km by 3.9km. The cells will be operated in pairs.

Water supply options include the large paleo channel located close to the Bindi and Dasher Prospects (refer Figure 1.2). Additional supplies are further afield.

Caravel Minerals (Quadrio Resources Pty Ltd) holds twelve Exploration Licences and one Prospecting Licence and owns 80% of Tenement E70/2343 held by Geodex Resources Pty Ltd (Table 1.1 and Figure 1.3). All tenements are on privately owned land (excluded from this assessment).

Table 1.1: Calingiri Copper Project Tenements.

Tenement Number	Holder	Tenement Area (ha)	Legal Area [Blocks]	Status	Grant Date
E70/2788	Bindi and Dasher Open Pits and Waste Rock Dumps; Processing Plant and Tailings Storage Facility	27,616	70	Live	6/03/2007
E70/2789	Opie Open Pit and Waste Rock Dump	14,070	35	Live	11/08/2006
E70/3680	Exploration	4,018	10	Live	23/11/2009
E70/3755	Exploration	2,009	5	Live	15/04/2010
P70/1593	Exploration	157	116	Live	10/02/2011
E70/3674	Bindi Open Pits and Waste Rock Dumps	2,277	6	Live	15/11/2010
E70/4517	Exploration	802	2	Live	26/08/2013
E70/4476	Exploration	2,140	6	Live	19/08/2013
E70/4675	Exploration	799	2	Live	12/01/2015
E70/4674	Exploration	22,993	58	Live	14/01/2015
E70/4676	Exploration	803	3	Live	11/03/2015
E70/4732	Exploration	3,215	8	Live	11/08/2015
E70/4746	Exploration	4,024	10	Live	31/08/2015
E70/2343	Exploration	2,407	6	Live	30/05/2001

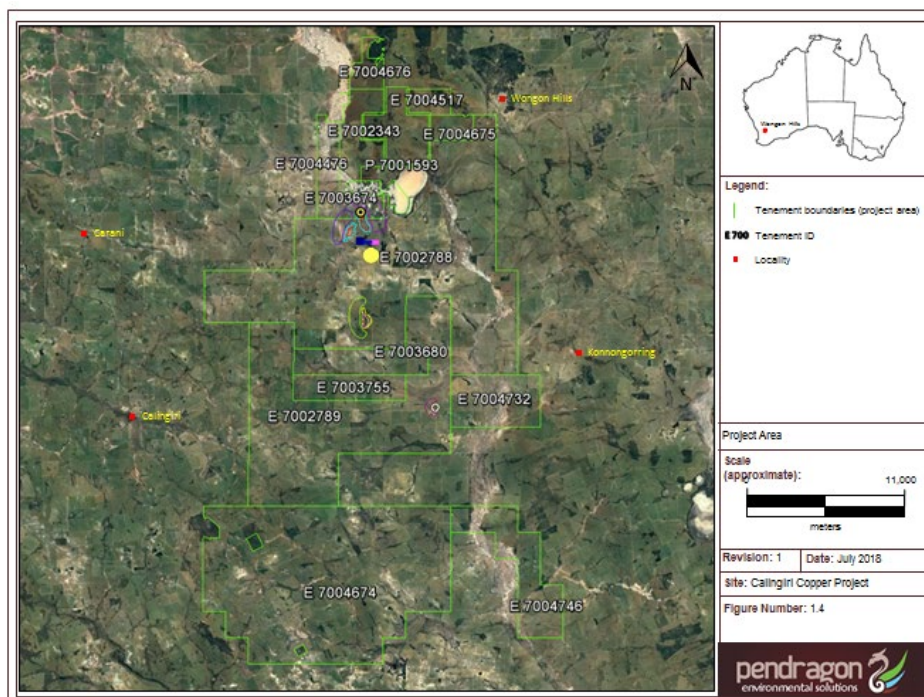


Figure 1.3: Tenements and Mine Infrastructure.

2. Hydrological Setting

2.1 Climate

The area has a Mediterranean warm and temperate climate with dry hot summers and mild winters. Rain falls (Table 2.1 and Figure 2.1) mostly in the winter and average 388mm/a. It is the most important variable that impacts productivity and land degradation and arises from two general climatic systems: southern frontal systems, which pass from west to east; and rain from tropical air with a general pattern that tends to be a mosaic of wet and dry localities, which shifts from year to year. The growing season rainfall from April to October accounts for 75% of the average annual rainfall.

Table 2.1: Climatic Data (Wongan Hills Weather Station 008137, Bureau of Meteorology, 2018).

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Temperature (°C)													
Maximum	34.6	34.1	30.9	26.5	21.6	18.2	17.0	17.9	20.7	25.2	29.2	32.5	25.7
Minimum	17.9	18.2	16.4	13.4	9.9	7.7	6.6	6.7	7.6	10.1	13.2	15.8	12.0
Mean Rainfall and Evaporation (mm)													
Mean Rainfall (mm)	15.5	15.4	20.7	22.4	51.6	69.4	69.3	51.6	29.8	19.6	12.4	10.0	388.2
Highest rainfall (mm)	134.6	110.5	165.8	81.3	187.9	220.2	174.4	131.1	97.3	121.6	60.3	71.4	675.4
Highest daily rainfall (mm)	71.6	79.8	81.3	61.7	63.5	69.6	86.2	34.3	37.1	53.2	38.6	57.2	86.2
Mean number of rain days	2.1	2.3	2.9	4.9	8.8	12.3	13.5	12.2	8.6	5.9	3.4	2.0	78.9
Days of rain \geq 25mm	0.2	0.2	0.2	0.1	0.3	0.4	0.3	0.1	0.0	0.0	0.0	0.1	1.9
Daily Evaporation	11.6	10.6	8.6	5.5	3.4	2.3	2.1	2.6	3.8	5.9	8.4	10.3	6.3
Daily Evaporation obtained from the Wongan Hills Res. Station 008138; 41 years, 1965 to 2013.													

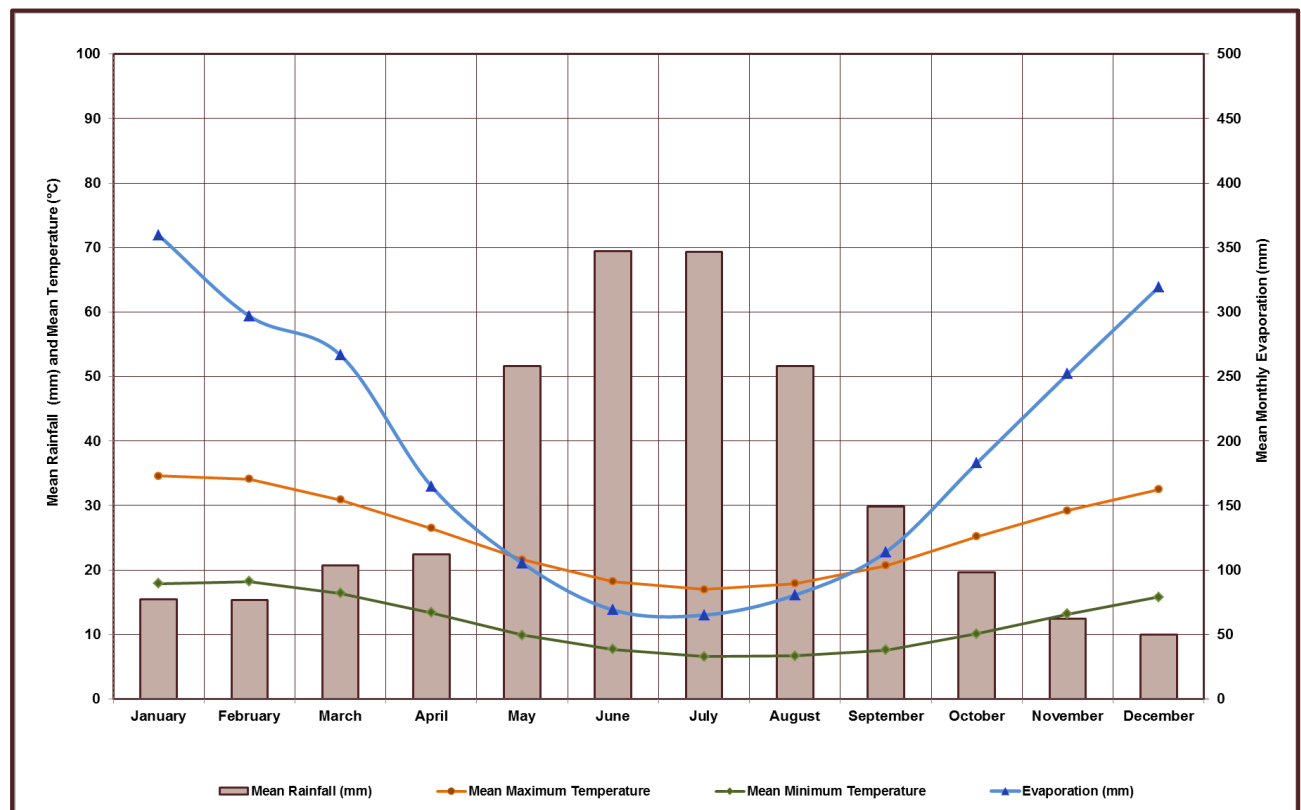


Figure 2.1: Monthly Climatic Data.

Since evaporation (averaging at about 2,276mm/a) exceeds rainfall (averaging at about 388mm/a) by almost six times, there is a water deficit across the region (Table 2.1). December, January and February are the hottest months with average maximum temperatures around 34°C. The lowest temperatures occur in winter, between June and September, when average maximum temperatures are below 20°C and average minimum temperatures are around 7°C (Table 2.1 and Figure 2.1).

2.2 Rainfall Runoff

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, were obtained from the Bureau of Meteorology. These IFDs are used in the design of infrastructure including culverts, stormwater drains, flood mitigation levees, retarding basins and dams. They can also be used to assess the severity of observed rainfall events.

The main terms used to describe design rainfalls are:

- Exceedances per year (EY): the number of times an event is likely to occur or be exceeded within any given year.
- Annual exceedance probability (AEP): the probability or likelihood of an event occurring or being exceeded within any given year, usually expressed as a percentage.

Table 2.2 lists the probability terminology used for the 2016 design rainfalls and shows in bold the standard EY and AEP values for which design rainfalls are available. Generally, EY terminology is used for *very frequent* design rainfalls, AEP (%) terminology is used for *frequent and infrequent* design rainfalls, and AEP (1 in x) terminology is used for *rare* design rainfalls.

Table 2.2: Australian Rainfall and Runoff Terminology (Bureau of Meteorology, 2018).

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI	Uses in Engineering Design
Very Frequent	6.0	99.8	1.00	0.17	Water Sensitive Urban Design
	4.0	98.2	1.02	0.25	
	3.0	95.0	1.05	0.33	
	2.0	86.5	1.16	0.50	
	1.0	63.2	1.58	1.00	
Frequent	0.7	50	2.00	1.44	Stormwater Design
	0.5	39.4	2.54	2.00	
	0.2	20	5.0	4.48	
	0.2	18.1	5.52	5	
	0.1	10	10	9.49	
Infrequent	0.1	5	20	20	Floodplain Management and Waterway Design
	0.0	2	50	50	
	0.0	1	100	100	
	0.0	0.5	200	200	
Rare	0.0	0.2	500	500	
	0.0	0.1	1000	1000	
	0.0	0.05	2000	2000	
Extremely Rare	0.0	0.02	5000	5000	Design of High-Consequence Infrastructure (e.g. major dams)
			↓		
Extreme			PMP		

Table 2.3 and Figure 2.2 details the IFD Design Rainfall Depths (in mm) and Design Rainfall Intensities (in mm/hr).

Table 2.3: IFD Design Rainfall Depths (in mm) and Design Rainfall Intensities (in mm/hr).

	Annual Exceedance Probability (AEP)						
Duration	63.2%	50%#	20%*	10.0%	5.0%	2.0%	1.0%
Design Rainfall Depth (mm/)							
1 min	1.3	1.5	2.1	2.5	3.0	3.7	4.2
2 min	2.2	2.5	3.5	4.3	5.1	6.3	7.3
3 min	3.0	3.4	4.8	5.8	6.9	8.5	9.9
4 min	3.7	4.2	5.9	7.1	8.5	10.4	12.0
5 min	4.2	4.8	6.8	8.3	9.8	12.0	13.9
10 min	6.3	7.2	10.2	12.4	14.7	18.0	20.7
15 min	7.7	8.8	12.4	15.1	17.9	21.9	25.1
30 min	10.3	11.7	16.5	20.0	23.7	29.0	33.3
1 hour	13.2	14.9	20.9	25.4	30.1	37.0	42.7
2 hour	16.5	18.7	26.0	31.6	37.6	46.4	53.9
3 hour	18.7	21.1	29.5	35.9	42.8	52.9	61.6
6 hour	23.1	26.1	36.4	44.5	53.3	66.2	77.3
12 hour	28.1	31.7	44.6	54.6	65.6	81.9	95.8
1 day	33.5	37.9	53.2	65.1	78.1	98.0	115.0
2 days	39.0	44.0	61.1	74.2	88.2	111.0	130.0
3 days	42.4	47.6	65.2	78.4	92.3	115.0	136.0
4 days	45.0	50.4	68.1	81.0	94.3	117.0	138.0
5 days	47.3	52.7	70.5	83.1	95.7	118.0	140.0
6 days	49.4	55.0	72.8	84.9	96.9	118.0	140.0
1 week	51.4	57.2	75.0	86.7	98.0	118.0	140.0
Design Rainfall Intensities (mm/hr)							
1 min	78	89	125	152	181	221	254
2 min	67	76	105	128	152	188	218
3 min	60	68	95	116	138	170	197
4 min	55	63	88	107	127	156	181
5 min	51	58	82	99	118	145	167
10 min	38	43	61	75	88	108	124
15 min	31	35	50	61	72	88	100
30 min	21	23	33	40	47	58	67
1 hour	13	15	21	25	30	37	43
2 hour	8	9	13	16	19	23	27
3 hour	6	7	10	12	14	18	21
6 hour	4	4	6	7	9	11	13
12 hour	2	3	4	5	5	7	8
1 day	1	2	2	3	3	4	5
2 days	1	1	1	2	2	2	3
3 days	1	1	1	1	1	2	2
4 days	0	1	1	1	1	1	1
5 days	0	0	1	1	1	1	1
6 days	0	0	1	1	1	1	1
1 week	0	0	0	1	1	1	1
# The 50% AEP IFD does not correspond to the 2 year Average Recurrence Interval (ARI) IFD; it rather corresponds to the 1.44 ARI.							
* The 20% AEP IFD does not correspond to the 5 year Average Recurrence Interval (ARI) IFD; it rather corresponds to the 4.48 ARI.							

The 1-hour duration event for the 2.0% AEP and 1% AEP, corresponding with the 50-year ARI and 100-year ARI events respectively (the highlighted cells in Table 2.3) are generally used for designing mine infrastructure.

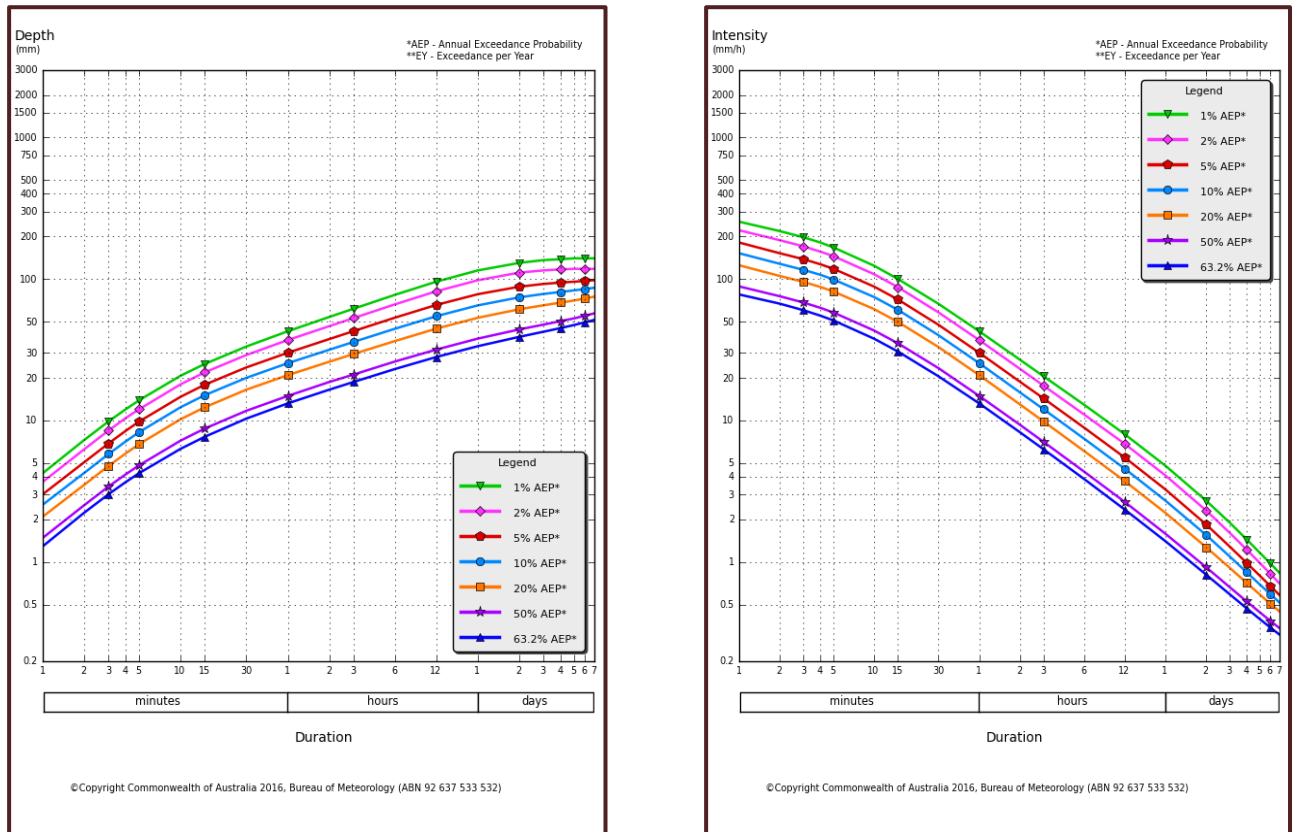


Figure 2.2: IFD Design Rainfall Depths and Design Rainfall Intensities.

2.3 Hydrology

The Calingiri Project falls within the catchment of the Mortlock River (north branch) and is one of the many systems responsible for feeding saline water (91t/a of salt) into the Avon River (WRC, 2003) west of Northam. Having a large catchment area (some 16,800km² at 103m hydraulic head), this perennial waterway (81km in length falling 103m or a gradient of 0.1%) drains the northern part of the Shire of Northam, most of the Shires of Goomalling and Wongan-Ballidu as well as the western portions of the Shires of Dowerin and Cunderdin and the eastern portions of the Shires of Toodyay and Victoria Plains.

There are a range of minor creek and perched water bodies located over the Project Area; the creeks systems remain dry for the majority of the year, however when the site was visited in March 2018, the water bodies were still full. It is assumed that these are surface expressions of groundwater. Soil salinity in the catchment, a major concern, is caused by evaporation as a result of a saturated soil profile which results either from rising groundwater or surface water inundation, or a combination of both. Deep drains (or groundwater drains) have been employed by some landholders in an attempt manage the impacts of salinity on agricultural land. It appears that whilst these drains may generate groundwater flow, they are ineffective for returning land to agricultural production (Cox, 2010).

The Mortlock River North has a primary catchment extends over an area of 265,000ha, with a secondary catchment, containing an extensive lake system, extending over a further 415,000ha. It contributes significant flow, salt and nutrients, particularly total phosphorus (TP), to the Avon River. Water quality monitoring between 2006 and 2008 (DoW, 2009) found that approximately 40% of TP measurements exceeded the target of 0.1 mg/L (Wheatbelt NRM) whilst only 13% of samples from the Avon River upstream of its confluence with the Mortlock River exceeded the threshold of 0.1 mg/L for the same period.

The Mortlock River is seasonal and flows intermittently after heavy rainfall events, usually during winter,

spring and early summer. Its channel is undefined and basically consists of a very wide shallow floodplain which makes it difficult to determine flow of water following light rainfall only obvious along the downstream reaches where the channel is more defined. Almost the entire catchment is cleared.

There are now limited numbers of shallow pools along the river; however anecdotal evidence indicated that in the past there were deep pools that would hold water throughout the dry summer months and act as a refuge and habitat for terrestrial and aquatic fauna. These pools are shallow because of sediment deposition and no longer provide these important refuges for organisms during the dry summer months. Consequently many ecosystems have had to adapt to the changing flooding conditions, catchment development and climate change (decreasing rainfall) or perish.

2.4 Topography

The topography across the three open pits, WRD's and plant site is depicted in Figure 2.3. Elevations vary between 240mAH (Opie Open Pit and WRD) and 240mAH to 255mAH (Bindi Open Pit, WRD, TSF and Plant) and 300mAH (Dasher Open Pit and WRD). Whilst locally undulating, topographic gradients are generally small at between 0.01 and 0.10.

The Bindi infrastructure drains predominantly in a northerly direction towards Lake Ninan. The Dasher Open Pit and WRD drain in a south easterly direction whilst the Opie Open Pit and WRD drain in a north-easterly direction (Figure 2.3) towards the Mortlock River between 3km and 5km away.

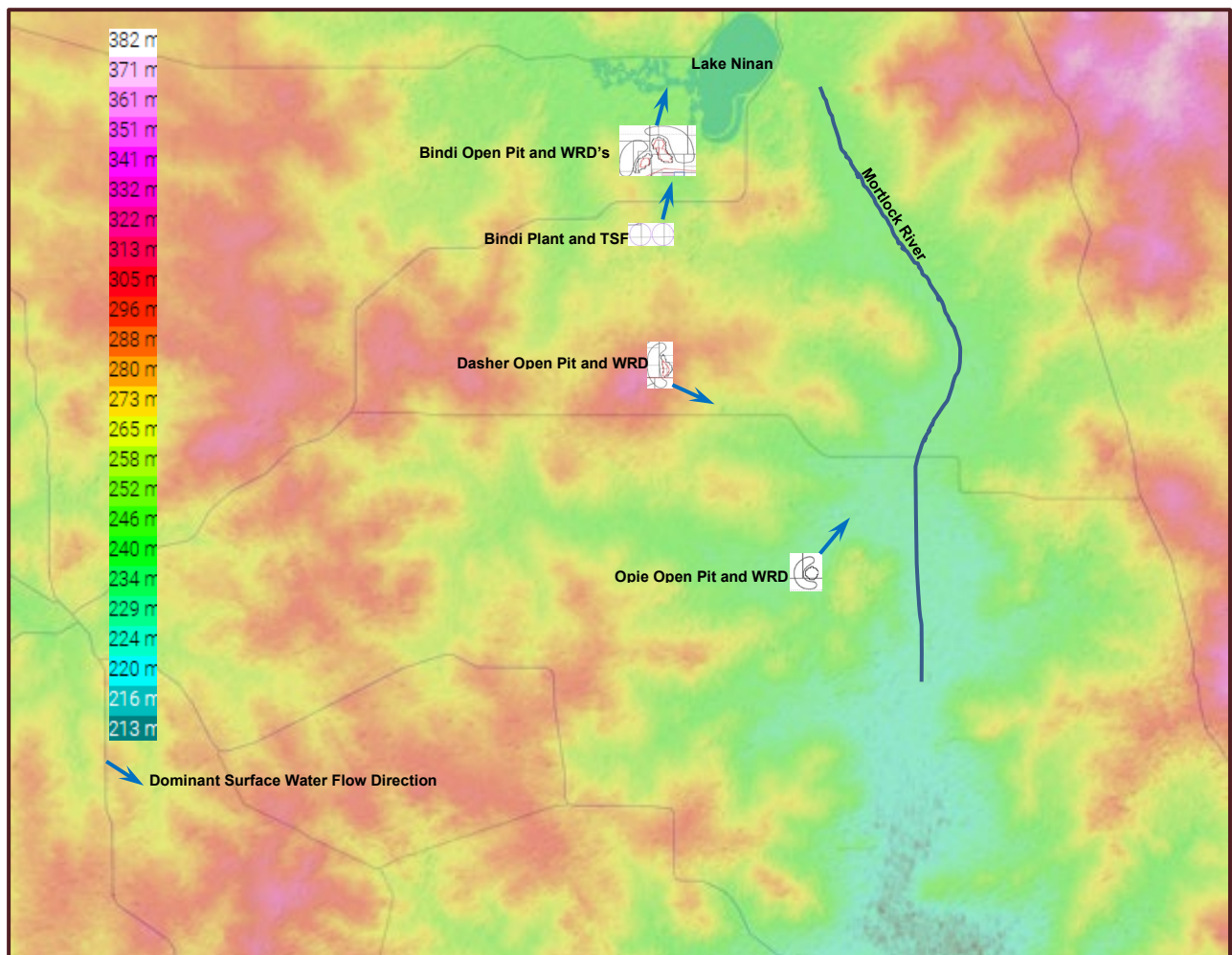


Figure 2.3: Topography.

3. Existing Water Use

3.1 Surface Water Use

Large proportions of dryland farms in Western Australia receive less than 600mm of rain on average and suffer from water supply shortages, poor quality or combinations of these two factors (DAFWA, 2007). The Farm Water Plan of 1994 (Farm Water Strategy Group, 1994) indicated that *the north-eastern and eastern wheatbelt is where the greatest difficulty for development of reliable on-farm water supplies is experienced*.

Water supplies are described as either low quality (livestock) or high quality (domestic) sources. Low quality water from dams and bores is generally used for livestock and gardens as well as laundry and toilet facilities. High quality water from rain water harvesting (tanks or excavated earth tanks or dams) and bores is used for drinking, domestic purposes (roughly 150L/person/day including amenities) and for specific needs such as crop spraying. Domestic water constitutes less than 15% of that used in agriculture.

4. Hydrological Assessment

The Bindi infrastructure drains predominantly in a northerly direction towards Lake Ninan. The Dasher Open Pit and WRD drain in a south easterly direction whilst the Opie Open Pit and WRD drain in a north-easterly direction (Figure 2.3) towards the Mortlock River between 3km and 5km away.

Approximate areas required for infrastructure:

- Bindi Plant and TSF (south of the Calingiri Wongan Hills Road): 1.6km by 1.6km.
- Bindi Open Pits and WRD's (north of the Calingiri Wongan Hills Road): 3.5km by 4.0km.
- Dasher Open Pit and WRD: 2.0km by 2.3km.
- Opie Open Pit and WRD: 1.3km by 1.4km.

Consequently the catchments that will host mine infrastructure will be relatively small which will render diversion of upstream clean surface water runoff and containment of dirty runoff relatively easy by means of low level cut off berms or drains or a combination thereof. Rain falling into the open pits, together with groundwater influx, should be used in the processing plant and disposal of tailings. Whilst the WRDs may not be acid forming (to be confirmed by further studies), rain falling onto these structures are to be contained and locally infiltrated and/or evaporated.

In total and on average, mining infrastructure (contained plant, open pit, TSF and WRD catchments) will decrease runoff by some 0.1% (based upon area and using a runoff coefficient of 0.25) which is considered negligible.

4.1 Surface Water Chemistry

There were no surface waters present during the March 2018 sampling event. The sample of water obtained from one of the open water bodies, considered surface expressions of groundwater, displayed the same chemical composition as samples of groundwater albeit much larger concentrations due to evaporation (Pendragon Environmental Solutions, 2018).

5. Assessment of Potential Impacts

This section details a preliminary identification of potential impacts to surface water, the downstream environment or other surface water users that may be caused by the proposed mining and processing.

Based on the results of desk study assessments, the potential impacts of mining and processing include:

- Discharge of impacted rain and/or surface water runoff to the receiving environment.
- Erosion and sediment/salt loads.
- Other users (private and public) including GDEs and subterranean fauna, where and if present.

The environmental factors (EPA, 2015) with reference to ground water include Hydrological Processes, Inland Waters Environmental Quality and Rehabilitation and Decommissioning. The primary objectives are to ensure that the quality of surface water is maintained to protect environmental values, ecological and social, and existing and potential uses to facilitate decommissioning and closure in an ecologically sustainable manner. To achieve these objectives, appropriate management of mining, waste rock and tailings disposal will be required.

The key risks for mining and processing pertain to:

- Reduction in catchment yield considered negligible.
- The potential for impacts to soils, sediment and surface water resources by seepages, leachates and/or runoff and discharges from the process plant ROM pad and stockpiles, WRDs and the TSF.

5.1 Potential AMD and Sediment/Salt Loads

The key risks for mining and processing pertain to:

- The potential for impacts to soils, sediment, surface and ground water resources by seepages, leachates and/or runoff from the ROM pad and stockpiles, waste rock and tailings containing potentially acid producing materials. Whilst this risk is currently considered low, further investigation and assessment pertaining to soil and waste characterisation is required (Pendragon Environmental Solutions, 2018).
- Exposure of sulfide-bearing materials in open pit excavations during mining and subsequent remaining exposures as groundwater sinks and/or pit lakes.

5.2 Beneficial Use and the Receiving Environment

Beneficial uses and the receiving environment within the zone impacted by mining and processing include other users and GDEs and subterranean fauna if present.

There seems to be no GDEs within the areas earmarked for mining and processing (to be confirmed by further investigation and assessment); hence the likely zone of impact of mining and processing is to be ascertained.

A desktop study assessment of stygofauna (EPA, 2013) to consider impacts of ground water abstraction/mine influx in a regional context and make conclusions about whether the area is likely to provide habitat for subterranean fauna indicated and/or to determine the level of survey and whether

sampling is necessary, if any, indicated that stygofauna is unlikely to be present due to the salinity of groundwater within the area.

5.3 Summary of Impacts

A summary of the impacts, proposed management measures and controls and actions appear overleaf.

Table 7.1: Summary of Impact Assessment.

Impacts during Mining and Operations	Potential Risk			Proposed Management Measure and Control	Residual Risk	Action
	L	C	R			
Surface Water and GDE's						
Infiltration/recharge, reduction in volume of surface water	L	Mi	Low	Minimise disturbances/footprint, divert clean runoff.	Low	Incorporate in design. Monitor water quality.
Deterioration of water quality in drainage lines	L	Mo	High	No discharge, contain dirty runoff, infiltration and seepage by design; provide pollution control measures including sufficient storage capacity.		
Base flow, increase/decrease flow to potential GDEs, impact on biota	U	Mo	Medium	No discharge, contain dirty runoff, infiltration and seepage by design; provide pollution control measures including sufficient storage capacity.	Low	Incorporate in design. Monitor water quality downstream of mine infrastructure.
Notes: C denotes Consequence, L Likelihood and R Risk Rating. Consequence: I - Insignificant, Mi – Minor, Mo – Moderate, Ma – Major and C – catastrophic. Likelihood: R – Rare, U – Unlikely, P – Probable, L – Likely and A – Almost Certain. Risk Categories: L – Low: acceptable, M – Medium: tolerable/acceptable – requires management, H – High: intolerable/unacceptable – requires high level of management; E – Extreme: unacceptable – discard activity.						

6. Surface Water Monitoring

The proposed preliminary surface water monitoring program aims at ascertaining pre-mining/ambient base-line groundwater levels and water quality for the subsequent determining the extent and severity of the subsequent impacts of mining and processing particularly with regard to disposal of mine wastes.

Dedicated surface water sampling locations are to be allocated in accordance with the mine layout (upstream and downstream) during further ongoing investigations and upon completion of construction of mine infrastructure such as at the open pits, stockpiles at the process plant, waste rock dumps and the tailings storage facility.

The monitoring program should be designed to adequately assess performance and determine any impact on surface water quality, other users and/or the receiving environment. The monitoring program should reflect the relevant conditions of any pollution control license under the *Environmental Protection Act 1986*, if required and once available.

The proposed surface water monitoring frequency and analytes required to establish a sound environment baseline appears in Table 8.1.

Table 8.1: Proposed Ground Water Monitoring Locations, Frequency and Analytes.

Monitoring Locations	Frequency	Measurements/Analytes
Surface Water Monitoring Locations: Locations are to be provided upstream and/or downstream of: <ul style="list-style-type: none"> ▪ Open Pit Mining. ▪ Process Plant. ▪ Waste Rock Dumps. ▪ Tailings Storage Facility. 	Continuous, if and when required Monthly After rain events exceeding 10mm	Flow rates and volumes, if any. Rainfall. Discharges from mining infrastructure, if any. Field measurements: General field <i>in situ</i> (field) water quality measurements: pH, EC, TDS, Salinity, Temperature, Dissolved Oxygen, Oxidation Reduction Potential including observations such as appearance, odour, colour, etc.) Laboratory analyses: Total Alkalinity (T_{alk} , mg/L). Total Acidity (T_{ac} , mg/L). Major anions (Cl, SO_4 , CO_3/HCO_3 , NO_3-N ; mg/L). Major cations (Ca, Mg, Na and K; mg/L). Dissolved metals (Al, As, B, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn, Fe; $\mu g/L$).
A full metal scan analysis will be undertaken for at least three sampling events and then periodically (e.g. annual) to confirm the proposed metal suite is appropriate for ongoing monitoring. Total metals analyses will also be undertaken at one monitoring site per sampling event as a quality control measure. Water discharged, if any, shall have no visible surface films, oils and greases, Total Petroleum Hydrocarbons, litter or suspended matter.		

Water quality data will be entered into an appropriate database and assessed against relevant water quality criteria and trigger values in order to immediately identify any potential impact as a consequence of mining and processing. Further investigation, if required, and remedial action will be undertaken promptly to address any potential water level and/or quality issues.

It is proposed that for surface water, the Australian Drinking Water Guidelines (NHMRC and NRMCC

2011) and the guidelines for 95 % species protection levels (hardness modified; ANZECC and ARMCANZ 2000) be adopted as trigger values. Site-specific trigger values (and possibly for individual monitoring locations) are to be developed when there is sufficient data available from baseline monitoring and reference sites.

Monitoring data will be reported on and raw data provided at the required intervals and in agreed formats and will include an analysis of trends and comparisons with ambient water quality established prior to mining and appropriate water quality criteria and trigger values.

7. Conclusions and Recommendations

7.1 Conclusions

Hydrological desk study assessments were undertaken to ascertain whether mining and processing will impact surface water resources and/or the receiving environment.

The primary impacts of mining and processing pertain to:

- The potential for impacts to soils, sediment and surface water resources (erosion and sedimentation).
- Potential seepage, runoff and/or discharge from mine impoundments such as ROM pads, stockpiles and plant water infrastructure, WRDs and the TSF impacting surface water quality.

Whilst the potential impacts appear to be negligible and manageable, appropriate best practice (during design, construction and operations) and site specific management of mining, waste rock and tailings disposal will be required to ensure that there is no impact on the receiving environment.

7.2 Recommendations

Consideration should be given to:

- Undertake a census of all available surface water sources within the mine tenements.
- Baseline sampling of surface waters upstream and downstream of the proposed mine infrastructure.
- Employ best practice during design, construction and operation of the proposed mine infrastructure.

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