


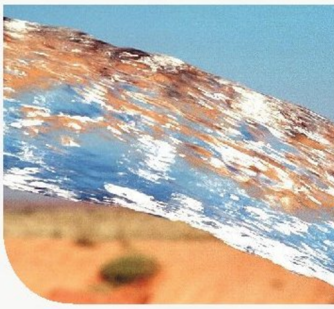


MUNGLINUP GRAPHITE PROJECT

HYDROLOGICAL REVIEW

REPORT FOR MRC GRAPHITE PTY LTD

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Report No. 65.5/20/01

Rockwater
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REVISION	AUTHOR	REVIEW	AUTHORISED	ISSUED
Final	SU	PHW		27/10/2020

1 INTRODUCTION

1.1 PROJECT DESCRIPTION

MRC Graphite Pty Ltd (MRC) is planning to mine graphite on Mining Lease M74/245, located four kilometres north of the town of Munglinup along the South Coast Highway and about 75 km ESE of Ravensthorpe (Figures 1 & 2). Six mine pits are proposed to be mined: Halberts Main, Halberts South, Harris, McCarthy West, McCarthy East and Whites (Figure 2). The associated infrastructure will include waste rock landforms (WRL), a tailings storage facility (TSF), processing plant, run-of-mine / low-grade stockpiles, power generation, workshops, administration buildings, and roads. The proposed activities will be within a 650 ha development envelope situated across tenements M74/245, G74/9, L74/55 and L75/56.

The proposed mine eastern access road will be located within L74/55, east of M74/245; and part of the TSF will be located on G74/9.

1.2 PURPOSE AND SCOPE

The objective of this hydrological assessment is to provide baseline surface hydrological data to characterise the existing hydrological regime, and to determine the changes to the regime that are likely to result from the proposed mining. The assessment will assist in identifying potential impacts associated with development of the proposed project and indicate any other information required to obtain environmental approvals for the project. The scope of work includes:

- Identifying catchment boundaries within the project area and upstream;
- Identifying flow paths downstream of the project area to allow assessment of dilution and potential impacts of discharge from the project area;
- Characterising the regional hydrology and potential for flooding as a result of surface runoff including peak flow rates for 1 in 5, 10, 20, 50 and 100 year events and the Probable Maximum Precipitation (PMP) event;
- Characterising potential runoff volumes and estimating peak flow rates from upstream catchments and operational areas;
- Producing maps indicating flood extents for recurrence intervals of 1 in 20, 50, and 100 year events, including the Munglinup River and drainage lines within the tenement;
- Identifying the potential risk of flood impacts on operations including pits, waste dump, TSF, roads and processing plant;
- Identifying the potential impact of project-related activities on the surface-water environment; and,
- Providing recommendations for surface water management during mine operations and post-closure, including diversion bund/channel layouts, design specifications and construction materials.

This report presents the Surface Water Assessment for the definitive feasibility study (DFS) and the environmental impact assessment (EIA) for the Munglinup Graphite Project, including the planned eastern mine access road. The assessment incorporates the findings and recommendations of the Stage 1 Desktop Initial Hydrology Assessment (Rockwater, 2018a). Rockwater previously completed a hydrological study to determine peak flood levels and drainage requirements for the mining lease (Report No 65/5/18/04 Rev 3). However, since the completion of the Stage 1 report there has been a significant change in the location, alignment and configuration of the mine infrastructure, pits and haul road. This study has been updated to include these recent changes to mine infrastructure.

A new guideline has been issued by the Environmental Protection Authority (EPA, 2018), requiring assessment of the impact of proposed mining projects on surface water, groundwater, groundwater-dependent ecosystems (GDE), and other water users; and, where there could be impacts, descriptions of the arrangements for monitoring, mitigation, management, closure and rehabilitation.

Consequently, this document covers the management of surface water flows in the planned area of operations; an assessment of pre-mining hydrological conditions; potential impacts of mining on the Munglinup River; and any mitigation measures required to maintain the quality of water in the river.

1.2.1 INFORMATION PROVIDED BY MRC GRAPHITE PTY LTD

The following information and data were provided by MRC:

- Detailed LiDAR topographical survey data around the project area.
- GIS datasets of the mine site layout plan and road network (Master_MRC_Munglinup_Site Layout.dxf).

1.3 METHODOLOGY

Rivers, creeks and their associated catchments were defined and delineated from the LiDAR topographical survey data provided by MRC.

The design peak flows for each catchment were determined using the methods given in Australian Rainfall and Runoff (ARR, 2019) including runoff-routing and the index and rational flow methods. Flows were first calculated for existing (pre-mining) conditions, and then for mining or post-mining conditions for catchments that will be impacted by mining.

One-dimensional hydraulic modelling (HEC-RAS) was used to assist with understanding flow paths within the catchments for various rainfall return periods to assist with the design of surface water management infrastructure and haul road crossings.

2 EXISTING ENVIRONMENT

2.1 REGIONAL DRAINAGE NETWORK

The project area lies within the Munglinup River catchment, a tributary of the Oldfield River. The Oldfield River basin has a catchment area of approximately 217,200 ha (Gee and Simons 1997). The Munglinup River catchment area is approximately 33,600 ha at the confluence with the Oldfield River. These catchment boundaries are presented in Figure 1.

Drainage across the project area tends southwards via Munglinup River and Clayhole Creek, a tributary of the Munglinup River (Rockwater, 2018a). The Munglinup River originates on the sandplain north of the project area and connects with inflow from Clayhole Creek approximately 3km south of the project area. Together these rivers meet Oldfield River approximately 17km south of the project area and continue to flow towards the Southern Ocean.

The Munglinup River is ephemeral, flowing predominantly in the winter months. The corridor in which the river flows is well vegetated, with land surrounding the corridor being cleared for agricultural uses including cropping and grazing.

2.2 LOCAL DRAINAGE NETWORK

Within the project area there are numerous small tributaries that drain south-westwards to meet Munglinup River. Figure 2 shows the location of tributaries draining the project boundary. At its closest point, the river is 40 m from the planned Halberts South pit.

The proposed eastern mine access road on L74/55 will cross over the main channel of Clayhole Creek, in addition to a smaller tributary (Figure 2).

2.3 TOPOGRAPHY

Site topography is shown in Figure 3, with a digital elevation model (DEM) derived from surveyed LiDAR data captured in August 2018. Topography across the project area is low to moderate with elevations varying from 130 m AHD to 75 m AHD, with some low-lying ridges with relief of less than 40m.

2.4 CULTRAL SIGNIFICANCE

The Oldfield River and its tributaries (Munglinup River, Clayhole Creek) are registered aboriginal heritage sites, considered as places of mythological significance that warrant protection under the Aboriginal Heritage Act 1972.

2.5 PHYSIOGRAPHY AND SOILS

The project area lies on a lightly-dissected peneplain (Johnson, 1998) which rises from the coast in the south to about 140 m AHD at the northern end of tenement M74/245. The peneplain is incised along the Munglinup River and Clayhole Creek. Elevated areas are generally covered by sandy soils, whereas there is colluvium with minor alluvium and rock outcrops in the incised areas.

Schoknecht and Pathan (2013) indicate that the soils at Munglinup are grey sandy duplexes over non-alkaline clay, commonly with gravel.

A detailed soil survey by Integrate Sustainability Pty Ltd (ISPL, 2018) identified six soil types within M74/245: white gravelly sand, grey sandy duplex, brown loam duplex, alkaline grey loam duplex, calcareous brown clay loam, and deep brown red silt loam.

More detail on the landforms and soils is given in ISPL (2018).

2.6 CLIMATE

Munglinup has a temperate climate with warm to hot summers and cool to mild winters.

Average monthly rainfalls at Munglinup (BoM Stn. 009868, 1970 to present) range from 23.6 mm in December to 63.6 mm in August. The average annual rainfall is 533 mm (Table 1). Rainfall is irregular, but on average is somewhat higher in winter than in summer. The highest monthly rainfall was in February 2017 when 226 mm fell, with 68 mm recorded within 24 hours on the 10th of February. It resulted from the passage of a tropical low – the resultant flooding washed away a bridge over the Phillips River on the South Coast Highway west of Ravensthorpe. According to the BoM Intensity-Frequency-Duration (IFD) curves for the project area, this 24-hour rainfall event is equivalent to a 1-in-10-year event (10% AEP).

Table 1: Average rainfall and dam evaporation (mm), Munglinup

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall	27.9	27.8	36.4	35.9	55.9	54.1	57.0	63.6	55.0	45.8	36.5	23.6	532.7
Dam Evap.	246	190	169	118	79	56	69	76	98	135	177	224	1,637

Average dam evaporation (Luke, Burke and O'Brien, 1988) exceeds average rainfall in all months of the year (Table 1), and by a factor of three overall.

Temperatures have been recorded at the Munglinup West BoM Station 012044 since 2002; they indicate monthly mean minimum temperatures ranging from 6.6°C in July to 15.1°C in February, and mean maximum temperatures ranging from 16.7°C in July to 28.9°C in January and February.

2.7 VEGETATION AND LAND-USE

Much of the area around Munglinup has been cleared for agriculture, but M74/245 is largely uncleared except on drillhole lines and at old mine workings (Figure 2).

Four vegetation system associations occur in the project area as per Woodman Environmental (2020). Of the four vegetation system associations that occur within the project area, two (Esperance 47 and Esperance 4048) have around 15 % of their pre-European extent remaining, with the remaining two vegetation system associations being relatively well-represented compared to pre-European extent (about 40 %).

Four vegetation associations were mapped by Woodman Environmental, although two covered most of the study area:

- Esperance 47: Shrublands; tallerack (*Eucalyptus pleurocarpa*) mallee-heath;
- Esperance 516: Shrublands; mallee scrub, black marlock (*Eucalyptus redunca* and allies);

The other two units are:

- Esperance 931: Medium woodland; yate (*Eucalyptus occidentalis*); and
- Esperance 4048: Shrublands; scrub-heath in the Esperance Plains including Mt Ragged scrub-heath.

During the spring survey (Woodman Environmental, 2019), seventeen vegetation units (VU) were described and mapped within the project area, the majority of vegetation units are Mallee woodlands. The VUs belong to two broad vegetation groups:

Group 1: Mallee woodlands or tall and mid shrublands on elevated plains with predominantly sandy soils and laterite at or near the surface (VUs 16 and 17);

Group 2: Mallee woodlands, woodlands or tall to mid shrublands on eroded valley slopes and floors with predominantly clay soils (VUs 1-15).

The BoM GDE Atlas tool indicates there is a potential chance for terrestrial Groundwater Dependent Ecosystems (GDE's) to occur within the development envelope in low-lying areas where groundwater depths are less than 10 m. However, in all the groundwater exploration holes drilled by Rockwater for the hydrogeological assessment (Rockwater, 2020), the groundwater was highly saline from where it was first intersected, and there were no indications of any shallow low-salinity groundwater that could support GDE's.

A report by Woodman Environmental (2019) states that four vegetation units (VUs) mapped along drainage lines in the project area are likely to be dependent on surface water flows, and are possibly dependent to some extent on groundwater. The results of subsequent hydrogeological investigations were provided to Woodman Environmental in April 2020, and the following conclusion was made by that organisation: "In summary it appears unlikely that any of the VUs recorded in the Study Area rely upon the local groundwater table for survival, rather utilising soil stored moisture from rainfall as their primary source of water during drier months. In particular, those VUs that occur higher in the landscape such as VUs 16 and 17 that comprise the Proteaceae Dominated Kwonkgan Shrublands of the Southeast Coastal Floristic Province of Western Australia TEC (Endangered – EPBC Act) are situated where the water table is located well in excess of 10m from the ground surface and therefore are not groundwater dependent".

2.8 STREAMFLOW

No streamflow data is available for Oldfield River or Munglinup Creek catchment areas. The nearest streamflow stations are on the Young River as shown in Figure 1 with station details outlined in Table 2.

Table 2: Streamflow gauging stations near project area

Name	Waterway	AWRC Reference	Catchment Area (km^2)
Neds Corner	Young River	601001	1,893.3
Cascades	Young River	601005	88.9

The contributing catchment of the 601005 Cascades streamflow gauge is approximately 89 km^2, slightly smaller than that of the main catchment area of Munglinup River for the project area (Catchment M1, Section 4.3); while the contributing area of the 601001 gauge is in the order of 1900 km^2, much greater than any catchment within the project area.

It is noted that the maximum daily discharge rate (m^3/s) recorded at these gauging stations is generally very small to zero, indicating that for the majority of the year, the creeks and river systems are not flowing. The maximum peak discharge recorded at the gauges during the February 2017 rainfall event was 34 m^3/s at gauge 601005 and 219 m^3/s at gauge 601001. It should be noted that gauge 601001 stopped recording flow values during this event suggesting that the readings from this gauge could be unreliable.

The Cascades Young River Gauge has a period of record of 25 years. The interpolated peak flows at this gauge according to available data on the ARR 2016 data hub are shown in Table 3. The physiographic characteristics of the catchments within the project area appear to be similar to the characteristics of this streamflow gauge and could be used to validate the peak flows generated for the project area.

Table 3: 601005 Young River – Cascades flood frequency analysis for design flows

ARI (1 in year)	5	10	20	50	100
Peak Flow (m^3/s)	3	8	19	57	126

2.9 LOCAL WATER USE / MANAGEMENT

The Department of Water and Environmental Regulation (DWER) Water Register (see References) has no record of licences to take water from the Munglinup River or its tributaries. The Munglinup town water supply utilises runoff collected from a paved catchment. It is unlikely that any river water is used for stock or domestic use, because of its high salinity at times of low flow.

South Coast Rivercare has an interest in the quality of water in the Oldfield River catchment, which includes the Munglinup River; and DWER has the regulatory responsibility to manage all rivers in the State. The main parameters of concern are likely to be nutrients (nitrogen and phosphorus), suspended solids/turbidity, and dissolved oxygen.

3 WATER QUALITY

The South Coast Rivercare website (see References) reports that the Munglinup River flows from the sandplain north of Munglinup. The river lies generally within a vegetated corridor. It flows for only short periods each winter, or negligibly in dry winters, and is naturally brackish to saline. This information is based on measurements taken by Andy Chapman since 1998.

It is likely that the salinity is lower in high flows, and probably fresh in flood flows.

There are a few water-quality data for the Munglinup River on the DWER Water Information Reporting (WIR) database. They are summarised in Table 4.

Table 4: Water quality, Munglinup River

Site No.	mE	mN	Sample	TDS	TSS	EC	pH	TN	TP	Turbidity
(WIR)	(GDA94)		Period	(mg/L)	(mg/L)	(µS/cm)		(mg/L)	(mg/L)	(NTU)
6011218	298919	6276715	26/08/2006	24,320	-	-	7.4	1.6	0.06	29.9
6011109	300900	6272766	Jun-98-Jun-00	-	-	0.06, 39,300	7.4-8.1	0.9-2.4	0.01-0.19	10-30
6011158	302033	6269455	Nov-98-Mar-00	-	-	-	7.2-8.0	0.9-3.5	0.02-0.08	10-40
6011029	302539	6268315	Jun-71-Jan-99	-	15, 90	27,500-37,200	7.8-8.3	1.0-4.2	0.04-0.14	55

The WIR data indicate that the river water is generally saline, slightly alkaline, contains some suspended sediment, and has generally low concentrations of nitrogen and phosphorus.

Water samples were collected from two drains (Nos. 1 & 2) and six sites on the Munglinup River on 10 to 12 April 2018 (WRM, 2018) and analysed for a comprehensive suite of water quality parameters. Locations are listed in Table 5. The six river sites (prefixes MRU and MRD) are shown in Figure 4, and the results of their analyses by the Chemistry Centre are given in Table 6.

Table 5: Surface water sample sites

Site	m E	m N
Drain 1	301204	6275241
Drain 2	305014	6274104
MRU5	299009	6277057
MRU3	300792	6274254
MRU2	301029	6273678
MRD5	301853	6270782
MRD4	302057	6269525
MRD3	302266	6268683

Table 6: Results of chemical analyses, Munglinup River samples

Parameter	Limits of Reporting	Unit	MRU5	MRU3	MRU2	MRD5	MRD4	MRD3
			10/04/2018	10/04/2018	10/04/2018	11/04/2018	11/04/2018	12/04/2018
Aluminium	*0.005*	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Alkalinity	*1*	mg/L	279	336	324	291	235	244
Arsenic	*0.001*	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Boron	*0.02*	mg/L	4.9	5	4.9	5	4	3.9
Barium	*0.002*	mg/L	0.092	0.085	0.085	0.087	0.076	0.078
Carbonate	*1*	mg/L	16	<1	<1	1	<1	<1
Calcium	*0.1*	mg/L	244	207	203	193	162	165
Cadmium	*0.0001*	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Chloride	*1*	mg/L	12000	11200	10800	10200	8350	7950
Cobalt	*0.0001*	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Chromium	*0.0005*	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Copper	*0.0001*	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Elect. Cond.	*0.2*	mS/m	3670	3380	3310	3090	2550	2390
Iron	*0.005*	mg/L	0.021	0.019	0.081	0.017	0.05	0.1
Bicarbonate	*1*	mg/L	308	409	394	352	287	297
Hardness	*1*	mg/L	3900	3400	3400	3100	2500	2500
Potassium	*0.1*	mg/L	159	149	147	140	112	109
Magnesium	*0.1*	mg/L	800	699	701	636	513	497
Manganese	*0.001*	mg/L	0.069	0.2	0.18	0.16	0.17	0.2
Molybdenum	*0.001*	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Ammonium-N	*0.01*	mg/L	<0.01	<0.01	0.04	0.01	<0.01	<0.01
Nitrite-N	*0.01*	mg/L	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
Nitrate-N	*0.01*	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nox-N	*0.01*	mg/L	<0.01	<0.01	0.02	<0.01	<0.01	<0.01
Total N	*0.01*	mg/L	1.6	1.2	1.5	1.1	1.2	1.4
Sodium	*0.1*	mg/L	7440	7010	6930	6760	4960	4850
Nickel	*0.001*	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Hydroxide	*1*	mg/L	<1	<1	<1	<1	<1	<1
Total P	*0.005*	mg/L	0.026	0.047	0.049	0.017	0.014	0.014
Lead	*0.0001*	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Sulphur	*0.1*	mg/L	660	620	610	580	460	450
Sulphate-S	*0.1*	mg/L	1980	1850	1820	1740	1380	1330
Selenium	*0.001*	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Silicon	*0.05*	mg/L	0.39	3.2	2.7	3.7	3.6	3.2
Strontium	*0.002*	mg/L	2.8	2.4	2.3	2.4	2	2
TDS (calc.)	*5*	mg/L	20000	19000	18000	17000	14000	13000
TSS	*1*	mg/L	8	9	11	10	5	8
Turbidity	*0.5*	NTU	<0.5	3.6	4.8	5.2	3.6	3.9
Uranium	*0.0001*	mg/L	<0.0010	<0.0010	<0.0010	0.0012	<0.0010	<0.0010
Vanadium	*0.0001*	mg/L	0.0015	0.0037	0.0015	0.0028	0.0028	0.0021
Zinc	*0.001*	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
pH	*0.1*		8.4	8.2	8	8.3	8.1	8.1

The samples represent low flows in the river, as they were taken in a relatively dry autumn; there had been only 3.2 mm of rainfall earlier in April 2018, and no major rainfall after a recording of 22 mm on 15 March 2018.

The results of the analyses indicate that the river water was highly saline, with salinity decreasing downstream from 20,000 mg/L TDS at MRU5, to 13,000 mg/L TDS at MRD3. The water was alkaline (pH 8.0 to 8.4) and of a sodium chloride type with elevated magnesium and sulphate. Metal concentrations were generally low or below reporting levels. Nutrient concentrations were also low: total nitrogen 1.1 to 1.6 mg/L; and total phosphorus 0.014 to 0.047 mg/L. There were elevated boron concentrations (4 to 5 mg/L); and strontium ranged from 2.0 to 2.8 mg/L.

Two surface water samples were collected from Drains 1 and 2 at locations given in Table 5 and shown in Figure 4. The drains follow natural drainage lines. Drain 1 was sampled at the southern edge of farmland; it discharges into a tributary of Munglinup River. Drain 2 was sampled on the western edge of farmland; it discharges into Clayhole Creek.

The results of the surface-water chemical analyses (presented in Appendix A) show that the water from Drain 1 is of much lower salinity than the water from Drain 2 (D2). However, sampling from Drain 1 was undertaken after overnight rain, and so the sample will have included rainfall runoff. The sample from Drain 2 is highly saline and of very similar chemistry to the groundwater samples, except that it had higher total nitrogen (4.5 mg/L) and was low in iron and manganese.

4 HYDROLOGICAL ANALYSIS

The Munglinup River and four unnamed small tributaries flowing south-westwards into the river, flow across or close to the planned mine infrastructure. For the purpose of this study, the tributary creeks have been named Creeks A to D (Figure 6).

The proposed eastern access road alignment crosses two watercourses – a small tributary and the main channel of Clayhole Creek (Figure 5). For the purpose of this study the tributary and main channel upstream of the access road waterway crossing are referred to as CC Trib and CC Main, respectively.

4.1 RAINFALL IFD

Intensity-Frequency-Duration (IFD) curves for the project area were obtained from the Bureau of Meteorology web-site, and are based on the statistical and meteorological analyses given in the ARR 2019 guideline. The IFD tables and curves are included in Appendix B.

The Probable Maximum Precipitation (PMP) was taken to be a 1-in-2000-year event, with a probability of it occurring in any year of 0.05%. The design rainfall for this event is also included in a table and chart in Appendix A. The Probable Maximum Flood (PMF) would result from a PMP event.

4.2 USE OF ARI AND AEP

The latest publication of Australian Rainfall and Runoff (ARR) 2019 uses the term Annual Exceedance Probability (AEP, expressed as %) to describe the design frequency levels. Previous ARR publications used Average Recurrence Interval (ARI, in unit of years). Table 7 presents the conversion of typically used AEP intervals to ARI, followed by the pre-ARR 2019 ARI equivalent.

Table 7: Conversion between ARI and AEP

AEP (%)	50%	20%	10%	5%	2%	1%	0.05%
Exact ARI (Years)	1.44	4.48	9.49	19.50	49.50	99.50	1999.50
Adopted ARI (Years)	2	5	10	20	50	100	2000

In order to maintain consistency, this report uses the term ARI with the context as given in Table 7. The IFD curves apply to both the planned mining area and the eastern access road.

4.3 CATCHMENT CHARACTERISTICS

The relevant catchments were identified using a combination of LiDAR topographical survey data provided by MRC where available, and the DEM-H version of the 1 second SRTM dataset (Geoscience Australia, 2011) for areas that fall outside this region. The catchment characteristics of the Munglinup River (Catchment M1, M2 & M3; Figure 5) and local sub-catchments within these catchments (Catchments M1 Trib and M3(A) to M3(G); Figure 6) are presented in Table 8, together with Clayhole Creek catchments (CC Main, CC Trib; Figure 5).

Table 8: Catchment characteristics pre-mining

Catchment	Area (km^2)	Length (km)
Catchments		
M1	109.2	19.7
M2	19.1	6.7
M3	6.5	3.3
CC Main	34.8	8.7
CC Trib	0.6	1.9
Sub-catchments		
M1 Trib*	8.7	3.6
M3 (A) #	0.5	1.5
M3 (B) #	0.8	1.6
M3 (C) #	1.0	2.2
M3 (D) #	1.1	1.6
M3 (E) #	0.4	0.6
M3 (F) #	0.2	0.6
M3 (G) #	0.8	1.3

* M1 Trib catchment is within the M1 catchment and has been accounted for in all M1 calculations
# M3(A) to M3(G) are sub-catchments of the greater M3 catchment and have been accounted for in all M3 calculations

4.4 RATIONAL METHOD

The Rational Method is a well-established method for determining runoff in ungauged catchments. The Statistical Rational Method, used in peak-flow estimation, is presented in Equation 1. As described in Section 2.5, soils in the project area are predominantly loamy in nature. For this reason, the techniques of peak flow estimation for loamy soils were used in the computation for both Rational and Index Flood estimation techniques.

$$Q_y = 0.278 \cdot C_y \cdot I_{tcy} \cdot A$$ ***Equation 1***

Where:
Q_y *is the peak flow for return period of y years (m³/s)*
0.278 is a dimensionless metric conversion factor
C_y *is the runoff coefficient for y years (dimensionless)*
I_{tcy} *is rainfall intensity (mm/hr)*
A *is catchment area (km²)*

The time of concentration is required to estimate the critical storm duration for peak flows in each catchment. This was estimated using Equation 2 for the Wheatbelt Region of Western Australia as recommended by ARR:

$$t_c = 0.76 \cdot A^{0.38}$$ ***Equation 2***

Where:
t_c *is the time of concentration (hours)*
A *is the catchment area (km²)*

A summary of the design peak flows, as estimated using the Rational Method, is shown in Table 9. The detailed calculations are presented in Appendix C.

Table 9: Rational Method Peak Flows (m^3/s), pre-mining

Catchment	Average Recurrence Interval (Years)						
	2	5	10	20	50	100	PMF*
M1	6.4	14.3	26.8	49.0	86.5	112.0	203.3
M2	2.7	6.0	11.2	20.1	34.9	44.7	81.2
M3	1.6	3.6	6.6	12.0	20.6	26.4	47.9
CC Main	3.3	7.2	13.0	22.3	36.8	52.8	95.9
CC Trib	0.3	0.7	1.3	2.4	4.1	5.2	9.5

4.5 FLOOD INDEX METHOD

The Flood Index Method is another method which uses catchment characteristics for estimating peak flows. The formula for peak flow estimation for the Wheatbelt Region is presented in Equation 3.

$$Q_5 = 2.77 \times 10^{-6} \cdot \mathrm{A}^{0.52} \cdot \mathrm{p}^{2.12}$$ ***Equation 3***

Where:
Q_5 *is the peak discharge for the 5-year ARI flow (m³/s)*
A *is the catchment area (km²)*
C_L *clearing measured as percentage of catchment area*

A summary of the design peak flows, as estimated using the Flood Index Method, is shown in Table 10. The detailed calculations are presented in Appendix C.

Table 10: Index Flood Method Peak Flows (m^3/s), pre-mining

Catchment	Average Recurrence Interval (Years)						
	2	5	10	20	50	100	PMF*
M1	9.2	19.2	35.3	62.0	117.0	124.7	226.4
M2	3.7	7.7	14.2	25.0	47.2	50.3	91.4
M3	2.1	4.4	8.2	14.3	27.1	28.9	52.4
CC Main	3.2	6.7	12.3	21.5	40.7	43.3	78.7
CC Trib	0.6	1.2	2.3	4.0	7.6	8.1	14.7

4.6 RORB RUNOFF-ROUTING

A hydrologic runoff-routing model of both the Munglinup River catchment and Clayhole Creek catchment was developed using the modelling software package RORB (Laurenson et al. 2010). A RORB model was established for the purpose of extracting hydrographs to estimate design peak flows for each of the catchments and provide boundary conditions (inflows) to the HEC-RAS hydraulic model.

RORB is a rainfall runoff and streamflow routing model that calculates flood hydrographs from rainfall and other channel inputs. Rainfall excess, calculated by subtracting losses from rainfall, is routed through catchment storages to produce runoff hydrographs at any location; losses are processes that occur on the catchment surface before the water enters the channel network.

The adopted methodology described is based on current guidelines described in ARR 2019. The temporal pattern that produces the peak flow at each hydrograph output location has been selected for design purposes and as such, the results can be considered conservative.

The hydrologic model has not been directly calibrated as no streamflow data were available for the catchments, however, output flows have been validated against predicted flows for the neighbouring streamflow gauge at Young River as described in Section 2.8.

4.6.1 MODEL SET-UP AND PARAMETERS

The Munglinup River RORB model has 21 sub-areas determined from topographic information and a total catchment area of 135 km^2. Given sub-catchments M3(E), M3(F) and M3(G) do not have a defined creek system, these sub-catchments were not modelled individually in RORB, but instead included within the greater M3 catchment runoff to Munglinup River. The sub-catchment delineation and reach network for the RORB model is shown in Appendix D.

The Clayhole Creek RORB model has 9 sub-areas and a total catchment area of 39 km^2. The sub-catchment delineation and reach network for the RORB model is shown in Appendix E.

As the catchments are ungauged, the RORB models were parameterised using regional methods for estimating the main parameters (Kc, m and losses). Kc is the primary routing parameter in RORB, which is used to estimate the flow routing and attenuation characteristic within the catchment. The RORB user manual outlines the regional relationships developed to calculate Kc for ungauged catchments and takes the form:

$$K_c = 2.2\sqrt{A}$$

The exponent m is the parameter that describes the non-linearity of a catchment's storage routing. A value of 0.8 was adopted for the exponent m, following recommendation by RORB developers (Laurenson et al. 2010) for ungauged catchments in the absence of more relevant information.

Design rainfall depths were determined using the Bureau of Meteorology (BoM) online IFD tool. The RORB model was used to generate probable maximum flood (PMF) flow hydrographs, which required the development of the probable maximum precipitation (PMP). The PMP was developed using CRC Forge (DoE, 2004) factors and the storm events were run using the RORB model. The model was run for storm durations between 30 minutes and 96 hours.

Areal reduction factors were used to convert point rainfall to areal estimates. ARR 2019 areal reduction factors were applied to the catchment area and extracted from the ARR data hub (See References). The catchment lies within the South West Coast area of aerial reduction factors and these were applied for all design modelling. Temporal patterns from ARR 2019 were utilised in the analysis and extracted from the ARR data hub. ARR 2019 guidance suggests analysis with various temporal patterns allows for exhibited variability in rainfall events of similar magnitude. The RORB model was run using the temporal pattern ensemble method to account for this variability in rainfall events.

4.6.2 LOSS MODEL

RORB generates rainfall excess (runoff) by subtracting losses at each time-step from the rainfall occurring in that time period. The "initial loss followed by a continuing loss" loss model was adopted. As described in Section 2.5, the soils in the catchment area are predominantly sandy loams. ARR 2019 suggests an initial loss of 28 mm with a continuing loss of 2 mm/hr for soils within this region.

4.6.3 PEAK FLOWS

The critical duration flow hydrographs from the RORB model were extracted at catchment outlet locations to provide input hydrographs to the hydraulic model (HEC-RAS) of the river. These locations are shown in Appendices D and E.

The critical duration at a particular location refers to the duration of a design storm event that produces the maximum flood peak for a given annual exceedance probability. The RORB simulations produced ten hydrographs for each output location in the RORB model for each ARI and duration. This produces a variety of simulated storm events for the range of durations and probabilities. The temporal pattern that produced highest peak flow for each ARI event was selected to be conservative.

A summary of the peak discharge from the RORB hydrologic model for each catchment and its associated critical duration for the pre-mining scenario is shown in Table 11. The critical storm duration hydrographs upstream of the project area along Munglinup River and for Clayhole Creek are shown in Text-Figures 1 and 2.

The RORB model simulation results show that the critical duration storm event is approximately 24 hours for the larger Munglinup River and Clayhole Creek catchments, but only 9 hours for each of the smaller tributaries crossing the project area.

Table 11: Summary of Peak Flows (m^3/s) and Critical Storm Durations at Catchment Outlets (See Appendices D & E)

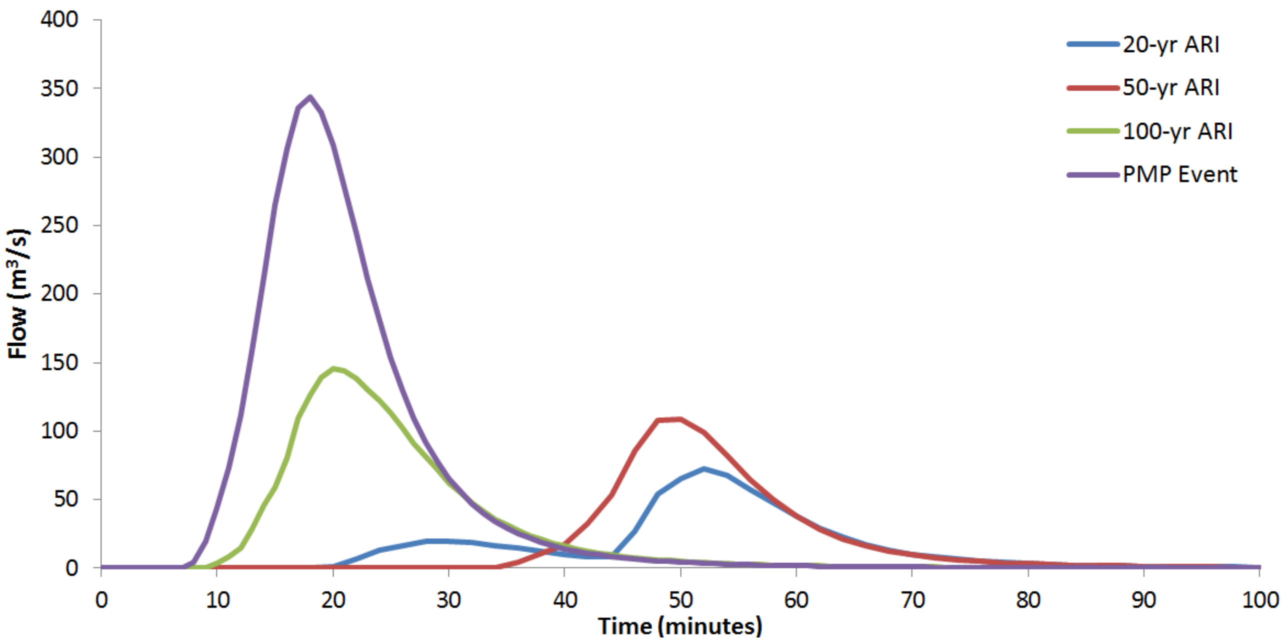
Catchment	Average Recurrence Interval (Years)					
	5	10	20	50	100	PMF#
Catchments						
M1	30.1 (48hr)	49.9 (48hr)	72.4 (48hr)	109.1 (48hr)	145.7 (24hr)	343.7 (18hr)
M2	13.6 (18hr)	19.7 (48hr)	27.3 (48hr)	31.4 (24hr)	41.1 (12hr)	91.6 (18hr)
M3	36.9 (48hr)	55.0 (48hr)	80.4 (24hr)	126.7 (48hr)	168.3 (48hr)	400.1 (48hr)
CC Main	14.2 (18hr)	23.2 (48hr)	33.3 (48hr)	47.3 (24hr)	60.6 (24hr)	136.2 (12hr)
CC Trib	0.9 (18hr)	1.1 (12hr)	1.5 (12hr)	2.1 (9hr)	2.6 (9hr)	5.4 (9hr)
Sub-catchments						
M1 Trib	6.9 (18hr)	9.8 (48hr)	13.5 (48hr)	15.7 (18hr)	20.7 (18hr)	45.6 (9hr)
M3(A)	0.6 (18hr)	0.7 (24hr)	1.0 (24hr)	1.4 (9hr)	1.7 (9hr)	3.5 (9hr)
M3(B)	1.0 (18hr)	1.2 (24hr)	1.6 (12hr)	2.2 (9hr)	2.8 (9hr)	5.7 (9hr)
M3(C)	1.1 (18hr)	1.4 (48hr)	1.9 (48hr)	2.4 (9hr)	3.1 (9hr)	6.7 (9hr)
M3(D)	1.5 (18hr)	1.8 (24hr)	2.4 (12hr)	3.4 (9hr)	4.3 (9hr)	8.7 (9hr)

 # PMF taken to be a 1-in-2000-year event, developed using CRC Forge.

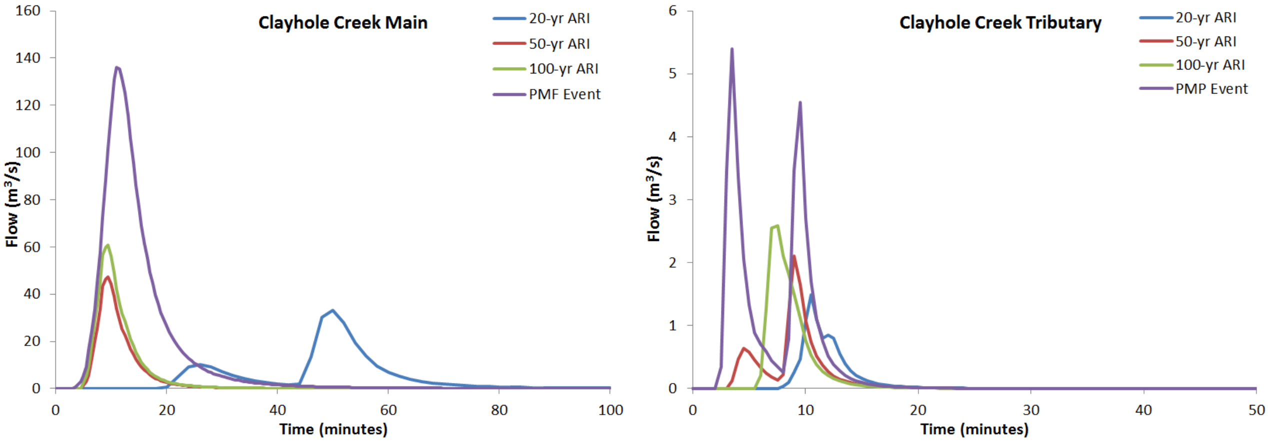
The absence of suitable local gauging data makes development of more accurate flood estimation methods problematic. However, a 100-year peak flow estimate of 146 m^3/s for the 109 km^2 M1 catchment seems within the correct range given the neighbouring Young River catchment (89 km^2) which has an estimated 100-year peak flow of 126 m^3/s (Section 2.8).

Collection of flow records, particularly peak flood levels during operation would be valuable to allow assessment of the accuracy of the available methods and provide potential for improvements to be made in flood estimation methods over the life of the project.

Text-Figure 1: RORB critical design flow estimation for flow at M1 (upstream of project area) for varying ARI events



Text-Figure 2: RORB critical design flow estimation for flow at Clayhole Creek Catchments for varying ARI events



5 HYDRAULIC MODELLING

HEC-RAS (Version 5.3) was used as the hydraulic modelling software to simulate flooding along Clayhole Creek, Munglinup River and associated tributaries within the vicinity of the project area as a result of design rainfall events.

HEC-RAS is a one-dimensional hydraulic programme which allows development of models to simulation both steady and unsteady flow to derive water surface profiles within a river network. The program solution is based on solving the one-dimensional energy equation.

The purpose of this analysis was to assess whether the 1-in-100 year ARI peak flows would adversely impact the pits and infrastructure, and to provide information for the concept design of protective measures, if required.

5.1 MUNGLINUP RIVER

Cross-sections for the Munglinup River hydraulic model were extracted from the local high-quality LiDAR survey data of the area. The locations of the model cross-sections are shown in Figure 7.

The value for the roughness coefficient, “n”, which represents the hydraulic roughness of the waterway, of 0.06 was adopted for the main channel and river banks of Munglinup River based on aerial photography.

The adopted downstream boundary condition for the HEC-RAS model was based on a normal depth calculation, using the average longitudinal bed-slope of Munglinup River in the area of interest of approximately 0.4%. The downstream boundary of the hydraulic model was located significantly downstream of the project to minimise any boundary effects within the area of interest.

A steady flow model was run to simulate the maximum peak flow extracted from the RORB output hydrographs. Figures 7 to 9 show the estimated extent of flooding for the 1 in 20, 50 and 100-year ARI events, respectively. It should be noted that the flood mapping shows the maximum inundation extent. This inundation extent only occurs for a short duration at the peak of the flood.

Flow for all events is generally limited to the defined flow channel and will not impact the neighbouring pits or infrastructure. Flood flows in the tributary drainages will be short-lived and generally of limited lateral extent.

5.2 CLAYHOLE CREEK

Design flood levels and the extent of flooding along Clayhole Creek was simulated using the inflow hydrographs from the RORB hydrologic model to quantify flood levels and flood behaviour at the two proposed road crossing locations. The locations of the HEC-RAS model cross-sections are shown in Figure 10, extracted from the high-quality LiDAR survey data of the area.

The value for the roughness coefficient, “n”, which represents the hydraulic roughness of the waterway, of 0.06 was adopted for the main channel and banks of Clayhole Creek based on aerial photography.

The adopted downstream boundary condition for the HEC-RAS model was based on a normal depth calculation, using the average longitudinal bed-slope of Clayhole Creek in the area of interest of approximately 0.35%.

Figure 10 shows the estimated extent of flooding for the 1 in 20, 50 and 100 year ARI events.

6 IMPACT ASSESSMENT

6.1 POTENTIAL IMPACTS

The potential impacts of the proposed mining operations on surface water resources include:

- Loss of catchment area draining back to Munglinup River due to capture of runoff within on-site storages and reduced surface flows. This could potentially reduce runoff volumes to Munglinup River;
- Interference with flood flows along Munglinup River and Clayhole Creek;
- Flood and drainage impacts associated with the proposed road access points crossing tributaries of Munglinup River and Clayhole Creek.
- Adverse impacts on the quality of surface runoff draining from the local creek catchments to Munglinup River;

An assessment of each of these potential impacts on the waterways is detailed in the following sections.

6.2 LOSS OF CATCHMENT AREA

The relative disturbance area within both the local and regional catchments provides a conservative indication of the potential impacts that the construction, operation and closure of the proposed project may have on the adjacent surface water regimes. The most significant change in hydrological processes related to the proposed mining infrastructure is the removal of catchments areas contributing to downstream receptors, in this case, Munglinup River to the west, which ultimately combines with Oldfield River.

Excavation of the pits, and construction of the tailings storage (TSF), will reduce the catchment area of M3 by approximately 31%, and is likely to reduce the flow into Munglinup River. Runoff from the waste rock landform (WRL) is assumed to be similar to that under pre-mining conditions (in reality it is likely to be reduced somewhat by infiltration). Clayhole Creek and its tributaries, which cross the eastern access road, will be unaffected provided the creek crossings do not restrict flows or cause erosion.

With the current mine layout, Whites and McCarthy West pits will lie between Catchments M3(A) and M3(B); McCarthy East pit lies in Catchment M3(B); and Harris pit will be between Catchments M3(B) and M3(C). The creek through Catchment M3(C) would lie partially within the area of the proposed WRL and passes through the planned Halberts Main pit (Figure 6), and so will need to be diverted. The planned TSF will cover much of Catchment M3(D), and Halberts South along with the workshops and ROM will cover much of Catchment M3(G).

As shown in Table 12, these impacted local sub-catchments (M3(A) to M3(G)) comprise approximately 3.6 % of the total Munglinup River catchment area (135 km^2) at the project boundary, and 1.4 % of the total catchment area at the junction with Oldfield River (336 km^2). As the affected catchments are a minor proportion of the greater regional catchment area, it is unlikely that the proposed mining infrastructure will have a significant impact on the downstream Munglinup River flows. The predicted impact was investigated below.

Table 12: Summary of Impacted Catchment Areas

Catchment	Catchment Area (pre-mining)	Percentage of Regional Munglinup Catchment Area to project area	Percentage of Regional Munglinup Catchment Area to Oldfield Junction
	(km^2)	(%)	(%)
M3 (A)	0.5	0.4%	0.1%
M3 (B)	0.8	0.6%	0.2%
M3 (C)	1.0	0.7%	0.3%
M3 (D)	1.1	0.8%	0.3%
M3 (E)	0.4	0.3%	0.1%
M3 (F)	0.2	0.1%	0.1%
M3 (G)	0.8	0.6%	0.2%
TOTAL	**4.8**	**3.6%**	**1.4%**

Catchment characteristics during and post-mining for these altered catchments are given in Table 13. The RORB hydrologic model was re-run adopting the smaller catchment areas and reach lengths, while regional parameters of Kc, m and losses were still used. Peak discharge outputs from the model for the mining scenario case are shown in Table 14.

As the upper Munglinup Catchments (M1 and M2) will remain unchanged they will result in the same flows as previously shown in Table 11. A summary of the predicted changes in peak flow that will result from the mining and infrastructure are given in Table 15. Impacted areas are assumed to be the same for construction, operation and closure.

Table 13: Tributary catchment characteristics, during- and post-mining

Catchment	Area	Length	Reduction in catchment area (in comparison to pre-mining)
	(km^2)	(km)	%
M3 (A)	0.4	1.5	-22%
M3 (B)	0.5	1.2	-33%
M3 (C)	0.6	1.7	-37%
M3 (D)	0.4	0.7	-65%
M3 (E)	0.4	0.6	-8%
M3 (F)	0.1	0.2	-45%
M3 (G)	0.3	0.8	-58%
M3 TOTAL	**4.5**	**3.3**	**-31%**

Table 14: Calculated peak flows (m^3/s), during- and post-mining

Catchment	Average Recurrence Interval (Years)					
	5	10	20	50	100	PMF#
M3 (A)	0.6	0.6	0.8	1.2	1.5	3.0
M3 (B)	0.7	0.8	1.1	1.5	1.9	4.1
M3 (C)	0.8	0.9	1.2	1.7	2.1	4.4
M3 (D)	0.6	0.7	0.9	1.3	1.6	3.3
Munglinup River Total (at project boundary, M3)outlet)	**36.6**	**54.8**	**80.5**	**126.3**	**167.9**	**398.8**

 # PMF taken to be a 1-in-2000-year event, developed using CRC Forge.

Table 15: Calculated change in peak flows (m^3/s) due to mining*

Catchment	Average Recurrence Interval (Years)					
	5	10	20	50	100	PMF
M3 (A)	0.0	-0.1	-0.2	-0.2	-0.2	-0.5
	-5%	-15%	-18%	-16%	-14%	-15%
M3 (B)	-0.3	-0.4	-0.5	-0.7	-0.9	-1.6
	-27%	-32%	-31%	-30%	-32%	-29%
M3 (C)	-0.3	-0.5	-0.7	-0.7	-1.0	-2.3
	-25%	-36%	-36%	-30%	-32%	-35%
M3 (D)	-0.9	-1.1	-1.5	-2.1	-2.7	-5.4
	-62%	-63%	-63%	-62%	-64%	-62%
Munglinup River Total (at project boundary, M3 outlet)	-0.3	-0.2	0.1	-0.4	-0.4	-1.3
	-0.7%	-0.4%	0.1%	-0.3%	-0.3%	-0.3%

** This tabulation includes areas that drain towards landforms. Runoff that is diverted around landforms will ultimately still reach the downstream receptors, with the primary impact being a change in the timing of the flow.*

The combined change in peak flows in sub-catchments M3(A) to M3(D) totals 1.5 m^3/s during a 1-in-5 year ARI event and 4.9 m^3/s during a 1-in-100 year ARI event (Table 15). The expected change in flow is greatest for Catchment M3(D), where a 64 % reduction of flow is expected as a results of the lost catchment associated with the TSF. However, as these local catchments have only small flows with a shorter critical duration (9 hours), these peak flows would be occurring at a different time to the peak flow in Munglinup River (24 to 48 hours), and so are unlikely to have any significant impact on the river during a large flood event. Due to the different timings of flow, the peak flow from Munglinup River at the project boundary is expected only to be reduced by 0.3% in comparison to pre-mining flows during a 1-in-100-year event (Table 15).

The peak flows of Munglinup River are expected to be impacted greatest during the 1-in-5-year event with a 0.7% reduction in peak flow expected as a result of the reduced catchment areas. During minor flow events, flows will largely be derived from groundwater discharge to the river, rather than runoff, however there is potential that groundwater discharge may be reduced due to evaporative losses from the pits.

6.3 INTERFERENCE WITH FLOOD FLOWS

It is evident from the flood extent maps of Munglinup River (Figures 7 to 9), that all mine infrastructure falls outside the 100-year ARI flood extent of the main Munglinup River waterway. Flows are generally maintained within the creek channels for all flood events with little breakout of flows. The project is therefore not expected to have any adverse impacts on the flood levels or flood behaviour along Munglinup River channel.

6.4 FLOOD IMPACT ON MINE INFRASTRUCTURE

It is evident from the flood extent maps (Figures 7 to 9) that a 1-in-100 year ARI storm event will not adversely impact the planned mining areas except Halberts Main pit – where a diversion drain will be needed to direct flows from Catchment M3(C) (Section 6.4.1) around the pit. The boundaries of all other pits are above the peak flow stages of the 1-in-100 year ARI event. The proposed ROM and other mine plant and facilities are located at the top of local catchments and so will not be within the extent of flooding resulting from surface runoff.

The tailings storage facility (TSF) will lie within the drainage line of Catchment M3(D), and when completed it will occupy much of the catchment. During construction, a perimeter bund will be needed to retain or redirect surface runoff (see Section 7.2).

6.4.1 CREEK C DIVERSION CHANNEL DESIGN

The proposed mine layout obstructs the natural flow of Creek C at the south-eastern boundary of Halberts Main Pit as shown in Figures 7 to 9. Based on the natural topography, construction of a perimeter bund and diversion drain is recommended to protect Halberts Main Pit and maintain surface water flow to Munglinup River during and post-mining. Without a diversion drain, the flood water would dam in the area east of the pit where an access road is proposed.

A conceptual long-section design of the proposed diversion channel is given in Text-Figure 3, and the path is shown in Figure 11. The longitudinal bed level must be designed to ensure continuous and progressive lowering with distance downstream until the channel discharges back into the natural drainage line of Creek C. Text-Figure 3 shows that the maximum cut (below natural surface) required to achieve the minimum grade (0.1%) is likely between 0.5 – 2.2 m for a length of 150 m. Minor incisions may be required for the remainder of the drain invert. The diversion channel should be constructed before commencement of any mining operations in order to protect the open pit mine from flooding.

The diversion channel is designed to protect the pit for all flood events up to the PMF event. Table 16 shows the conceptual dimensions of the diversion channel and a typical cross-section for the channel is shown in Text-Figure 4.

Table 16: Proposed diversion channel dimensions

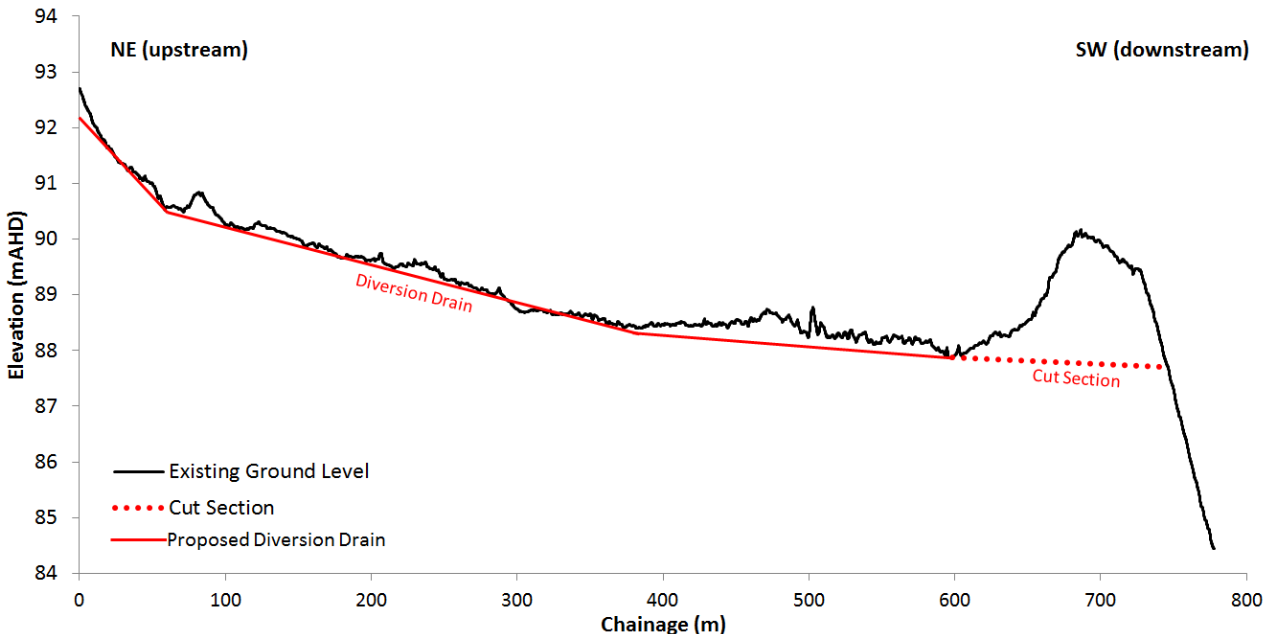
Catchment	Design Peak Discharge	Levee Bank Slope	Levee Height	Channel Depth	Channel bottom width	Flow velocity	Manning's roughness
	(m^3/s)	(v:h)	(m)*	(m)	(m)	(m/s)	n
M3(C)	4.4	1:2	1.2	0.5	3.0	1.1	0.03

** These values are indicative and should be considered as minimum requirements*

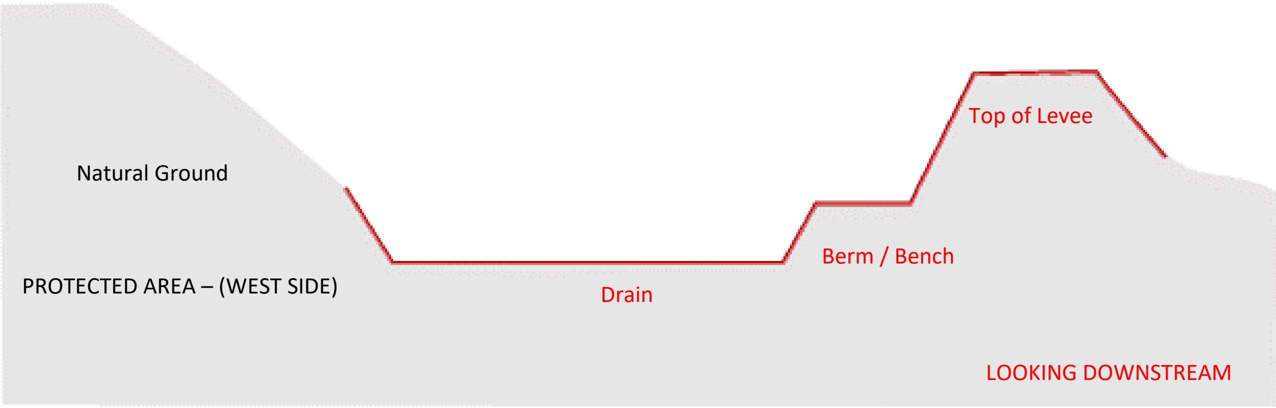
These dimensions will convey both the 1-in-100 year ARI and PMF peak flow of 2.1 m^3/s and 4.4 m^3/s, respectively, ensuring sufficient freeboard. At the detailed design stage, it is recommended that some sections along the diversion drain be re-sized to optimise earthworks and construction costs.

The results of the analysis indicate flow velocities within the proposed diversion drain will be up to 1.1 m/s for the 1-in-100 year ARI and PMF event. Although these velocities are low, rip-rap (graded rock) protection and a scour control layer are recommended for the batter slopes of the drain to prevent bank erosion, bed scour, or sedimentation.

Text-Figure 3: Conceptual long-section of proposed diversion channel (LS1)

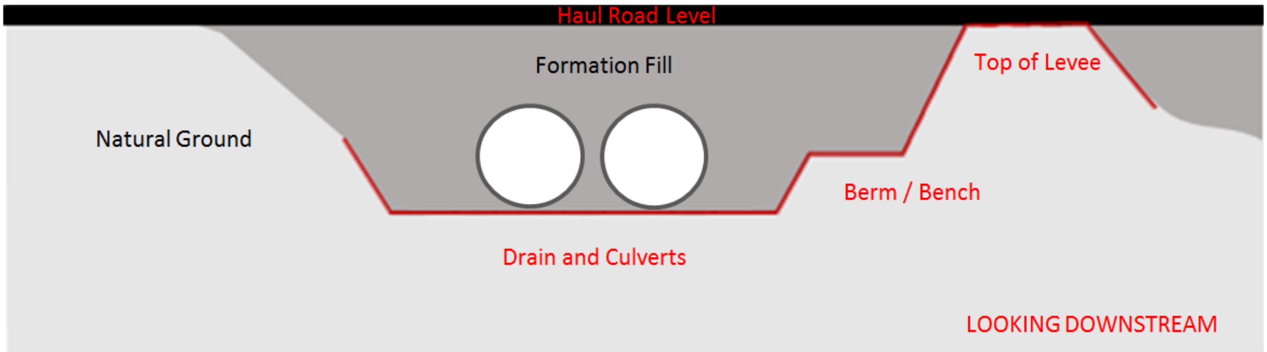


Text-Figure 4: Concept cross-section of diversion drain and levee system (not to scale)



This diversion drain and levee system will intersect the proposed haul road network at MR Crossing 4 and MR Crossing 5 (Figure 11). Due to the combined total levee height and drain depth of approximately 1.70 m, it may not be possible to construct a floodway and culvert system at these crossings. Therefore, it is recommended that only culverts be installed at these crossings to accommodate the diverted Creek C flow. Due to the available head provided by the levee formation, it is possible to convey the 1-in-100 year ARI and PMF events peak flows of 2.1 m^3/s and 4.4 m^3/s, respectively, with 2 x 900 mm pipe culverts at each of the locations. Because the peak flows are relatively small, each crossing will remain dry during rare flood events. A concept typical cross-section of the culvert waterway crossing is shown in Text-Figure 5.

Text-Figure 5: Conceptual cross-section of diversion drain and levee system at road crossing (MR Crossing 3 and Crossing 4) (not to scale)



6.5 FLOOD IMPACT ON HAUL / LV ROAD CROSSINGS

6.5.1 WESTERN ACCESS ROAD

The western mine access road which connects the project (mining) area with Mills Road will be upgraded as part of the development (see Figure 2). The access road crosses over a tributary of the Munglinup River (M1 Trib) at MR Crossing 1 as identified from the flood extent maps in Figures 7 to 9. The remainder of the road is located on a ridge and will not be affected by surface water flows.

A cross-section at the road crossing was analysed to determine design flood levels and velocities: the results are provided in Table 17. Text-Figure 6 shows the conceptual cross-section at MR Crossing 1.

The analyses indicate that in a 1-in-100 year ARI flood, the peak levels at the crossing from the M1 tributary catchment would be at about 93.18 m AHD with a width of about 39 m, and the level would be around 0.27 m higher in a PMF (Text-Figure 6). The maximum depth of the 1-in-100-year flood would be about 0.74 m and the maximum velocity in the order of 1.2 m/s (Table 17).

Text-Figure 6: MR Crossing 1 flood levels

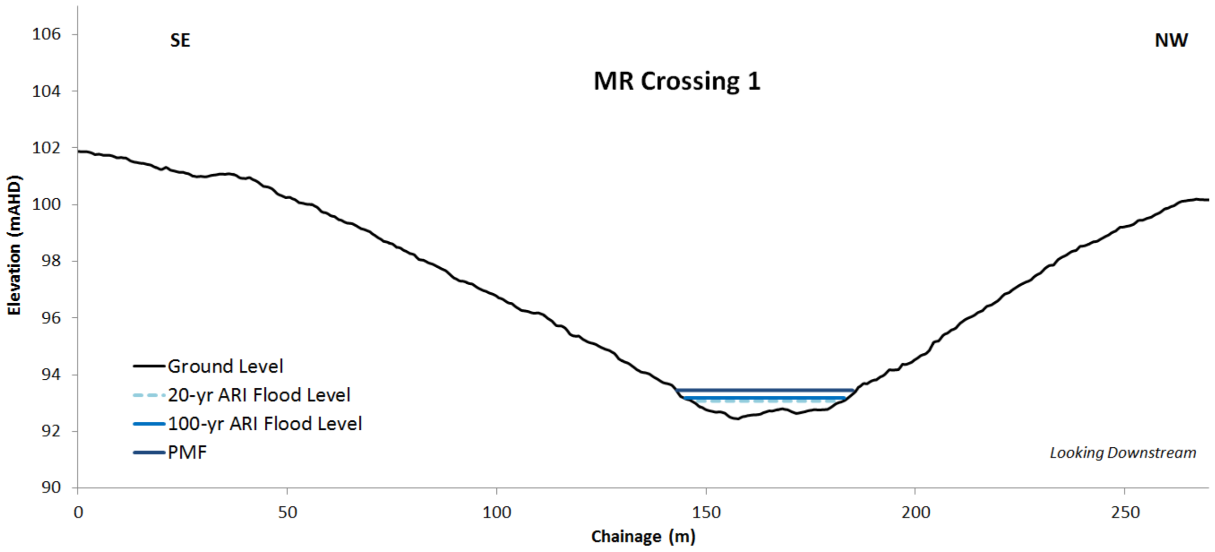


Table 17: Munglinup Tributary MR Crossing 1* - flood summary

Flood Analysis	Q	V	Elevation	Max Depth	Extent
	(m^3/s)	(m/s)	(m AHD)	(m)	(m)
5 year	7	0.87	92.94	0.50	32.77
10 year	10	0.98	93.00	0.56	34.10
20 year	14	1.09	93.07	0.63	36.20
50 year	16	1.13	93.10	0.66	37.00
100 year	21	1.24	93.18	0.74	39.20
PMF	46	1.64	93.45	1.01	42.90

** Catchment M1 Trib*

It is assumed that the proposed road is an unformed un-sheeted road following the natural topographic contours as provided. To remain serviceable, the critical depth of the flood flow above the floodway should be no greater than 200 mm for light vehicles and 500 mm for heavy vehicles. An un-modified crossing at this location would be closed for both light and heavy vehicles in every flood event above the 1-in-5 year ARI.

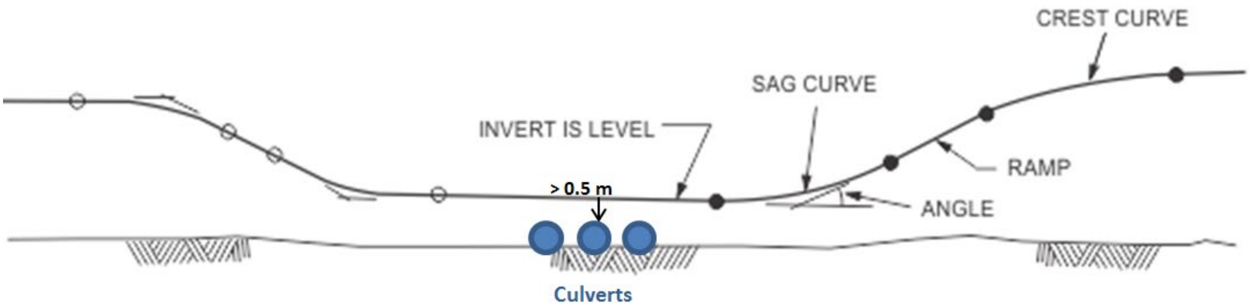
A floodway culvert system will be required in order to keep the road passable during flood events and to facilitate drainage, prevent ponding and maintain flows into Munglinup River.

6.5.1.1 Recommended Floodway Design

It is recommended that nominal concrete or corrugated steel culverts be installed to drain the annual minor flows in order to ensure no bogging at the road embankment, and that a raised floodway be constructed to pass the rare flood events.

The culverts should be at a minimum of 600mm diameter to avoid obstruction from sediment transportation and should be placed at the lowest possible level. The number, size and locations of the culverts should be decided on site. Also, a minimum of 0.5 m cover above the culverts is required in order to prevent the roadway from failing due to vertical type loading of heavy vehicles, as resented in Text-Figure 7 below.

Text-Figure 7: Typical long-section of a floodway (MRWA)



Considering the serviceability requirements for both light and heavy vehicles, the length of the floodway permitting the road to be passable in case of peak flows were calculated using the broad crested weir capacity equation and are shown in Table 18. Note that in the calculations below, the discharge through the culverts is considered nominal and was ignored.

Table 18: Required floodway length for the road to be serviceable in major flood events

		Length of floodway for serviceability (m)	
Flood Event	**Q (m^3/s)**	**Light vehicles (i.e. max. depth of flow over road = 200mm)**	**Heavy vehicles (i.e. max. depth of flow over road = 500mm)**
1-in-5 yr	7	25	-
1-in-10 yr	10	35	9
1-in-20 yr	14	49	12
1-in-50 yr	16	57	14
1-in-100 yr	21	75	19

Main Roads Western Australia (MRWA) recommends serviceability for events up to the 1-in-20 year for rural minor roads or the 1-in-50-year event for rural main roads. A 49 m length floodway would allow the road to remain serviceable in the 1-in-20-year flood for light vehicles and for the all flood events for heavy vehicles.

No sustained sediment transport of significant quantity is postulated to be transported to the receiving waters. The floodway further reduces the potential of sediment transport as velocities are reduced significantly on the upstream end of the floodway which will promote the settlement of sediments. For information purposes, a typical floodway protection design, as recommended by MRWA for low velocity floods, is presented in Appendix F.

6.5.2 ROAD ACCESS TO MINE SITE

The locations of flow paths that could impact the western access road and mine haul / LV road into the mine project area were identified from the flood extent maps in Figures 7 to 9. These locations, named

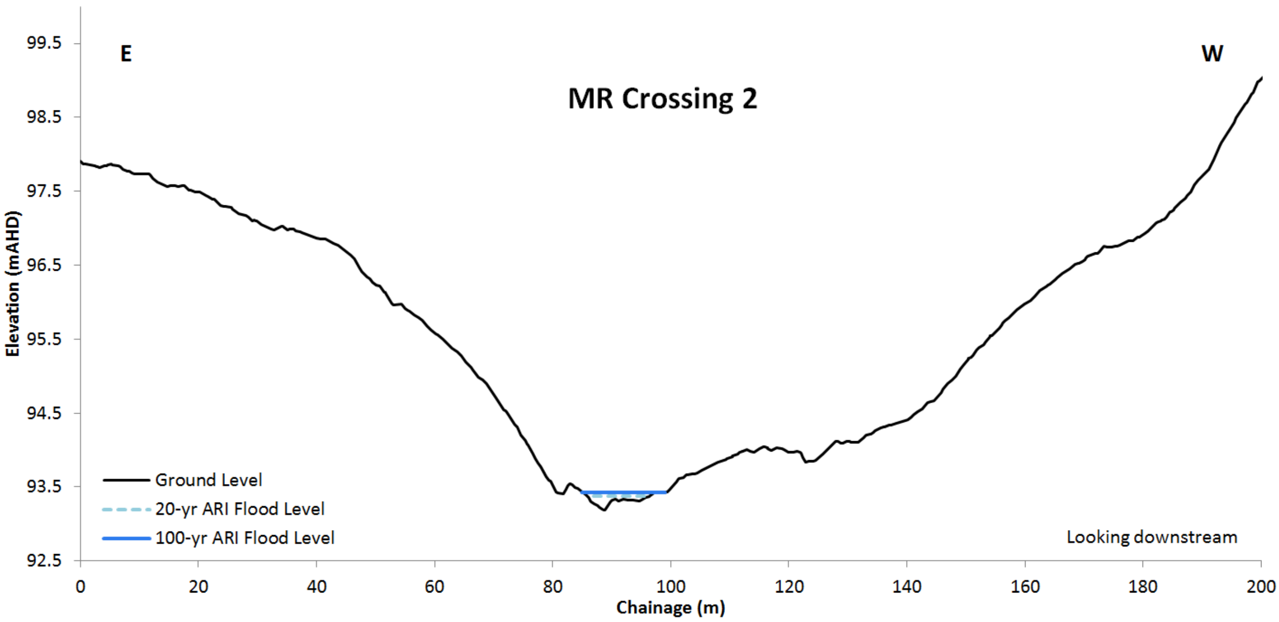
MR Crossing 2 to MR Crossing 6, are listed in Table 19. The road will need to be appropriately designed to allow access during flood events while minimising interference with natural flow patterns by appropriate placement of culverts and/or floodways.

Table 19: Road floodway and culvert crossing locations

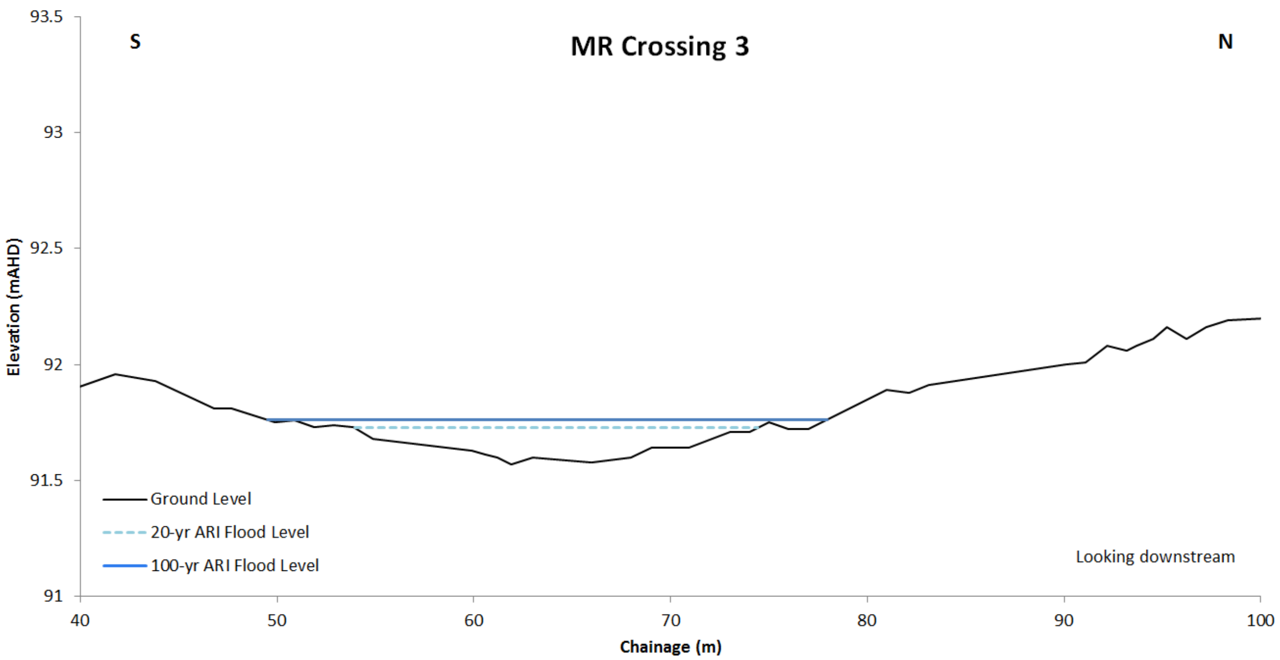
Location	Crossing
MR Crossing 2	Creek A
MR Crossing 3	Creek B
MR Crossing 4	Creek C, Diversion Drain [See Section 6.4.1]
MR Crossing 5	Creek C, Diversion Drain [See Section 6.4.1]
MR Crossing 6	Creek D

The extent, velocity and flows within these flow paths during and post-mining were then extracted at these selected cross-sections from the HEC-RAS model to determine flood management requirements at each crossing. Text Figures 8 to 10 show these extracted cross-sections at MR Crossings 2, 3 and 6 and the hydraulic results are presented in Table 20.

Text-Figure 8: MR Crossing 2 natural 20 year and 100 year ARI flood level.



Text-Figure 9: MR Crossing 3 natural flood levels.



Text-Figure 10: MR Crossing 6 natural flood levels.

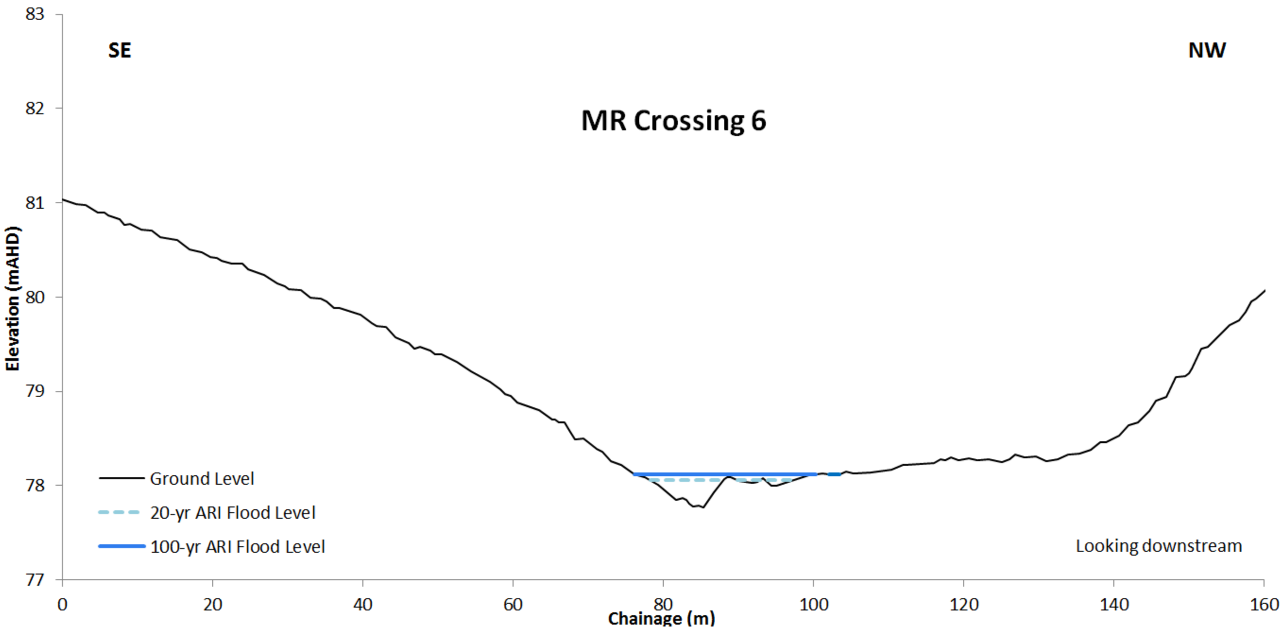


Table 20: Munglinup River Crossings - flood summary

Crossing	Flood Analysis	Q (m^3/s)	V (m/s)	Elevation (m AHD)	Max Depth (m)	Extent (m)
MR Crossing 2	20 year	0.8	0.92	93.38	0.20	10.7
	100 year	1.5	1.06	93.43	0.25	15.2
MR Crossing 3	20 year	1.1	0.5	91.73	0.16	31.4
	100 year	1.9	0.55	91.76	0.19	44.3
MR Crossing 6	20 year	0.9	0.51	78.06	0.29	16.7
	100 year	1.6	0.53	78.12	0.35	25.6

The peak flows at these crossings are low and slow, and therefore it is expected that any concerns relating to serviceability and vulnerability of the road network will likely be associated with drainage, rather than damage from flooding.

It is recommended that nominal culverts of minimum 450mm diameter be installed at these crossings in order to convey surface water flows back to Munglinup River and direct local drainage away from the road to prevent road damage, bogging of heavy vehicles and adverse environmental impacts. Given the velocities and duration of peak flows during the 1-in-100 year ARI event, no sustained sediment transport of significant quantity is postulated to be transferred to the receiving waters at these crossings.

6.5.3 EASTERN ACCESS ROAD

The proposed eastern mine access road is located predominantly within the mining reserve E74/565 and will connect to the project (mining) area with Clayhole Road (see Figure 2). The preferred alignment is approximately 5.8 km long and was selected from three options that were assessed of as part of the Stage 1 study presented in Appendix G (Rockwater, 2018c).

The access road will cross over the main channel of Clayhole Creek at CC Crossing 1 and a small tributary at CC Crossing 2 (Figure 10).

Cross-sections at each road crossing were extracted from the HEC-RAS model to determine design flood levels and velocities, the results are provided in Table 21. Text-Figure 11 shows the conceptual cross-section at CC Crossing 1. Figure 10 shows the predicted extent of flooding for the 100-year ARI event along this section of Clayhole Creek extracted from the HEC-RAS hydraulic model.

The overall objective for the road crossings is to provide surface water management infrastructure for conveyance of surface water flows under the roads with no infrastructure damage and minimal disruption to the hydrologic regime of Clayhole Creek.

6.5.3.1 Crossing 1

The analyses indicate that in a 1-in-100 year ARI flood, the peak levels at the crossing from the Clayhole Creek Main catchment would be at about 91.94 m AHD with a width of about 29 m, and the level would be around 0.64 m higher in a PMF (Text-Figure 11).

The maximum depth of the 1-in-100 year flood would be about 2.04 m and the maximum velocity in the order of 1.9 m/s (Table 21).

Text-Figure 11: CC Crossing 1 natural flood levels.

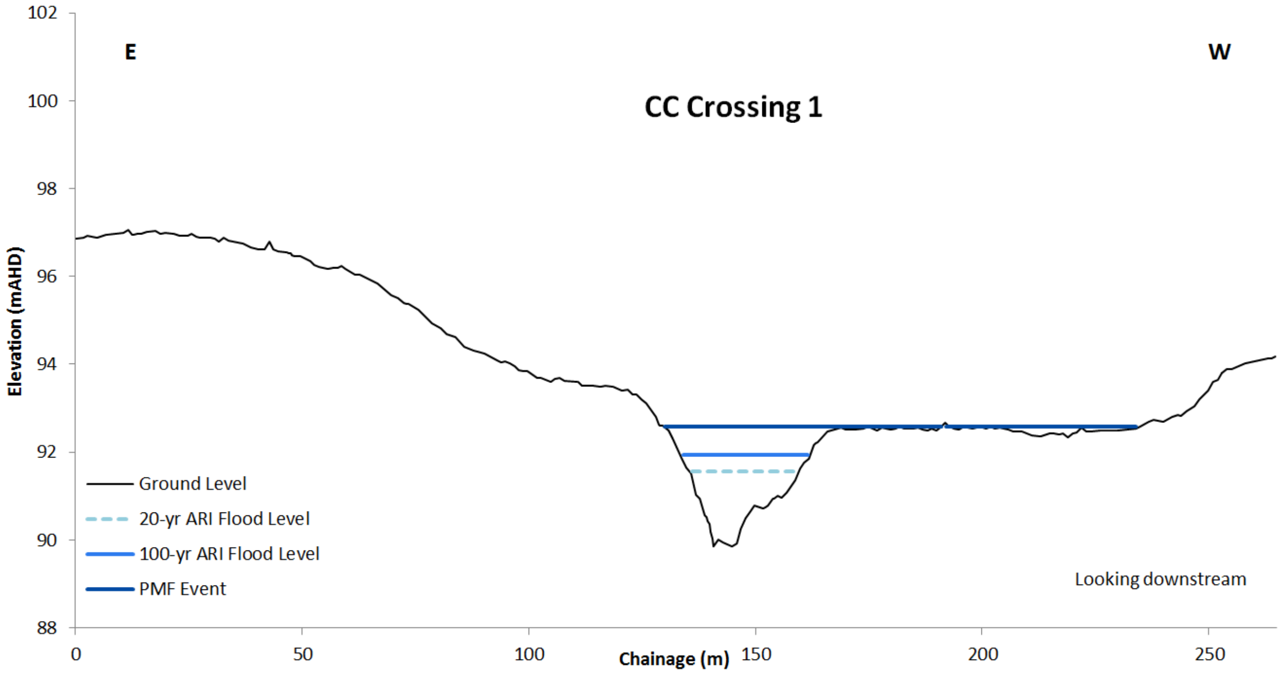


Table 21: Clayhole Creek Crossing 1* - flood summary

Flood Analysis	Q	V	Elevation	Max Depth	Extent
	(m^3/s)	(m/s)	(m AHD)	(m)	(m)
5 year	14	1.05	91.16	1.26	20.89
10 year	23	1.25	91.39	1.49	22.88
20 year	33	1.47	91.57	1.67	24.21
50 year	47	1.7	91.77	1.87	26.68
100 year	61	1.88	91.94	2.04	28.76
PMF	136	2.55	92.58	2.68	103.19

** Catchment CC Main*

It is assumed that the proposed road is an unformed un-sheeted road following the natural topographic contours as provided. To remain serviceable, the critical depth of the flood flow above the floodway should be no greater than 200 mm for light vehicles and 500 mm for heavy vehicles. An un-modified crossing at this location would be closed for both light and heavy vehicles in every flood event.

A floodway culvert system will be required in order to keep the road passable during flood events and to facilitate drainage, prevent ponding and maintain flow peaks in Clayhole Creek downstream consistent with pre-development flows.

6.5.3.2 Recommended Floodway Design

It is recommended that nominal concrete or corrugated steel culverts be installed to drain the annual minor flows (up to the 1-in-5 year ARI) in order to ensure no bogging at the road embankment and a raised floodway be constructed to pass the rare flood events. The crossing will be overtopped, but still serviceable to traffic for events greater than the 1-in-5 year ARI.

The culverts should be at a minimum of 600mm diameter to avoid obstruction from sediment transportation. The number, size and locations of the culverts should be decided on site and placed at the lowest possible level. Also, a minimum of 0.5 m cover above the culverts is required in order to prevent the roadway from falling due to vertical tyre loading of heavy vehicles. A typical long-section of a floodway is presented in Text-Figure 7 (Section 6.5.1).

Considering the serviceability requirements for both light and heavy vehicles, the length of the floodway permitting the road to be passable in case of peak flows were calculated using the broad crested weir capacity equation and are shown in Table 22. Note that in the calculations below, the discharge through the culverts is considered nominal and was ignored.

Table 22: Required floodway length for the road to be serviceable in major flood events

		Length of floodway for serviceability (m)	
Flood Event	**Q (m^3/s)**	**Light vehicles (i.e. depth of flow over road = 200mm)**	**Heavy vehicles (i.e. depth of flow over road = 500mm)**
1-in-5 yr	14	51	13
1-in-10 yr	23	84	21
1-in-20 yr	33	120	30
1-in-50 yr	47	170	43
1-in-100 yr	61	218	55

Main Roads Western Australia (MRWA) recommends serviceability for events up to the 1-in-20 year for rural minor roads or the 1-in-50 year event for rural main roads. A 120 m length floodway would allow the road to remain serviceable in the 1-in-50-year flood for both light vehicles and for the all flood events for heavy vehicles.

Although the predicted velocities are relatively low, the road is likely to be vulnerable to scouring damage in rare flood events. It is recommended that the protection on the downstream shoulder and batter slope be graded rocks with a maximum diameter of 200-300 mm. The risk of damage to the downstream shoulder can be reduced by rounding the shoulder as much as possible, to avoid the generation of negative pressures at the change of flow direction.

For information purposes, a typical floodway protection design, as recommended by MRWA for low velocity floods, is presented in Appendix F.

6.5.3.3 Crossing 2

At Crossing 2, the 1-in-100 year ARI and PMF peak flows are 3 m^3/s and 5 m^3/s, respectively. Based on the hydraulic model results, the 1-in-100-year flow is expected to be in the order of 0.45 m deep and 27 m wide (Table 23 and Text-Figure 12).

Text-Figure 12: CC Crossing 2 natural flood levels.

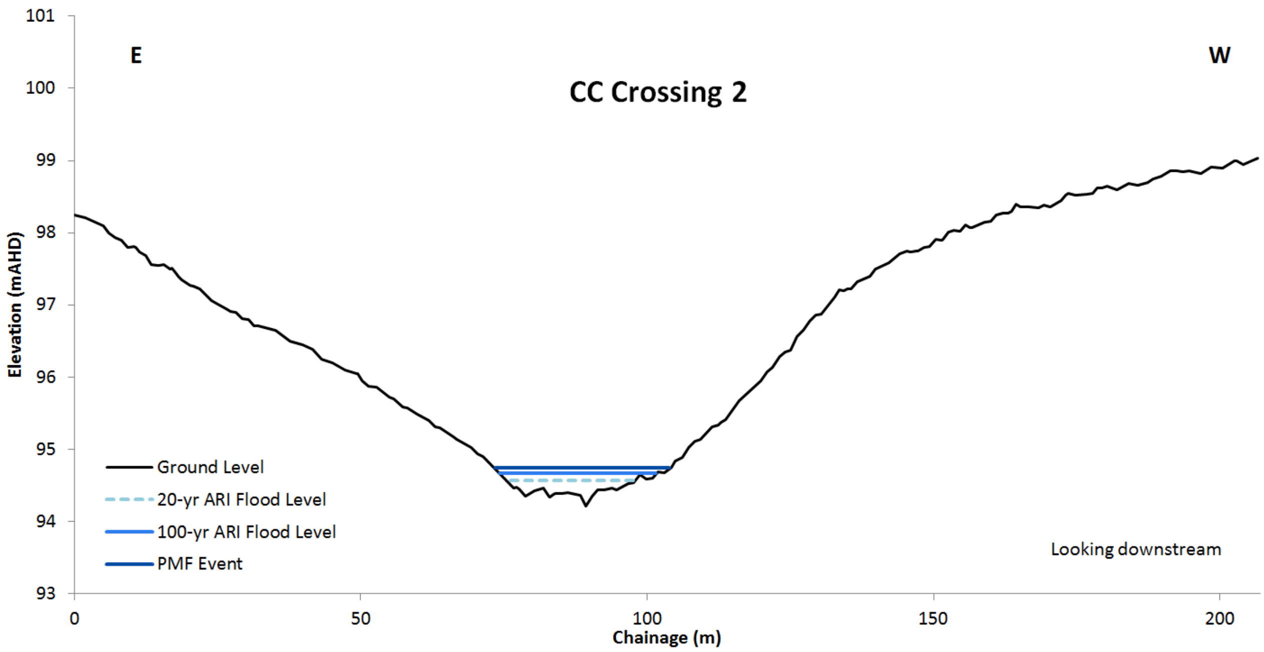


Table 23: Clayhole Creek Crossing 2* - flood summary

Flood Analysis	Q	V	Elevation	Depth	Extent
	(m^3/s)	(m/s)	(m AHD)	(m)	(m)
5 year	0.9	0.35	94.53	0.32	21.49
10 year	1.1	0.38	94.54	0.33	22.14
20 year	1.5	0.42	94.57	0.36	22.75
50 year	2.1	0.46	94.61	0.40	25.28
100 year	2.6	0.52	94.66	0.45	27.35
PMF	5.4	0.62	94.74	0.53	30.69

** Catchment CC Trib*

An unmodified crossing at this location would be closed to light vehicles in every flood event but open to heavy vehicles for events up to and including the 1-in-100 year ARI event.

As the channel at this crossing is relatively well defined, it is recommended that 3 x 600 mm pipe culverts are installed at the lowest possible level to drain flows of up to 2.6 m^3/s. This will provide the crossing with serviceability up to and including the 1 in 100 year ARI event. Culverts should be installed with rock protection at the downstream end to dissipate the increased velocities that arise from large flood events flowing through culverts, limiting erosion impacts downstream of the culverts.

7 POTENTIAL IMPACTS ON SURFACE WATER QUALITY

Land disturbances associated with mining and operations at the mine site have the potential to adversely affect the quality of surface runoff into the downstream receiving waters and environment through increased sediment loads, unless measures are taken to prevent these impacts. In addition, runoff from active mining areas may have increased concentration of salts and other pollutants compared to natural runoff.

This section presents comments and recommendations relating to environmental issues to be considered and addressed for mining approval purposes and to comply with the EPA (2018) Environmental Factor Guideline (Inland Waters).

The project will ensure no adverse impacts on receiving waters by implementing surface water management measures pre- and post-closure which will include:

- Sediment management measures downstream of all areas of ground disturbance.
- Perimeter bunds to prevent inadvertent access to the pits, protect against flood flows (locally) and to prevent erosion of storage areas;
- Suitable floodways, diversion drains and culverts to transfer flow past operation areas and across roads and return to its natural flow path.
- Monitoring of water quality to show management measures are effective.
- Storage of potentially hazardous materials in bunded areas.

Further details of these water quality control measures are outlined below.

7.1 CONSTRUCTION MANAGEMENT

During construction an increase in sediment runoff and scour may occur as a result of ground disturbance and vegetation removal. Sediment-laden runoff should be diverted to downstream sediment ponds. The purpose of the sediment pond is to capture and trap sediment-laden runoff to allow for the settling of sediments, before the runoff is allowed to enter the receiving environment, reducing the risk of sediment concentrations in excess of natural conditions. During operation, sediment ponds would be maintained. Following closure, however, sediment ponds would fill over time and eventually become ineffective, with the intention that exposed slopes would have been rehabilitated and vegetation established while the sediment ponds are still in used.

Residence times of the sediment ponds should be designed to allow for sands and coarse silts to be captured and to settle out, thereby minimising the potential for increased sediment runoff. Larger magnitude events will not be contained within sediment ponds. In a naturally occurring scenario, sediment loads during large events are high, so the impact of releasing water from the sediment ponds during these events should be minimal on a regional scale.

7.2 EROSION AND SEDIMENT CONTROL

Flows in the main channel of the Munglinup River will be unaffected by the proposed mining activities and so remedial measures associated with sediment transport and scour within the river channel are not warranted.

As flows are reduced as a result of mining infrastructure, the runoff from local creeks (A to D) are unlikely to cause adverse conditions such as sediment transport and scouring, beyond what occurs naturally in pre-mining conditions. However, there is potential for increased sediment load due to increased velocities associated with drainage infrastructure at the proposed road crossing locations. All crossings were examined with regard to sediment transport issues considering both suspended sediments and bed load sediments. All drainage infrastructure such as culverts and floodways will be designed in accordance with industry standard methodologies, which involve the use of rip-rap protection (graded rocks) downstream of the culverts to mitigate any concerns associated with erosion and sediment transport where required. At the detailed design stage, should sediment traps be required at any of the proposed crossing they will be located in an appropriate location downstream of the crossing.

As discussed in Section 6.4.1, a section of Creek C is proposed to be realigned and diverted at the south-eastern boundary of Halberts Main Pit. The natural flow of the PMF event has a peak flow of 4.4 m^3/s and velocity is in the order of 1.1 m/s. In order to prevent any erosion and sediment transport, rip-rap (graded rock) protection and a scour control layer is recommended for the batter slopes of the drain to prevent bank erosion, bed scour, or sedimentation.

The flows within Creek D will be greatly reduced, as discussed in Section 6.2, as much of the catchment will be filled by the TSF, and so there will be a lower potential for erosion than for the pre-mining case. In order to prevent any sediment from the TSF walls from flowing into the natural creek, it is recommended that a suitably configured perimeter bund be constructed at the base of the TSF to retain runoff which could then be pumped back into the TSF or allowed to evaporate. Alternatively, drainage can be directed to a collection pond from where runoff is pumped back to the TSF or a process water pond. Post-mining, the TSF walls should be stabilised if necessary, so that there is no erosion.

Due to the small size of the project and its associated surface water catchments in respect to the greater Munglinup River catchment (as described in Section 6.2, Table 12), any streamflow leaving the project area will be rapidly diluted by streamflow from the greater Munglinup River catchment. Consequently, any impacts on water quality parameters such as sediment load and salinity can be effectively ameliorated by dilution.

7.3 POTENTIALLY HAZARDOUS MATERIALS

All potential contaminants such as hydrocarbons will be stored with a surrounding bund wall that has a minimum volume identical to the storage tank itself or within a self-bunded storage tank. Any maintenance workshops will have a sediment pond constructed to prevent sediments or contaminants from reaching Munglinup River at the outlet of the creek. Spill management procedures should also be in place. Post mining, any sources of contamination in these areas will have to have been removed.

7.4 SURFACE WATER MONITORING PROGRAMME

A programme of water quality monitoring will be required to demonstrate that mining activities have no impact on surface water quality downstream of the mine. Water samples should be collected at a minimum of two sites along the Munglinup River, one upstream and one downstream of the proposed mining area (Sites MRU3 and MRD5, Figure 11) and analysed for a comprehensive suite of water quality parameters to compare with pre-mining results (Table 6). In addition, water samples should be taken at an appropriate location both upstream and downstream of CC Crossing 1 along Clayhole Creek. Proposed water sampling locations are summarised in Table 24 and shown on Figure 11. Samples should be taken quarterly, or when the river is flowing.

Table 24: Summary of proposed surface water monitoring sites

Site Name	River	Frequency
MRU3	Upstream Munglinup	Quarterly
MRD5	Downstream Munglinup	Quarterly
CC_S1	Upstream Clayhole Creek	Quarterly
CC_S2	Downstream Clayhole Creek	Quarterly

Installation of two streamflow gauges to record flow upstream and downstream of the proposed mine activity area will allow for an assessment of the impact to the flows of Munglinup River. In addition, recording peak flood flows during operation would provide potential for improvements to be made in flood estimation methods over the life of the project. The streamflow gauges should be installed on suitable sections of Munglinup River; proposed locations are shown in Figure 11.

7.5 MINE CLOSURE

To comply with the Department of Mines, Industry Regulation and Safety (DMIRS) and Environmental Protection Authority's (EPA) guideline for mine closure the following are required:

- Post mine operation abandonment bunds are required around all pits and are to be constructed to the final configuration of all the pits.
- Perimeter bunds are to be constructed at the Waste Rock Landform and TSF to prevent erosion and to contain runoff, unless the walls of these are stabilised on completion of mining and not subject to erosion. The Stockpile and ROM should be removed at the end of mining and the ground surface treated to prevent erosion.
- The detail, design and configuration of any bunds needed will be determined at the detailed design stage when all pits, infrastructure and road designs are confirmed. Perimeter bunds are to be designed for safety requirements and will be in accordance with DMIRS regulatory specifications (DIR, 1997).
- Based on this assessment, these bunds will not be required to protect against flood water and are expected to be nominal in size, typically 1–2 m in height.

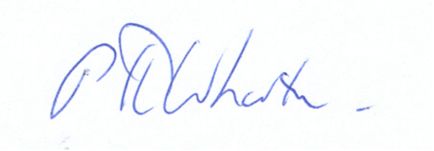
As the proposed conceptual diversion drain of Creek C is to be designed to maintain the flow regime of the natural creek, no additional adjustments are needed for mine closure.

8 CONCLUSIONS AND RECOMMENDATIONS

The following are concluding comments and recommendations related to surface water management at the Munglinup Graphite Project for mining approval and environmental requirements.

- All proposed mine infrastructure falls outside the 100-year ARI flood extent of the main Munglinup River waterway. The project is therefore not expected to have any adverse impacts on the flood levels or flood behaviour along Munglinup River channel.
- The presence of mine pits and the TSF will reduce flood flows in the tributary drainages that pass through the mine-site, and in theory, reduce peak flood flows in Munglinup River. However, the local catchments that cover the project area (Catchments M3(A) to M3(G)) only account for 3.6% of the greater Munglinup River catchment area and flows.
- In general, flooding from the main Munglinup River and local creeks will not adversely impact the pits, and therefore no flood protection measures are warranted. The exception is the flow path of Creek C, which will be obstructed by Halberts Main Pit. The recommended remedial measure of a diversion drain is described in Section 6.4.1.
- The proposed eastern mine access road is located east of the planned pits and infrastructure. For surface water management purposes, two moderately-sized crossings will be needed as presented in Section 6.5.2.
- Based on the proposed layout plan, there are five locations where the local creeks will cross the proposed haul/LV road network (MR Crossing 1 to 5). Predicted peak flows for the PMF event are low (between 3 m^3/s and 4 m^3/s) at these locations. Appropriate sized culverts should be constructed at these crossings to allow ephemeral drainage and prevent bogging due to heavy vehicle pounding
- A programme of water quality monitoring will be required to demonstrate that mining activities have no impact on surface water quality downstream of the mine.
- All recommendations presented in this report are part of a conceptual design and may require adjustments depending on site-specific conditions.

Dated: 27 October 2020 **Rockwater Pty Ltd**



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Hydrologist

P Wharton
Principal

REFERENCES

Australian Rainfall and Runoff (ARR) 2019, A Guide to Flood Estimation. The Institution of Engineers, Australia, Canberra.

BoM, 2016, http://www.bom.gov.au/water/designRainfalls/ifd/

DIR (1997), Safety bund walls around abandoned open pit mines. Department of Industry and Resources document No. ZMA048HA.

DoE, 2004, Estimation of Rare Design Rainfalls for Western Australia: Application of the CRC-FORGE Method, Department of Environment, Government of Western Australia, Surface Water Hydrology Report Series Report No. HY17.

DWER Water Information Reporting: http://wir.water.wa.gov.au/Pages/Water-Information-Reporting.aspx

DWER Water Register: http://atlases.water.wa.gov.au/ags/waterregister/

EPA, 2018, Environmental Factor Guideline, Inland Waters.

Flavell, D, 2012, "Design Flood Estimation in Western Australia", Australian Journal of Water Resources, Vol. 15, No. 1, pp. 1-20, https://dx.doi.org/10.7158/W11-865.2012.16.1.

ISPL, 2018, Munglinup Graphite Project – S38 & EPBC Referral: supporting information. Prepared for MRC Graphite Pty Ltd.

Johnson, S.L., 1998, Hydrogeology of the Ravensthorpe 1:250 000 sheet. Water & Rivers Commission hydrogeological map explanatory notes series, Report HM4.

Laurenson, E.M. Mein, R.G. and Nathan R.J., 2010, RORB Version 6 – Runoff Routing Program User Manual" Monash University Department Of Civil Engineering in conjunction with Sinclair Knight Merz Pty. Ltd. and the support of Melbourne Water Corporation.

Main Roads Western Australia, 2006, Floodway Design Guide, prepared by MRWA Waterways Section and BG&E Pty Ltd.

Rockwater, 2018a, Initial desktop hydrology assessment for proposed mining operation at Munglinup Graphite Project. Report to MRC Graphite Pty Ltd.

Rockwater, 2018b, Munglinup Graphite Project, Stage 2 hydrogeological assessment. Report to MRC Graphite Pty Ltd.

Rockwater, 2018c, Initial desktop hydrology assessment for part of mining tenement E74/565 at Munglinup Graphite Project. Report to MRC Graphite Pty Ltd.

Rockwater, 2020, Stage 3 Hydrogeological Assessment. Report to MRC Graphite Pty Ltd. June 2020.

Schoknecht, N.R., and Pathan, S., 2013, Soil groups of Western Australia: a simple guide to the main soils of Western Australia (4th ed.). Dept. of Agriculture and Food, Western Australia, Perth. Report 380.

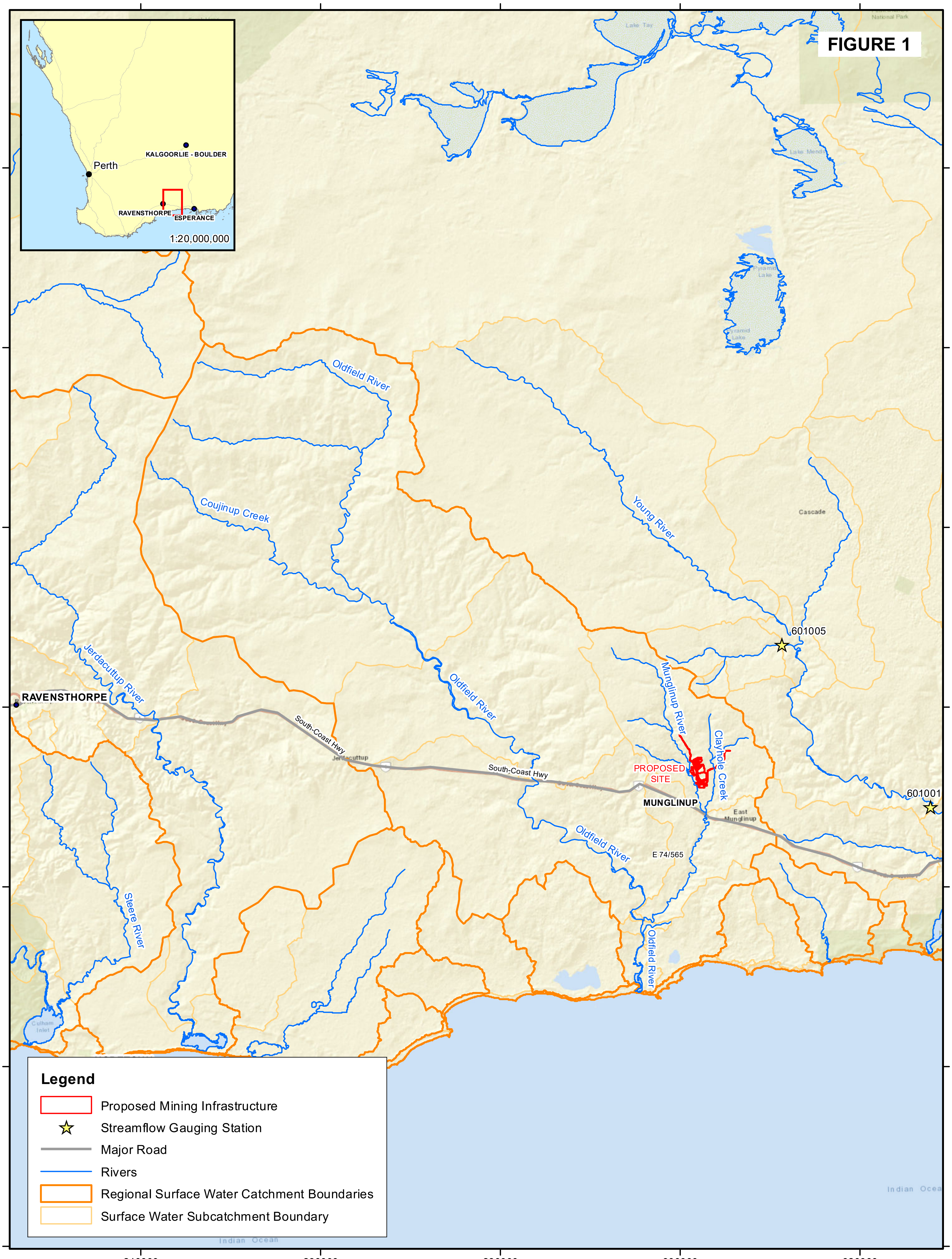
South Coast Rivercare website: http://www.rivercare.southcoastwa.org.au/

Woodman Environmental, 2019, Munglinup Graphite Project, Flora and Vegetation Assessment. Report to MRC Graphite Pty Ltd.

Woodman Environmental, 2020, Munglinup Graphite Project detailed flora and vegetation assessment. Report for MRC Graphite Pty Ltd

WRM, 2018, Munglinup Graphite Project, Munglinup River baseline water quality & aquatic fauna survey, April 2018 interim field trip report. Report to MRC Graphite Pty Ltd.

FIGURES



Data Source: ESRI World Street Map (2019)

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Grid: MGA 1994 Zone 51

CLIENT: MRC Graphite

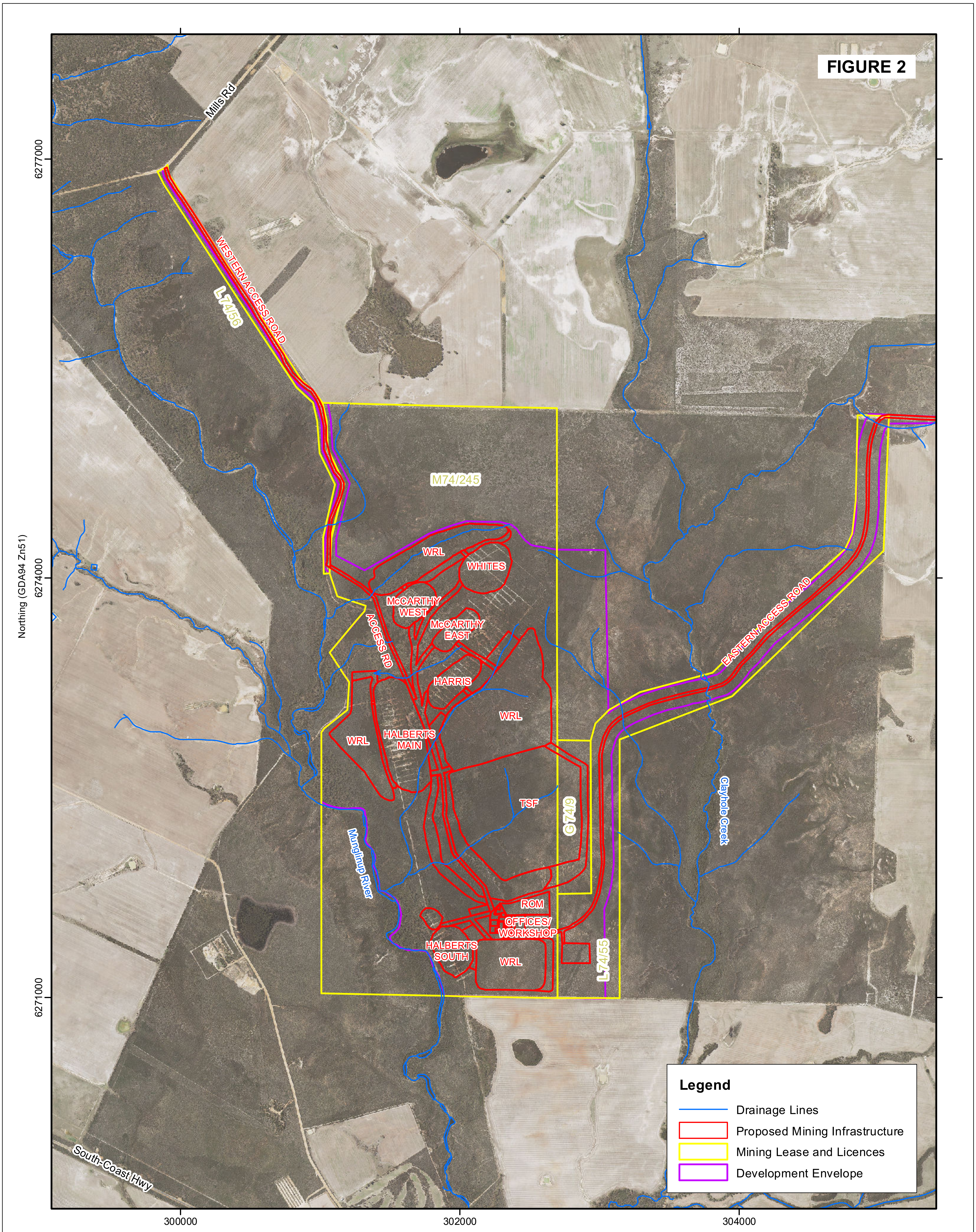
PROJECT: Munglinup Graphite Project

DATE: October 2020

DWG NO: 65-5/20/01-1

REGIONAL SETTING

Rockwater



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Grid: MGA 1994 Zone 51

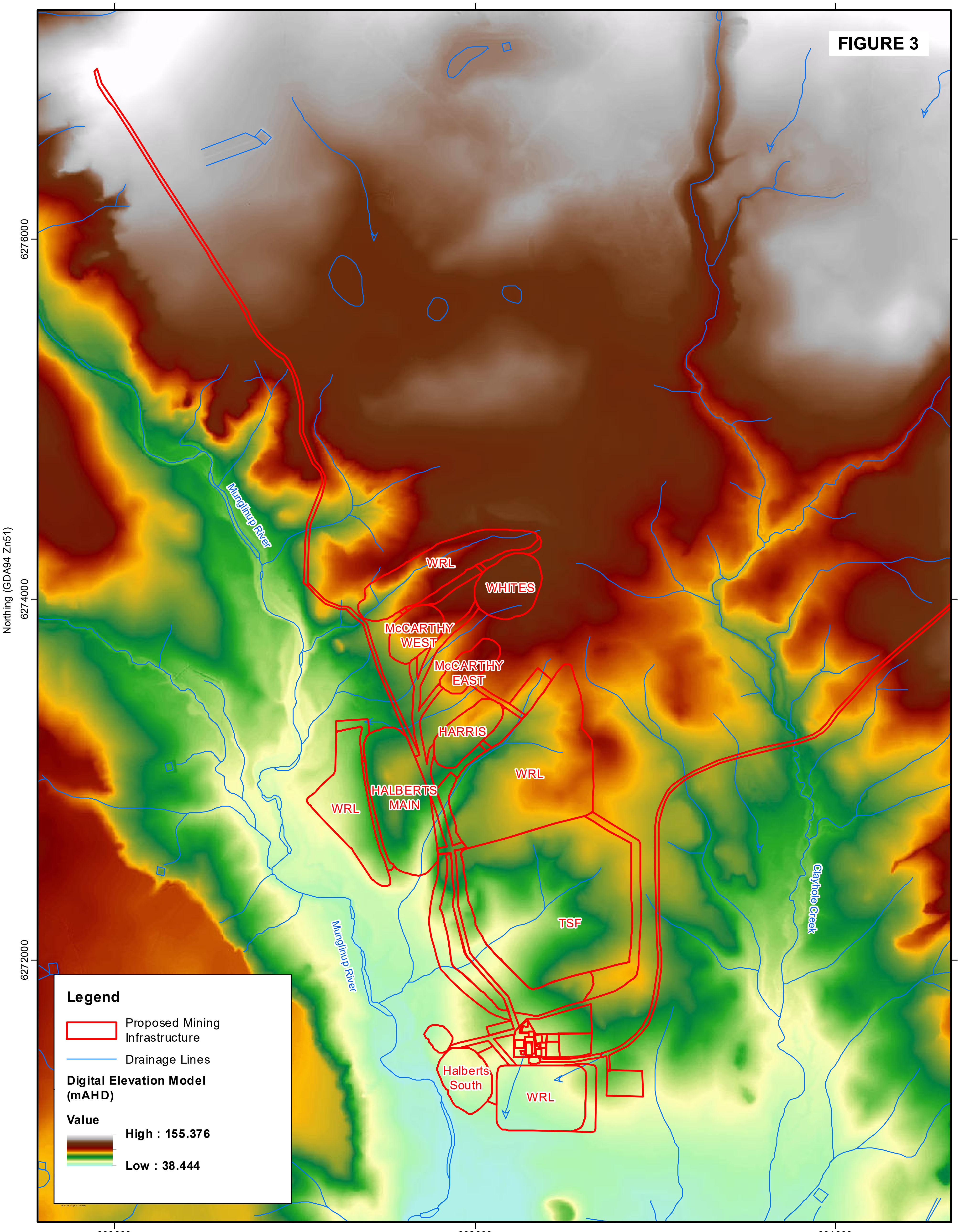
CLIENT: MRC Graphite

PROJECT: Munglinup Graphite Project

DATE: October 2020

DWG NO: 65-5/20/01-2

PROPOSED MINE INFRASTRUCTURE



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Grid: MGA 1994 Zone 51

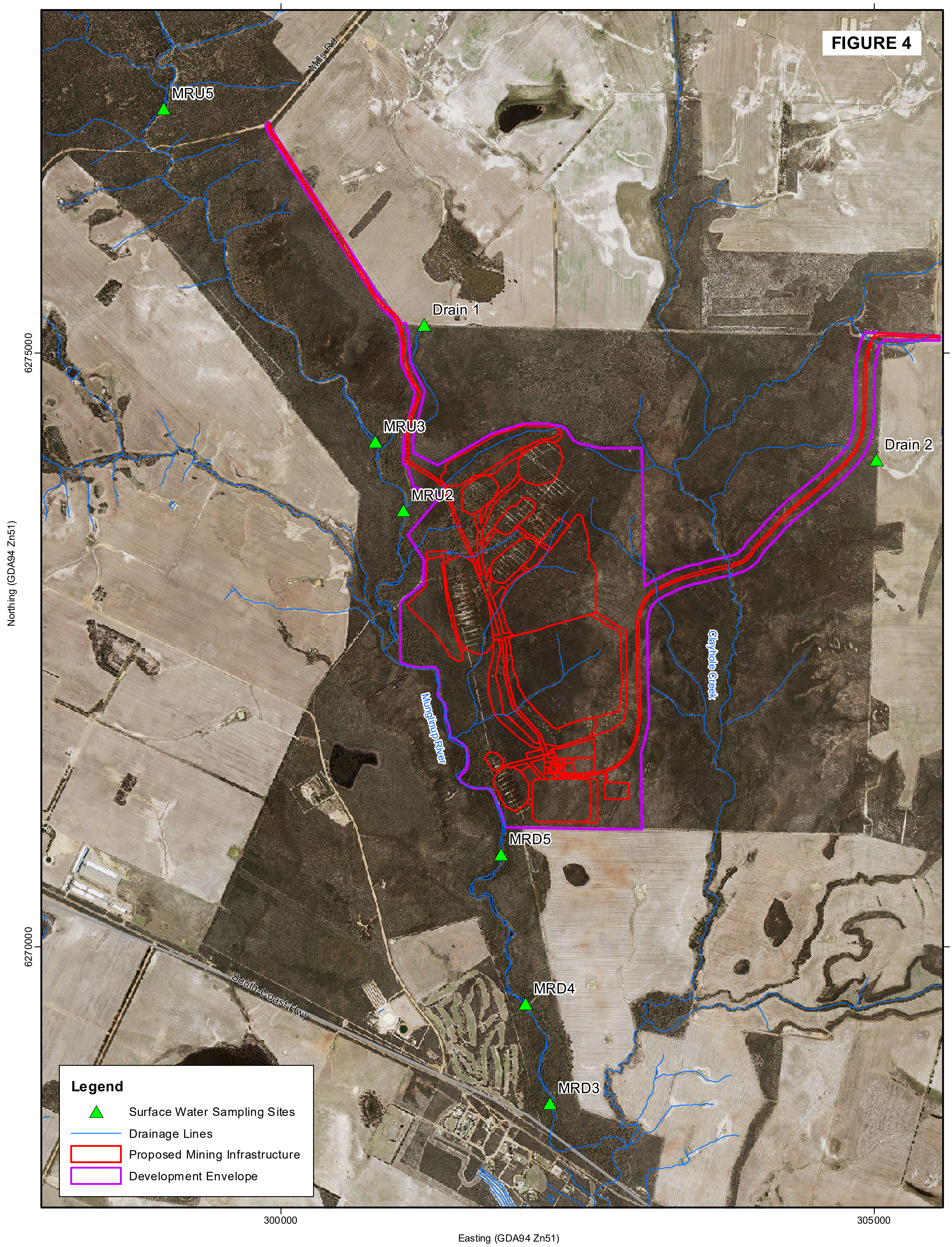
CLIENT: MRC Graphite

PROJECT: Munglinup Graphite Project

DATE: October 2020

DWG NO: 65-5/20/01-3

SITE TOPOGRAPHY



Data Source: Aerial Photography provided by MRC Graphite (04/03/2018)

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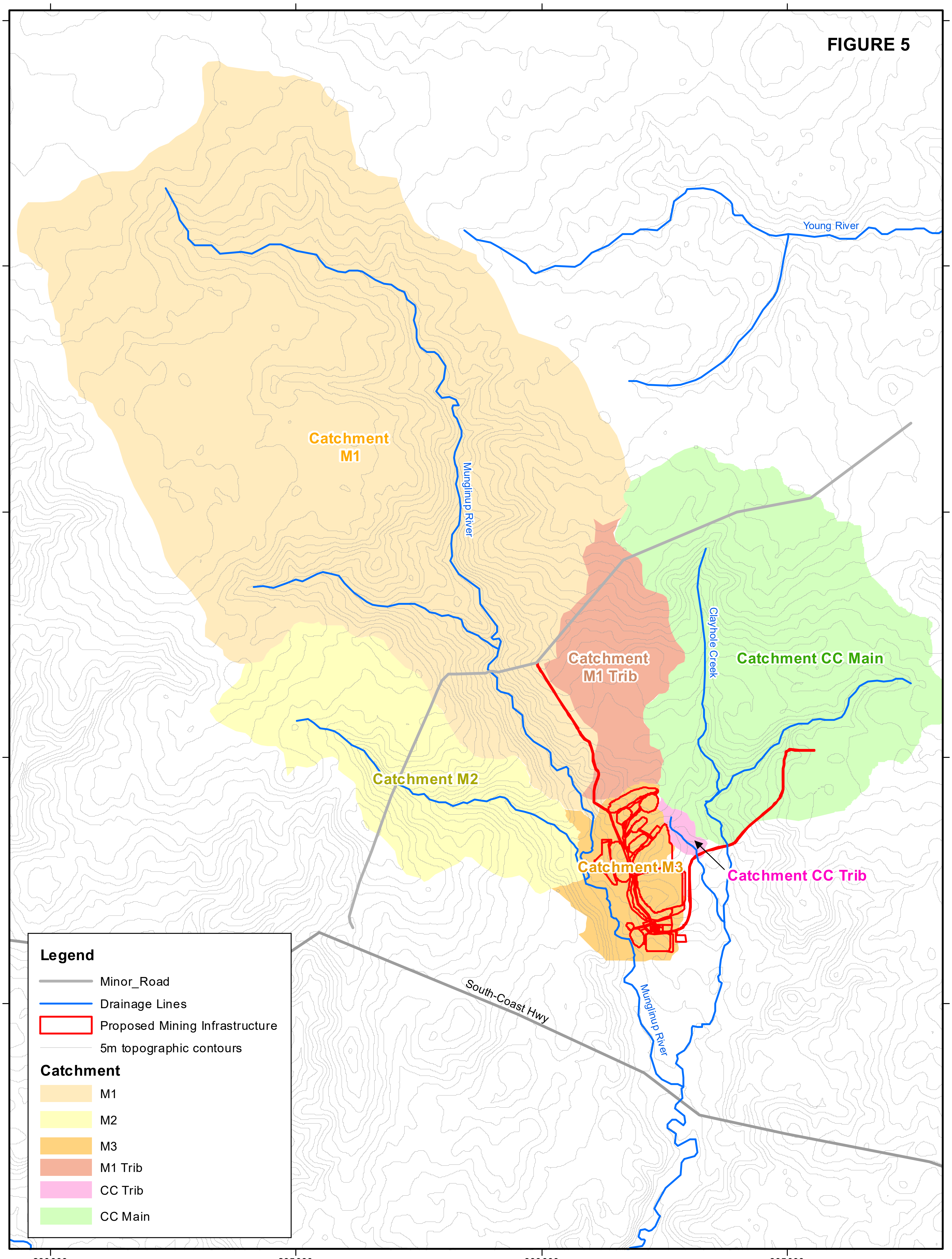
Grid: MGA 1994
Zone 51

CLIENT: MRC Graphite
PROJECT: Munglinup Graphite Project
DATE: October 2020
DWG NO: 65-5/20/01-4

SURFACE WATER SAMPLING SITES



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Grid: MGA 1994
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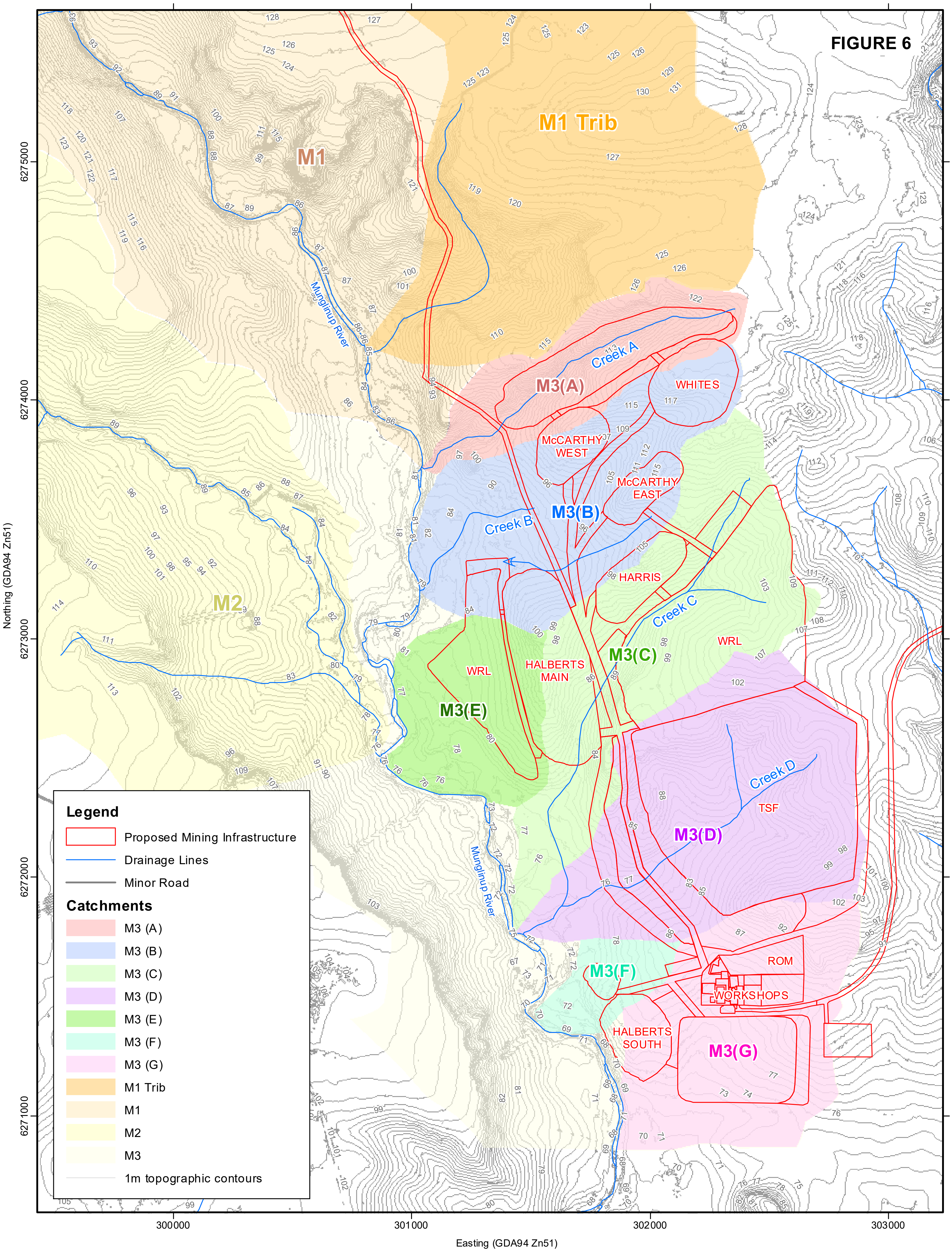
CLIENT: MRC Graphite
PROJECT: Munglinup Graphite Project
DATE: October 2020
DWG NO: 65-5/20/01-5

PROJECT CATCHMENTS



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Grid: MGA 1994
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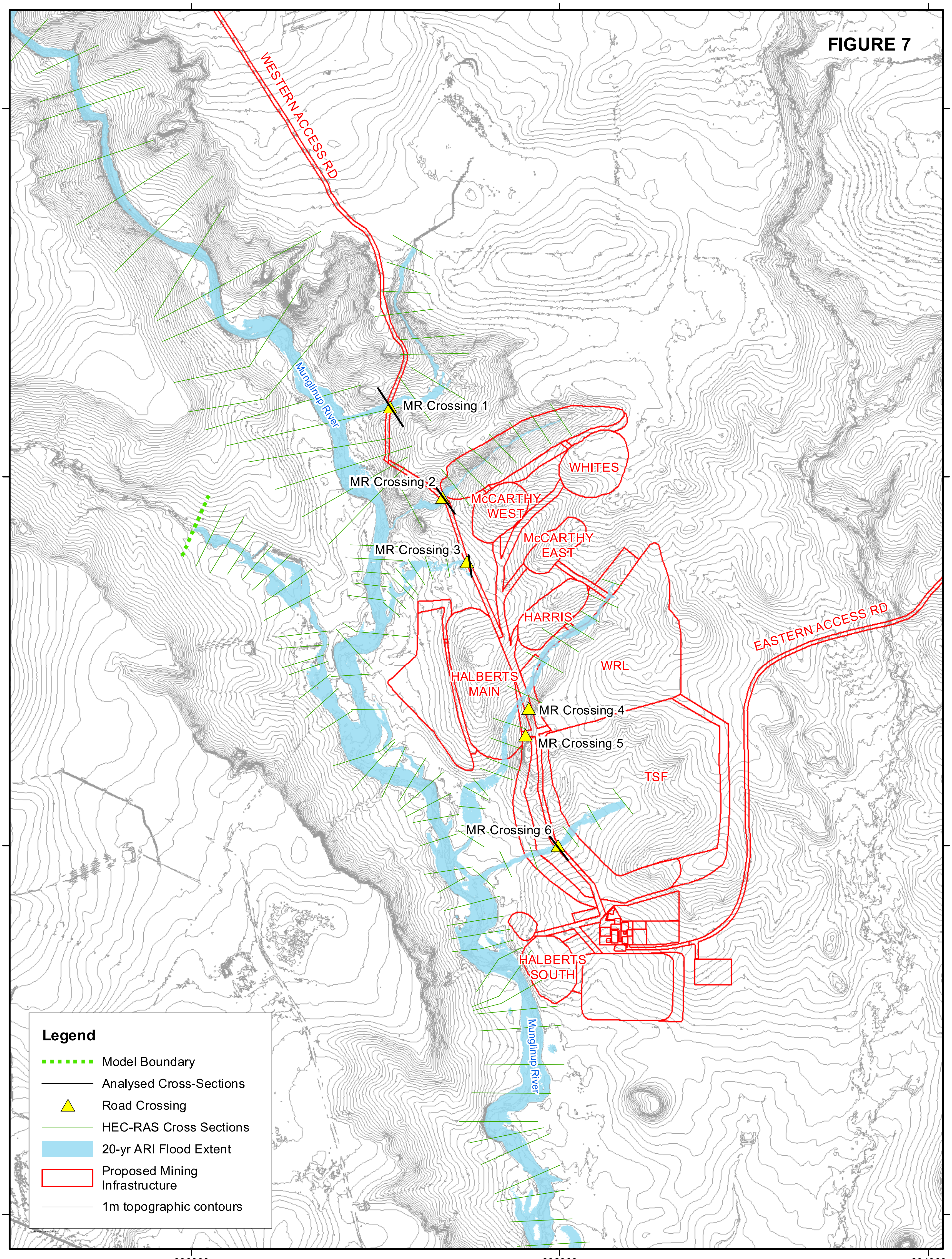
CLIENT: MRC Graphite

PROJECT: Munglinup Graphite Project

DATE: October 2020

DWG NO: 65-5/20/01-6

LOCAL CATCHMENTS



Data Source: MRC Graphite (Aug 2019)

I:/65-5/Hydrology/ArcGIS/Figure.7.mxd

1:20,000

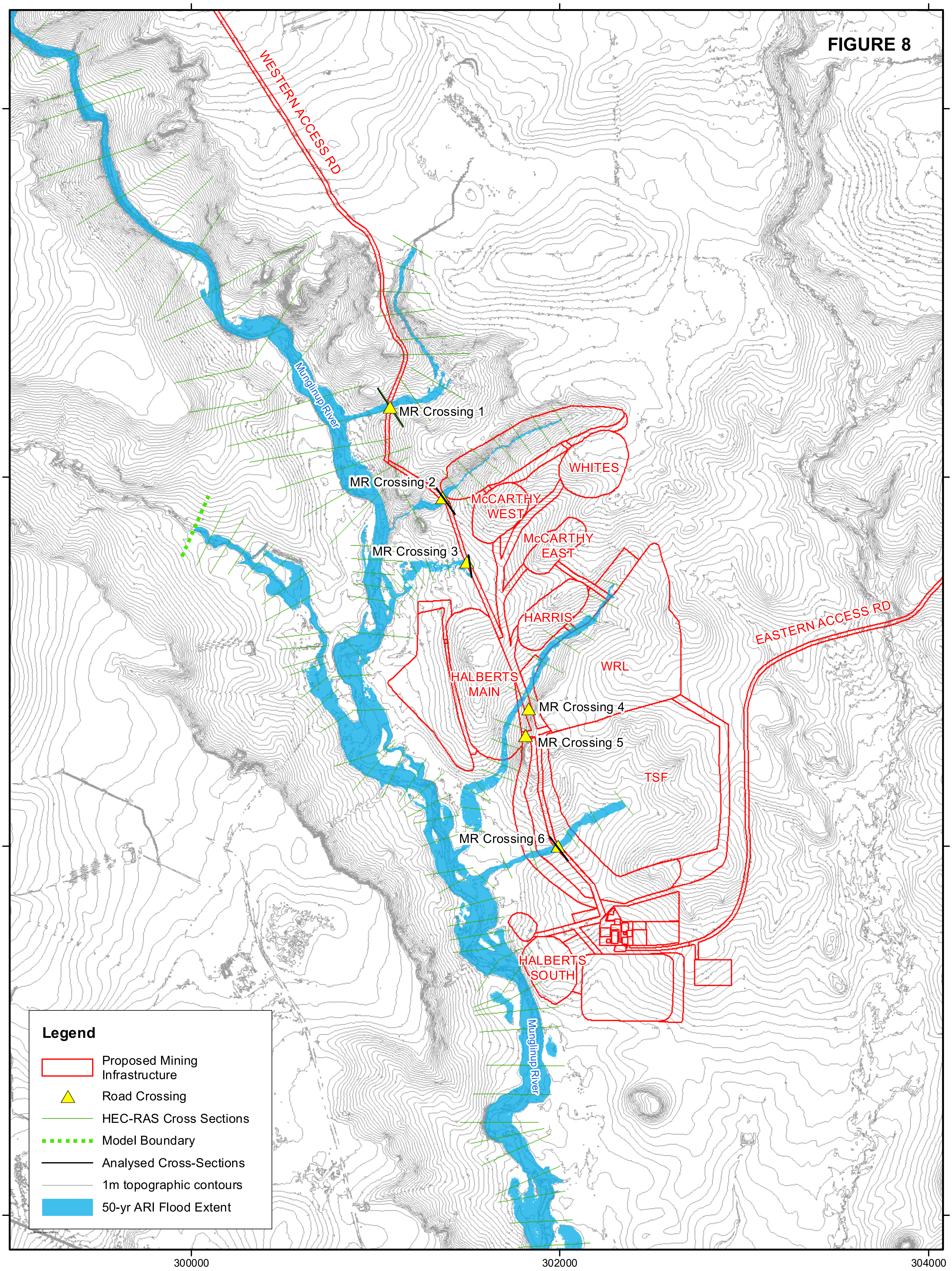
A4

Grid: MGA 1994
Zone 51

CLIENT: MRC Graphite
PROJECT: Munglinup Graphite Project
DATE: October 2020
DWG NO: 65-5/20/01-7

MUNGLINUP RIVER 20-YEAR ARI FLOOD EXTENT
(Pre-Mining)

Rockwater



Data Source: MRC Graphite (Aug, 2019)

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1:20,000

A4

N

Grid: MGA 1994 Zone 51

CLIENT: MRC Graphite

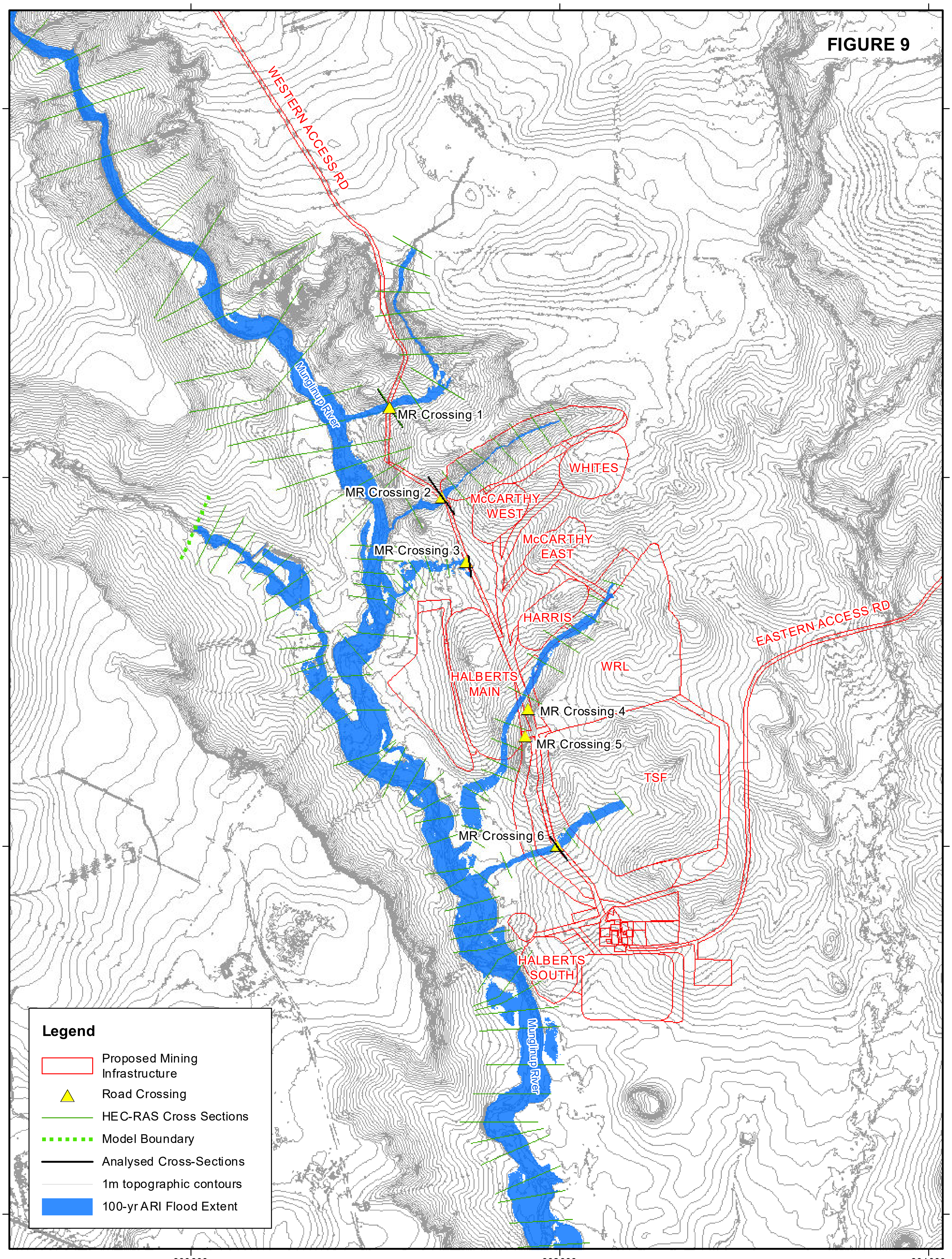
PROJECT: Munglinup Graphite Project

DATE: October 2020

DWG NO: 65-5/20/01-8

MUNGLINUP RIVER 50-YEAR ARI FLOOD EXTENT (Pre-Mining)

Rockwater



Data Source: MRC Graphite (Aug, 2019)

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1:20,000

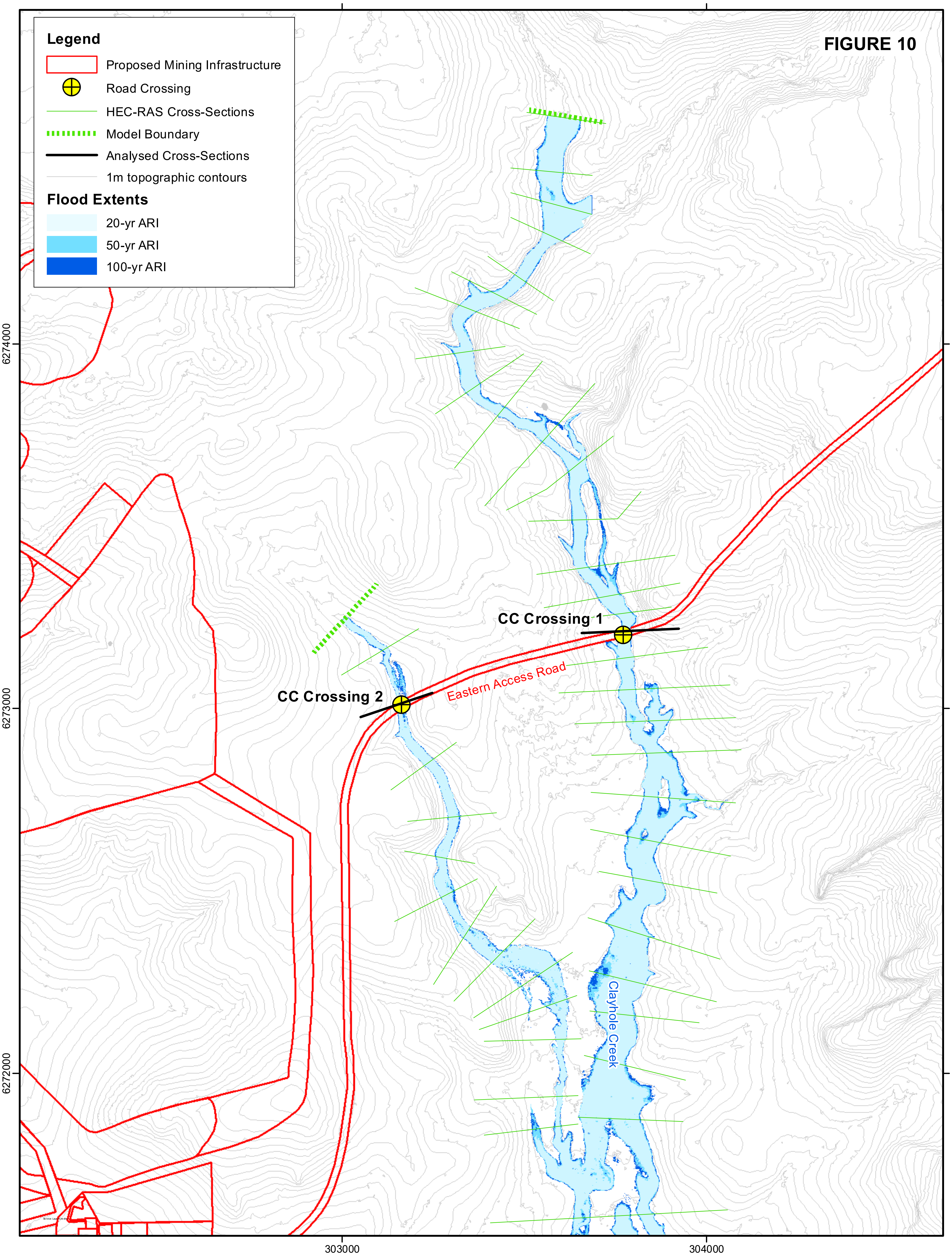
A4

N

Grid: MGA 1994
Zone 51

CLIENT: MRC Graphite
PROJECT: Munglinup Graphite Project
DATE: October 2020
DWG NO: 65-5/20/01-9

MUNGLINUP RIVER 100-YEAR ARI FLOOD EXTENT
(Pre-Mining)



Data Source: MRC Graphic (August, 2019)

I:/65-5/Hydrology/ArcGIS/Figure.10.mxd

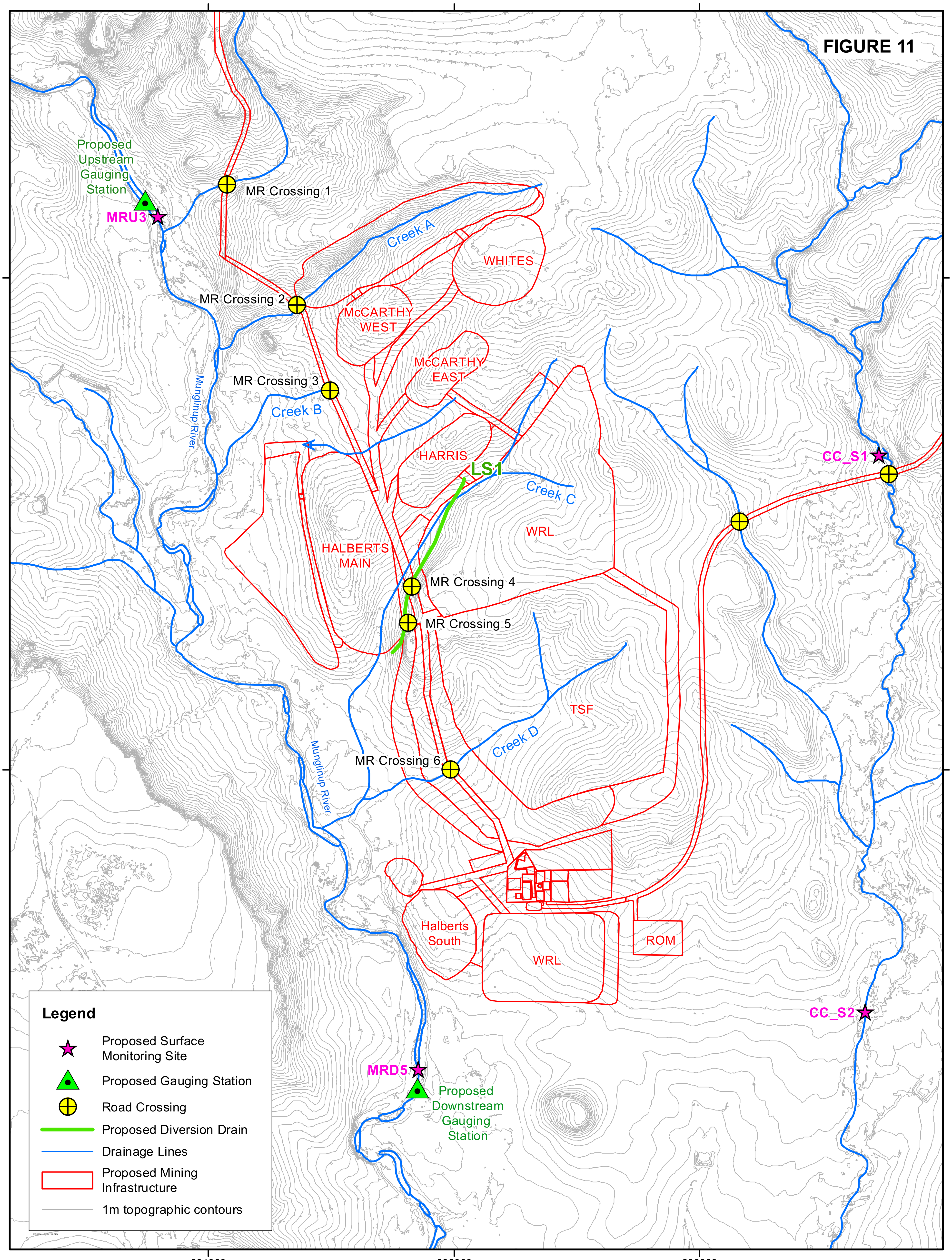
1:10,000
A4

N

Grid: MGA 1994
Zone 51

CLIENT: MRC Graphite
PROJECT: Munglinup Graphite Project
DATE: October 2020
DWG NO: 65-5/20/01-10

CLAYHOLE CREEK FLOOD EXTENT



Data Source: MRC Graphite (Aug, 2019)

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1:15,000

A4

N

Grid: MGA 1994 Zone 51

CLIENT: MRC Graphite

PROJECT: Munglinup Graphite Project

DATE: October 2020

DWG NO: 65-5/20/01-11

PROPOSED PROTECTION MEASURES AND MONITORING SITES

Rockwater

APPENDIX A

SURFACE WATER ANALYSES

CERTIFICATE OF ANALYSIS

Work Order	: **EP1812737**	Page	: 1 of 4
Client	: **ROCKWATER PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: STEVE BOLTON	Contact	: Rhiannon Steere
Address	: 1ST FLOOR, 76 JERSEY ST WEMBLEY WA, AUSTRALIA 6014	Address	: 26 Rigali Way Wangara WA Australia 6065
Telephone	: +61 08 9284 0222	Telephone	: 08 9406 1306
Project	: Munglinup	Date Samples Received	: 30-Oct-2018 17:10
Order number	:	Date Analysis Commenced	: 30-Oct-2018
C-O-C number	: ----	Issue Date	: 05-Nov-2018 17:05
Sampler	: Claire Corthier		
Site	:		
Quote number	: EP/479/18		
No. of samples received	: 5		
No. of samples analysed	: 5		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Canhuang Ke	Inorganics Supervisor	Perth Inorganics, Wangara, WA
Tyrone Cole	Inorganics Preparation Supervisor	Perth Inorganics, Wangara, WA

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EG020: Metals LOR for sample #1, 3, 4 and 5 raised due to high TDS content.
- Ionic balances were calculated using: major anions - chloride, alkalinity and sulfate; and major cations - calcium, magnesium, potassium and sodium.
- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

Analytical Results

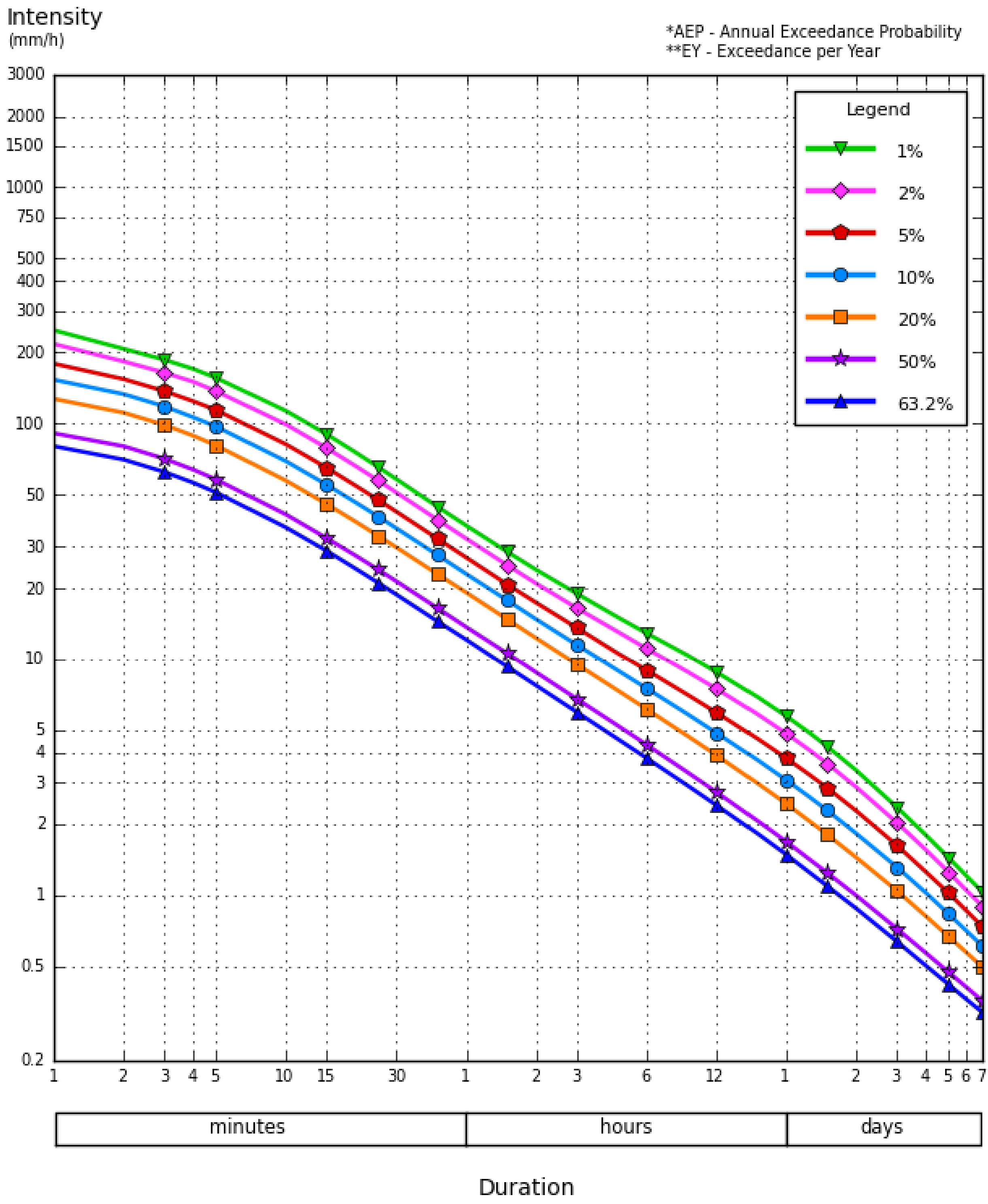
Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	HSPB01	Drain 1	D2	MWPB01	HMPB02
			Client sampling date / time	14-Oct-2018 06:40	15-Oct-2018 09:40	16-Oct-2018 13:40	17-Oct-2018 07:00	25-Oct-2018 05:00
Compound	CAS Number	LOR	Unit	EP1812737-001	EP1812737-002	EP1812737-003	EP1812737-004	EP1812737-005
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**7.41**	**8.00**	**7.32**	**7.05**	**7.44**
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**35100**	**3650**	**22200**	**27600**	**38100**
EA015: Total Dissolved Solids dried at 180 ± 5 °C								
Total Dissolved Solids @180°C	----	10	mg/L	**24600**	**2160**	**16600**	**19600**	**25900**
EA065: Total Hardness as CaCO3								
Total Hardness as CaCO3	----	1	mg/L	**4130**	**314**	**4800**	**4860**	**4290**
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**505**	**85**	**74**	**928**	**863**
Total Alkalinity as CaCO3	----	1	mg/L	**505**	**85**	**74**	**928**	**863**
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**1950**	**136**	**1580**	**1750**	**2000**
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**12700**	**1090**	**7950**	**9900**	**13700**
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**236**	**30**	**971**	**413**	**170**
Magnesium	7439-95-4	1	mg/L	**860**	**58**	**577**	**930**	**938**
Sodium	7440-23-5	1	mg/L	**7500**	**687**	**3580**	**5080**	**8240**
Potassium	7440-09-7	1	mg/L	**164**	**20**	**86**	**137**	**183**
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.05	**0.04**	<0.05	**0.67**	<0.05
Arsenic	7440-38-2	0.001	mg/L	<0.005	<0.001	<0.005	<0.005	<0.005
Cadmium	7440-43-9	0.0001	mg/L	<0.0005	<0.0001	<0.0005	**0.0010**	<0.0005
Chromium	7440-47-3	0.001	mg/L	<0.005	<0.001	<0.005	<0.005	<0.005
Lead	7439-92-1	0.001	mg/L	<0.005	<0.001	<0.005	<0.005	<0.005
Manganese	7439-96-5	0.001	mg/L	**0.989**	**0.004**	**0.118**	**10.1**	**0.435**
Selenium	7782-49-2	0.01	mg/L	<0.05	<0.01	<0.05	<0.05	<0.05
Zinc	7440-66-6	0.005	mg/L	**0.035**	<0.005	<0.025	**0.513**	**0.079**
Iron	7439-89-6	0.05	mg/L	**2.58**	**0.63**	<0.25	**5.99**	**0.21**
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	HSPB01	Drain 1	D2	MWPB01	HMPB02
			Client sampling date / time	14-Oct-2018 06:40	15-Oct-2018 09:40	16-Oct-2018 13:40	17-Oct-2018 07:00	25-Oct-2018 05:00
Compound	CAS Number	LOR	Unit	EP1812737-001	EP1812737-002	EP1812737-003	EP1812737-004	EP1812737-005
				Result	Result	Result	Result	Result
EG052G: Silica by Discrete Analyser								
Reactive Silica	----	0.05	mg/L	**70.6**	**0.22**	<0.05	**72.6**	**57.2**
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	**0.09**	**0.05**	**0.92**	**0.06**	**0.04**
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	14797-65-0	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N	14797-55-8	0.01	mg/L	<0.01	<0.01	<0.01	**0.10**	<0.01
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	<0.01	<0.01	**0.10**	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	<0.1	**0.8**	**4.5**	**0.2**	**0.4**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ Total Nitrogen as N	----	0.1	mg/L	<0.1	**0.8**	**4.5**	**0.3**	**0.4**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	**0.08**	**0.19**	**0.20**	**0.20**	**0.06**
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.01	mg/L	**0.02**	<0.01	**0.05**	**0.02**	**0.02**
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**409**	**35.3**	**259**	**334**	**445**
Total Cations	----	0.01	meq/L	**413**	**36.7**	**254**	**322**	**449**
Ionic Balance	----	0.01	%	**0.49**	**1.93**	**0.93**	**1.92**	**0.38**

APPENDIX B

IFD CURVES (BOM 2016)


Intensity
(mm/h)
*AEP - Annual Exceedance Probability
**EY - Exceedance per Year
Legend
1%
2%
5%
10%
20%
50%
63.2%
3000
2000
1500
1000
750
500
400
300
200
100
50
30
20
10
5
4
3
2
1
0.5
0.2
1 2 3 4 5 10 15 30 1 2 3 6 12 1 2 3 4 5 6 7
minutes
hours
days
Duration

APPENDIX C

RATIONAL AND INDEX FLOOD METHOD HYDROLOGIC CALCULATIONS

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **WHEATBELT**

LOCATION: **Munglinup**

CATCHMENT: **M1**

Wheatbelt Region (Loamy soil catchments 75 – 100% cleared)

Catchment	A (km^2)	L (km)	P (mm)	% Cleared (Cl)
Characteristics	109.2	19.7	533	80

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	0.034 - 20500	km^2
L =	0.492 - 440	km
Se =	0.65 – 40.3	m/km
P =	300 - 600	mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ .... **(1.1)**

$t_c = 0.76 A^{0.38}$ .... **(1.29)**

$t_c =$ 4.52 Hrs

$C_{10} = 3.46 \times 10^{-1} L^{-0.42}$ .... **(1.30)**

$C_{10} =$ 0.10

Frequency Factors (C_Y/C_{10})

	ARI (YEARS)					
	2	*5*	*10*	20	*50*	*100*
C_Y/C_{10}	0.41	0.65	1.00	1.54	2.2	*2.47*

100 year ARI extrapolated using the logarithmic trend-line

REGION: WHEATBELT

LOCATION: Munglinup

CATCHMENT: M1

RATIONAL METHOD CONTINUES:

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 4.52 hours

Use IFD curves

	ARI (YEARS) [mm/hr]					
Duration (hours)	*2*	*5*	10	20	*50*	100
4.52	5.2	7.3	8.9	10.6	13.1	15.1

Calculate peak discharge using equation (1.1)

	ARI (YEARS)					
Discharge (m^3/s)	*2*	*5*	*10*	20	*50*	100
Q	6.4	14.3	26.8	49.0	86.5	112.0

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION:	**WHEATBELT**
LOCATION:	**Munglinup**
CATCHMENT:	**M1**

INDEX FLOOD METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	0.034	-	20500	km^2
L =	0.492	-	440	km
Se =	0.65	-	83.4	m/km
P =	300	-	680	mm

$Q_5 =$ $2.77 \times 10^{-6} A^{0.52} p^{2.12}$ .... **(1.31)**

$Q_5 =$ 19.19 m^3/s

Frequency Factors (Q_Y/Q_5):

	ARI (YEARS)					
	2	*5*	*10*	20	*50*	*100*
Area km^2	0.48	1.00	1.84	3.23	6.10	6.50

100 year ARI extrapolated using the power trend-line

Therefore the peak discharge:

	ARI (years)					
Discharge (m^3/s)	*2*	*5*	*10*	20	*50*	*100*
Q	9.2	19.2	35.3	62.0	117.0	124.7

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION:	**WHEATBELT**
LOCATION:	**Munglinup**
CATCHMENT:	**M1**

SUMMARY OF RATIONAL AND INDEX METHODS:

Wheatbelt Region

Catchment M1	ARI (years) / Discharge (m^3/s)						
Method:	2	5	10	20	50	100	PMF
Rational	6	14	27	49	86	112	203
Index	9	19	35	62	117	125	226

*PMF estimated using CRC Forge Factors

REGION:	**WHEATBELT**
LOCATION:	**Munglinup**
CATCHMENT:	**M2**

Wheatbelt Region (Loamy soil catchments 75 – 100% cleared)

Catchment	A (km^2)	L (km)	P (mm)	% Cleared (Cl)
Characteristics	19.1	6.7	533	80

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	0.034 - 20500	km^2
L =	0.492 - 440	km
Se =	0.65 – 40.3	m/km
P =	300 - 600	mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ .... **(1.1)**

$t_c = 0.76 A^{0.38}$ .... **(1.29)**

$t_c =$ 2.33 Hrs

$C_{10} = 3.46 \times 10^{-1} L^{-0.42}$ .... **(1.30)**

$C_{10} =$ 0.16

Frequency Factors (C_Y/C_{10})

	ARI (YEARS)					
	2	*5*	*10*	20	*50*	*100*
C_Y/C_{10}	0.41	0.65	1.00	1.54	2.2	*2.47*

100 year ARI extrapolated using the logarithmic trend-line

REGION: **WHEATBELT**

LOCATION: **Munglinup**

CATCHMENT: **M2**

RATIONAL METHOD CONTINUES:

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 2.33 hours

Use IFD curves

	ARI (YEARS) [mm/hr]					
Duration (hours)	*2*	*5*	10	20	*50*	100
2.33	8.0	11.2	13.5	15.8	19.2	21.9

Calculate peak discharge using equation (1.1)

	ARI (YEARS)					
Discharge (m^3/s)	*2*	*5*	*10*	20	*50*	100
Q	2.7	6.0	11.2	20.1	34.9	44.7

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **WHEATBELT**

LOCATION: **Munglinup**

CATCHMENT: **M2**

INDEX FLOOD METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	0.034	-	20500	km^2
L =	0.492	-	440	km
Se =	0.65	-	83.4	m/km
P =	300	-	680	mm

$Q_5 =$ $2.77 \times 10^{-6} A^{0.52} p^{2.12}$ .... **(1.31)**

$Q_5 =$ 7.74 m^3/s

Frequency Factors (Q_Y/Q_5):

	ARI (YEARS)					
	2	*5*	*10*	20	*50*	*100*
Area km^2	0.48	1.00	1.84	3.23	6.10	6.50

100 year ARI extrapolated using the power trend-line

Therefore the peak discharge:

	ARI (years)					
Discharge (m^3/s)	*2*	*5*	*10*	20	*50*	*100*
Q	3.7	7.7	14.3	25.0	47.2	50.3

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION:	**WHEATBELT**
LOCATION:	**Munglinup**
CATCHMENT:	**M2**

SUMMARY OF RATIONAL AND INDEX METHODS:

Wheatbelt Region

Catchment M2	ARI (years) / Discharge (m^3/s)						
Method:	2	5	10	20	50	100	PMF
Rational	3	6	11	20	35	45	81
Index	4	8	14	25	47	50	91

*PMF estimated using CRC Forge Factors

REGION:	**WHEATBELT**
LOCATION:	**Munglinup**
CATCHMENT:	**M3**

Wheatbelt Region (Loamy soil catchments 75 – 100% cleared)

Catchment	A (km^2)	L (km)	P (mm)	% Cleared (Cl)
Characteristics	6.5	3.3	533	80

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A = 0.034 - 20500 km^2

L = 0.492 - 440 km

Se = 0.65 – 40.3 m/km

P = 300 - 600 mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ .... **(1.1)**

$t_c = 0.76 A^{0.38}$ .... **(1.29)**

$t_c =$ 1.55 Hrs

$C_{10} = 3.46 \times 10^{-1} L^{-0.42}$ .... **(1.30)**

$C_{10} =$ 0.21

Frequency Factors (C_Y/C_{10})

	ARI (YEARS)					
	2	*5*	*10*	20	*50*	*100*
C_Y/C_{10}	0.41	0.65	1.00	1.54	2.2	*2.47*

100 year ARI extrapolated using the logarithmic trend-line

REGION: **WHEATBELT**

LOCATION: **Munglinup**

CATCHMENT: **M3**

RATIONAL METHOD CONTINUES:

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 1.55 hours

Use IFD curves

	ARI (YEARS) [mm/hr]					
Duration (hours)	*2*	*5*	10	20	*50*	100
1.55	10.4	14.5	17.4	20.4	24.6	28.0

Calculate peak discharge using equation (1.1)

	ARI (YEARS)					
Discharge (m^3/s)	*2*	*5*	*10*	20	*50*	100
Q	1.6	3.6	6.6	12.0	20.6	26.4

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **WHEATBELT**

LOCATION: **Munglinup**

CATCHMENT: **M3**

INDEX FLOOD METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	0.034	-	20500	km^2
L =	0.492	-	440	km
Se =	0.65	-	83.4	m/km
P =	300	-	680	mm

$Q_5 = 2.77 \times 10^{-6} A^{0.52} p^{2.12}$ .... **(1.31)**

$Q_5 =$ 4.44 m^3/s

Frequency Factors (Q_Y/Q_5):

	ARI (YEARS)					
	2	*5*	*10*	20	*50*	*100*
Area km^2	0.48	1.00	1.84	3.23	6.10	6.50

100 year ARI extrapolated using the power trend-line

Therefore the peak discharge:

	ARI (years)					
Discharge (m^3/s)	*2*	*5*	*10*	20	*50*	*100*
Q	2.1	4.4	8.2	14.3	27.1	28.9

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION: **WHEATBELT**

LOCATION: **Munglinup**

CATCHMENT: **M3**

SUMMARY OF RATIONAL AND INDEX METHODS:

Wheatbelt Region

Catchment M3	ARI (years) / Discharge (m^3/s)						
Method:	2	5	10	20	50	100	PMF
Rational	2	4	7	12	21	26	48
Index	2	4	8	14	27	29	52

*PMF estimated using CRC Forge Factors

REGION: **WHEATBELT**

LOCATION: **Munglinup**

CATCHMENT: **CC Main**

Wheatbelt Region (Loamy soil catchments 75 – 100% cleared)

Catchment	A (km^2)	L (km)	P (mm)	% Cleared (Cl)
Characteristics	34.8	8.7	533	80

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	0.034 - 20500	km^2
L =	0.492 - 440	km
Se =	0.65 – 40.3	m/km
P =	300 - 600	mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ ………. **(1.1)**

$t_c = 0.76 A^{0.38}$ …………. **(1.29)**

$t_c =$ 2.93 Hrs

$C_{10} = 3.46 \times 10^{-1} L^{-0.42}$ …………. **(1.30)**

$C_{10} = 0.12$

Frequency Factors (C_Y/C_{10})

	ARI (YEARS)					
	2	*5*	*10*	20	*50*	*100*
C_Y/C_{10}	0.41	0.65	1.00	1.54	2.2	2.47

100 year ARI extrapolated using the logarithmic trend-line

REGION: WHEATBELT

LOCATION: Munglinup

CATCHMENT: CC Main

RATIONAL METHOD CONTINUES:

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 2.93 hours

Use IFD curves

	ARI (YEARS) [mm/hr]					
Duration (hours)	*2*	*5*	10	20	*50*	100
2.93	6.9	9.7	11.7	13.8	16.7	19.2

Calculate peak discharge using equation (1.1)

	ARI (YEARS)					
Discharge (m^3/s)	*2*	*5*	*10*	20	*50*	100
Q	3.3	7.2	13.0	22.3	36.8	52.8

REGION:	**WHEATBELT**
LOCATION:	**Munglinup**
CATCHMENT:	**CC Main**

INDEX FLOOD METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	0.034	-	20500	km^2
L =	0.492	-	440	km
Se =	0.65	-	83.4	m/km
P =	300	-	680	mm

$Q_5 = 2.77 \times 10^{-6} A^{0.52} p^{2.12}$ .... **(1.31)**

$Q_5 =$ 10.59 m^3/s

Frequency Factors (Q_Y/Q_5):

	ARI (YEARS)					
	2	*5*	*10*	20	*50*	*100*
Area km^2	0.48	1.00	1.84	3.23	6.10	6.50

100 year ARI extrapolated using the power trend-line

Therefore the peak discharge:

	ARI (years)					
Discharge (m^3/s)	*2*	*5*	*10*	20	*50*	*100*
Q	3.2	6.7	12.3	21.5	40.7	43.3

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION:	**WHEATBELT**
LOCATION:	**Munglinup**
CATCHMENT:	**CC Main**

SUMMARY OF RATIONAL AND INDEX METHODS:

Wheatbelt Region

Catchment CC Main	ARI (years) / Discharge (m^3/s)						
Method:	2	5	10	20	50	100	PMF
Rational	3	7	13	22	37	53	96
Index	3	7	12	22	41	43	79

*PMF estimated using CRC Forge Factors

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION:	**WHEATBELT**
LOCATION:	**Munglinup**
CATCHMENT:	**CC Trib**

Wheatbelt Region (Loamy soil catchments 75 – 100% cleared)

Catchment	A (km^2)	L (km)	P (mm)	% Cleared (Cl)
Characteristics	0.6	1.9	533	80

RATIONAL METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	0.034 - 20500	km^2
L =	0.492 - 440	km
Se =	0.65 – 40.3	m/km
P =	300 - 600	mm

$Q_Y = 0.278 C_Y . I_{tc,Y} . A$ ………. **(1.1)**

$t_c = 0.76 A^{0.38}$ …………. **(1.29)**

$t_c =$ 0.61 Hrs

$C_{10} = 3.46 \times 10^{-1} L^{-0.42}$ …………. **(1.30)**

$C_{10} =$ 0.26

Frequency Factors (C_Y/C_{10})

	ARI (YEARS)					
	2	*5*	*10*	20	*50*	*100*
C_Y/C_{10}	0.41	0.65	1.00	1.54	2.2	2.47

100 year ARI extrapolated using the logarithmic trend-line

REGION: WHEATBELT

LOCATION: Munglinup

CATCHMENT: CC Trib

RATIONAL METHOD CONTINUES:

DETERMINE AVERAGE RAINFALL INTENSITY FOR DESIGN DURATION

t_c = 0.61 hours

Use IFD curves

	ARI (YEARS) [mm/hr]					
Duration (hours)	*2*	*5*	10	20	*50*	100
0.61	18.7	26.1	31.4	36.8	44.4	50.5

Calculate peak discharge using equation (1.1)

	ARI (YEARS)					
Discharge (m^3/s)	*2*	*5*	*10*	20	*50*	100
Q	0.3	0.7	1.3	2.4	4.1	5.2

REGION: **WHEATBELT**

LOCATION: **Munglinup**

CATCHMENT: **CC Trib**

INDEX FLOOD METHOD:

Care needs to be taken when catchment characteristics fall outside the following:

A =	0.034	-	20500	km^2
L =	0.492	-	440	km
Se =	0.65	-	83.4	m/km
P =	300	-	680	mm

$Q_5 = 2.77 \times 10^{-6} A^{0.52} p^{2.12}$ .... **(1.31)**

$Q_5 = 1.25\ m^3/s$

Frequency Factors (Q_Y/Q_5):

	ARI (YEARS)					
	2	*5*	*10*	20	*50*	*100*
Area km^2	0.48	1.00	1.84	3.23	6.10	6.50

100 year ARI extrapolated using the power trend-line

Therefore the peak discharge:

	ARI (years)					
Discharge (m^3/s)	*2*	*5*	*10*	20	*50*	*100*
Q	0.6	1.2	2.3	4.0	7.6	8.1

AUSTRALIAN RAINFALL AND RUNOFF VOLUME 1 & 2 (1987)
RATIONAL AND INDEX METHODS - WESTERN AUSTRALIA

REGION:	**WHEATBELT**
LOCATION:	**Munglinup**
CATCHMENT:	**CC Trib**

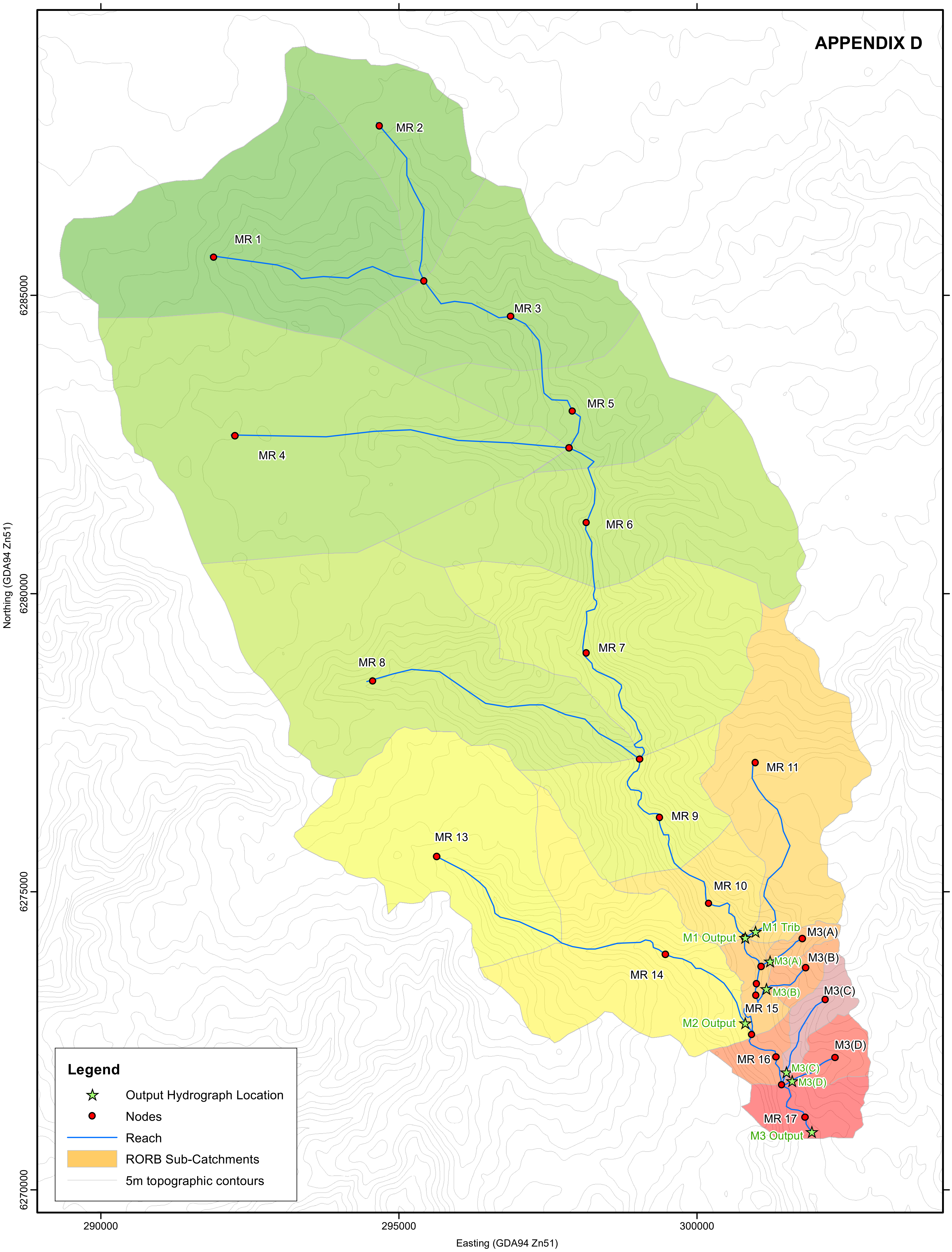
SUMMARY OF RATIONAL AND INDEX METHODS:

Wheatbelt Region

Catchment CC Trib	ARI (years) / Discharge (m³/s)						
Method:	2	5	10	20	50	100	PMF
Rational	0	1	1	2	4	5	10
Index	1	1	2	4	8	8	15

*PMF estimated using CRC Forge Factors

APPENDIX D
MUNGLINUP RIVER
RORB MODEL SETUP



Data Source: SRTM-H 1m contours (Geoscience Australia, 2011)

I:/65-5/Hydrology/ArcGIS/App.D.mxd

1:60,000

A4

N

Grid: MGA 1994
Zone 51

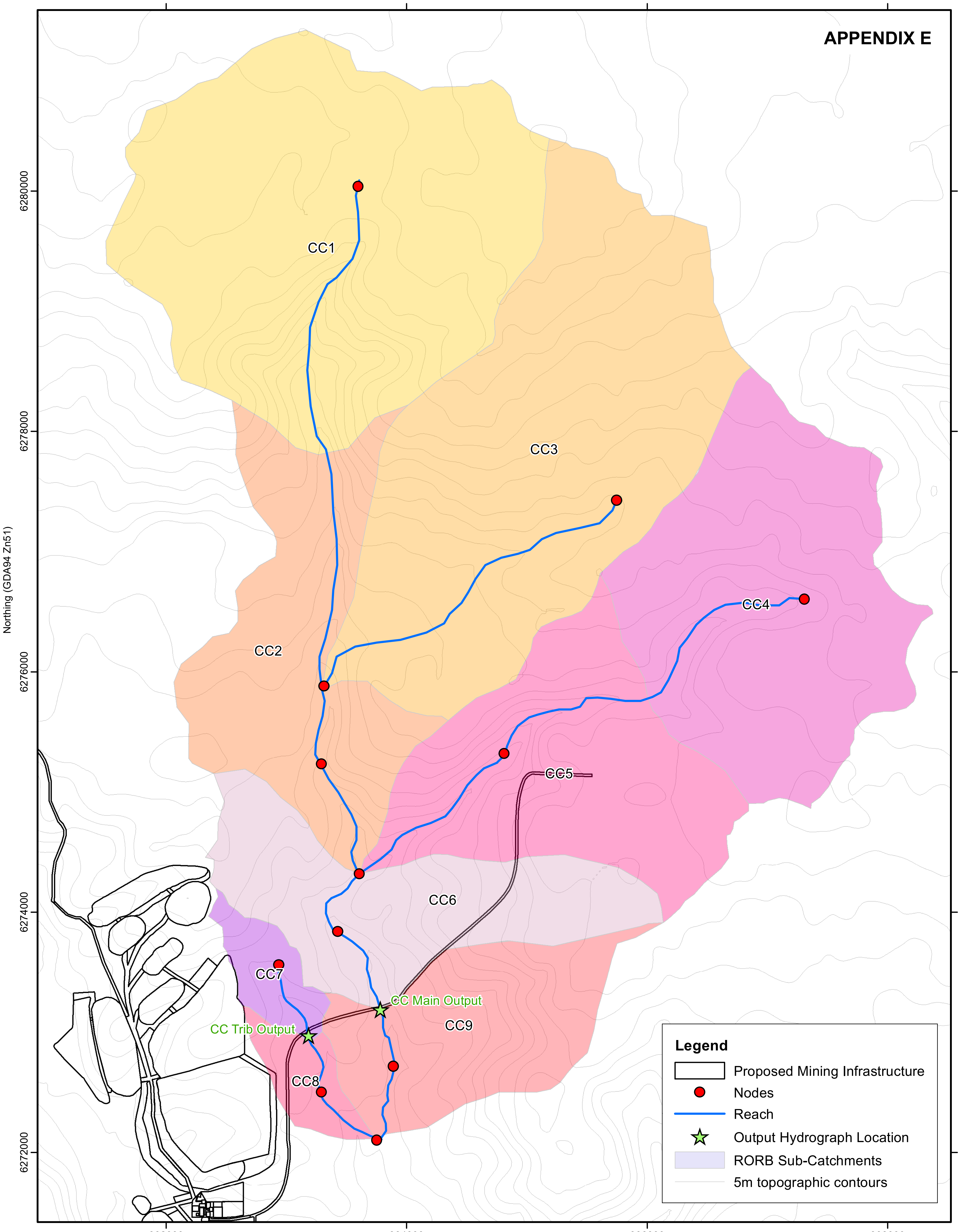
CLIENT: MRC Graphite
PROJECT: Munglinup Graphite Project
DATE: October 2020
DWG NO: 65-5/ArcGIS/20/AppD

MUNGLINUP RIVER
RORB MODEL SETUP

APPENDIX E

CLAYHOLE CREEK

RORB MODEL SETUP



Data Source: Westold (2019), ESRI (2019), digitalGlobe, Geoeye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS Iser Community

I:/65-5/Hydrology/ArcGIS/App.E.mxd

1:30,000
A4

N

Grid: MGA 1994
Zone 51

CLIENT: MRC Graphite
PROJECT: Munglinup Graphite Project
DATE: October 2020
DWG NO: 65-5/20/AppE

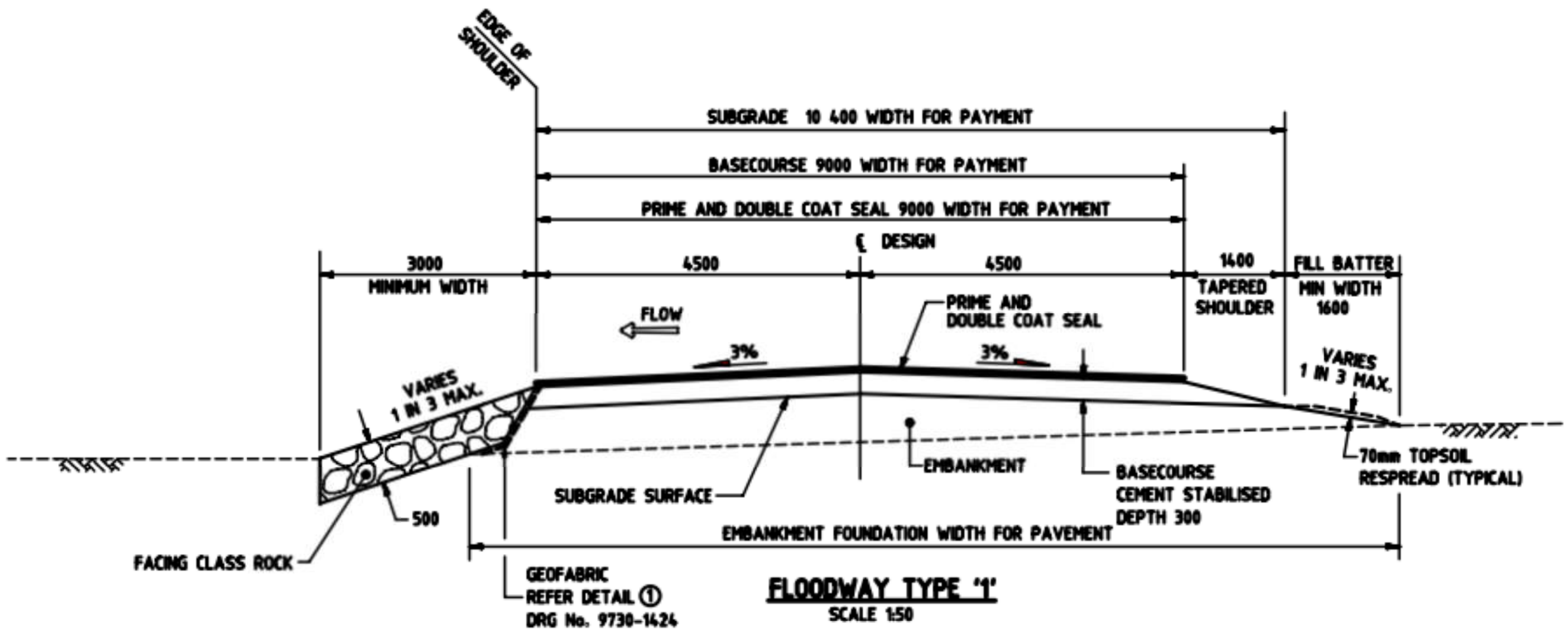
CLAYHOLE CREEK
RORB MODEL SETUP

Rockwater

APPENDIX F

TYPICAL FLOODWAY SCOUR PROTECTION DESIGN
(MRWA STANDARDS)

Appendix F



FLOODWAY TYPE '1'

SCALE 1:50

I/65-5/Hydrology/Surfer/App F-Typical Floodway

CLIENT: MRC Graphite

PROJECT: Munglinup Graphite Project

DATE: October 2020

DWG NO: 65-5/20-01/App F

Typical Floodway Scour Protection Design (MRWA standards)

Rockwater PROPRIETARY LIMITED

APPENDIX G

INITIAL DESKTOP HYDROLOGY ASSESSMENT

(Rockwater, 2018c)

Rockwater
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MRC GRAPHITE PTY LTD

INITIAL DESKTOP HYDROLOGY ASSESSMENT FOR PART OF MINING TENEMENT E74/565 AT MUNGLINUP GRAPHITE PROJECT

SEPTEMBER 2018

1. INTRODUCTION

This report presents the initial desktop assessment (Stage 1) of the hydrology relevant to surface-water flow in an area east and south-east of the Munglinup Graphite Project at M74/245, which is planned to be a mining operation undertaken by MRC Graphite Pty Ltd (MRC).

The study area is located within mining tenement E74/565, immediately east of Mining Lease M74/245 and Munglinup township (about 75 km ESE of Ravensthorpe) and north of South Coast Highway. It contains the south-draining Clayhole Creek just upstream of the confluence with Munglinup River (Figure 1).

This initial assessment follows the method used for the Stage 1 assessment of Mining Lease M74/245, to estimate peak surface-water flows from the Clayhole Creek catchment. The analysis provides calculated values of typical design peak flows up to the Probable Maximum Flood (PMF) / 2000 year Average Recurrence Interval (ARI) event.

Preliminary hydraulic analysis has been made to assess flood impact on the planned eastern access road to determine whether a more appropriate route should be sought. Detailed hydraulic analysis will be undertaken in Stage 2 once the route has been finalised, as well as any other mining infrastructure planned in the area.

The purpose of this Stage 1 work is to provide the following:

- The best flood estimation methodology for application to the Stage 2 hydrological evaluation. The adopted method will be selected by assessing the estimated peak flows of the Clayhole Creek catchment (Catchment CC) using all available current industry best practice and guidelines such as Australian Rainfall and Runoff 2016 (ARR2016).
- Locations of local watercourses that could potentially impact or be impacted by the planned access road and any other mine infrastructure in the area.
- Comments relating to the potential flood impact on the planned road and whether changes should be made to the route.

1.1. AREA DESCRIPTION

The Munglinup project area lies about 20 km north of the southern coastline of Western Australia at an elevation of about 90 m above sea level. Topography is low to moderate, with relief of less than 40 m in the surrounding 5 km. Drainage trends southwards via two main features, Munglinup River and Clayhole Creek. Geologically, there is thin cover of Quaternary-age colluvium and Tertiary-age siltstone over crystalline bedrock (migmatite) of Archaean or Proterozoic age.

Based on data from BoM Munglinup Stn. 009868, the average annual rainfall (1970 to 2018) is 533.8 mm, with monthly averages between 24 mm (in December) and 62 mm (in August). The highest recorded daily rainfall at Munglinup was 153.6 mm (for 5 January 2007). Any account of the extent of flooding (if any) from this event is not to hand.

Floods were reported from the Ravensthorpe area in early February 2017, when a total rainfall of 238.6 mm was recorded over a period of five days at Ravensthorpe, and 198.2 mm at Munglinup. No data are to hand concerning flooding at this time near Munglinup.

1.2. DATA USED

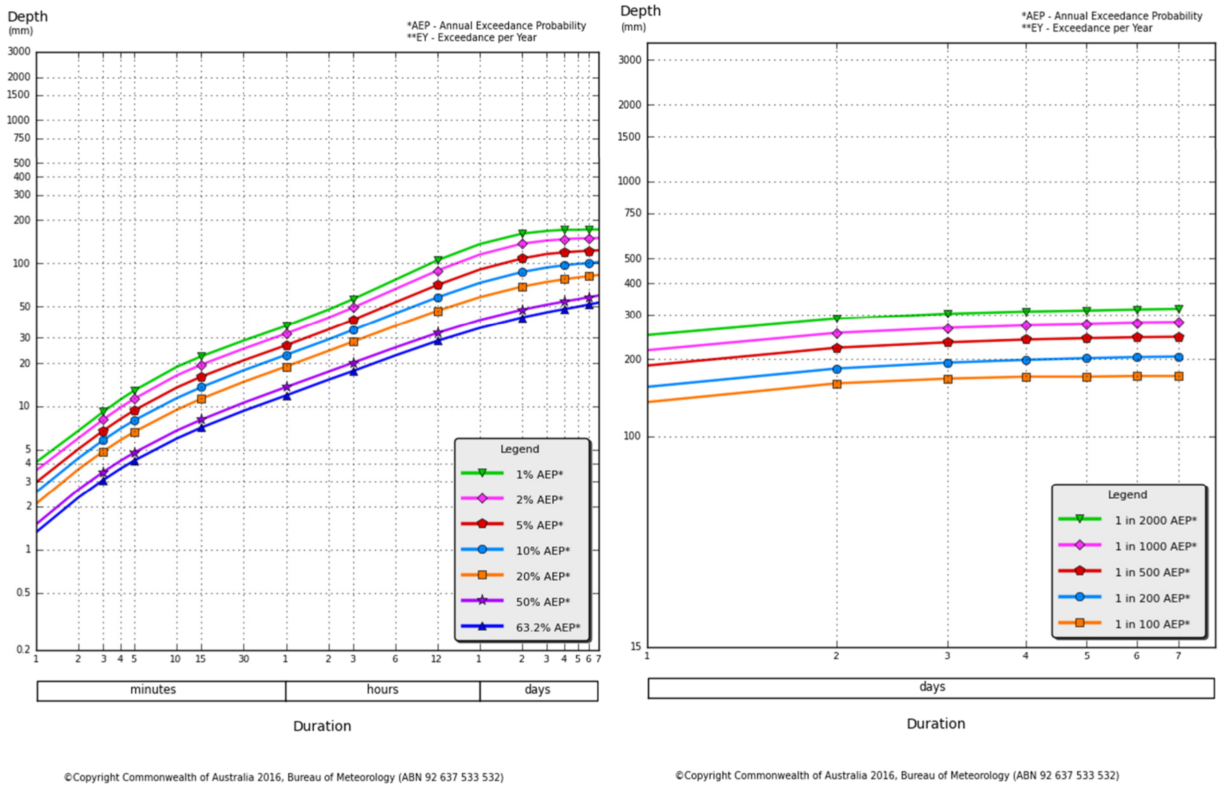
The following project-specific data were used to conduct the assessment described in this report:

- Satellite imagery from Google Earth Pro (Google, 2018).
- Digital elevation model (DEM) covering the project area from Shuttle Radar Topography (SRTM) dataset (NASA, 2011); it gives ground surface contours at 5 m intervals.
- A polygon showing the expanded surface water assessment area, east of M74/245 (July 2018).
- Preliminary site layout for M74/245 which also includes the proposed location of the Eastern Access Corridor through E74/565 (August 2018).

2. HYDROLOGY

2.1. RAINFALL

Intensity Frequency Duration (IFD) curves for the Munglinup Graphite Project site were prepared using the web-based tool developed by the Bureau of Meteorology (BOM, 2016). The IFD curves for all design intervals up to the 1 in 2000 Annual Exceedance Probability (AEP) are presented in Text-Figure 1.



Text-Figure 1: IFD curves for Munglinup Graphite Project site (BOM, 2016)

2.2. USE OF ARI AND AEP

The latest publication of Australian Rainfall and Runoff (ARR) 2016 uses the term Annual Exceedance Probability (AEP, expressed as %) to describe the design frequency levels. Previous ARR publications used Average Recurrence Interval (ARI, in unit of years). Table 1 presents the conversion of typically used AEP intervals to ARI, followed by the pre-ARR2016 ARI equivalent.

Table 1: Conversion between ARI and AEP

AEP (%)	50%	20%	10%	5%	2%	1%	0.05%
Exact ARI (Years)	1.44	4.48	9.49	19.50	49.50	99.50	1999.50
Adopted ARI (Years)	2	5	10	20	50	100	2000

In order to maintain consistency, this report uses the term ARI with the context as given in Table 1.

2.3. CATCHMENT AREA DELINEATION

The proposed project area domain shows that there is the potential for flood impact from the Clayhole Creek catchment system. For the Stage 1 assessment:

- Satellite imagery and the 5 m interval contours were used to estimate the flow paths of the Clayhole Creek and contributing watercourses (Figure 2). It is noted that the contours do not accurately incorporate the narrow channel of the river bed, leading to imprecise evaluation of flood levels and extent.

- The contour plan and delineated watercourses show that the proposed project area domain includes the direct flow path of the main channel of Clayhole Creek. A large tributary of the creek, which flows east to west passes through the southern portion of the project area.
- The topographic contours were used to delineate two sub-catchments of Clayhole Creek: Catchment CC Upper and Catchment CC Lower.
- The characteristics of Catchments CC, CC Upper and CC Lower are presented in Table 2.

Table 2: Catchment HS characteristics

Catchment	Area (km^2)	Length (km)	Slope (m/km)	Clearing (%)
Clayhole Creek (CC)	70.8	13.1	9.90	80
CC Upper	30.3	5.9	13.6	80
CC Lower	40.5	7.2	6.3	80

2.4. PEAK FLOW ESTIMATION

In Western Australia, peak flows from ungauged catchments are estimated using the rational and index flood methods provided by Australian Rainfall and Runoff in 1987 (ARR1987).

Peak flow estimation methods for the Clayhole Creek catchment area are included in the ARR1987 for the Wheatbelt climatic region. The peak flows estimated using the rational and index flood methods for the three catchments are presented in Table 3. The 2000 year ARI peak flow was determined by extrapolation based on the frequency factors calculated from the IFD curves.

Table 3: Calculated peak flows using rational and index flood methods

ARR1987 Method	Average Recurrence Interval (Years) / Peak Flow (m^3/s)						
	2	5	10	20	50	100	2000
Catchment CC							
Rational	5.26	10.75	18.69	32.38	54.74	72.09	118.98
Index Flood	5.10	10.21	17.96	31.13	57.67	61.57	81.54
Adopted design	5.26	10.75	18.69	32.38	57.67	72.09	118.98
Catchment CC Upper							
Rational	3.57	7.29	12.69	22.00	37.22	49.04	80.93
Index Flood	3.07	6.13	10.80	18.71	34.66	37.00	56.14
Adopted design	3.57	7.29	12.69	22.00	37.22	49.04	80.93
Catchment CC Lower							
Rational	4.17	8.53	14.83	25.71	43.48	57.28	94.53
Index Flood	3.65	7.30	12.85	22.27	41.25	44.04	63.91
Adopted design	4.17	8.53	14.83	25.71	43.48	57.28	94.53

The higher peak flow for each recurrence interval was selected as the adopted design flow for all catchments.

It should be noted that in the publication of ARR 2016, the regional flood methods used by ARR1987 were replaced with the web-based Regional Flood Frequency Estimation (RFFE) model. The results produced by the RFFE model for many regions in WA have been found to be unrealistic. It is likely that other States encountered the same problems with the method, because shortly after publication, the RFFE model was re-issued as a draft along with a Limits of Applicability statement.

Despite the caveats associated with using the RFFE model, the industry still acknowledges its value as an additional flood estimation method where applicable. For completeness, the RFFE model was applied to the three catchments to generate the estimated peak flows in Table 4. The much higher flows calculated using the RFFE model compared to those using the ARR1987 methods highlight the limitations of applying the RFFE model in WA. From our experience the flows calculated by the 1987 methods generally give a good indication of actual flows. Note also that the error message "*Arid region temporarily unavailable*" is encountered when using the model for Catchment CC Upper. This suggest that according to ARR 2016, Catchment CC Upper lies on the cusp of two different hydrological zones, which is unlikely.

Table 4: RFFE model results (Not recommended – for information only)

ARR2016 RFFE Model	Average Recurrence Interval (Years) / Peak Flow (m^3/s)						
	2	5	10	20	50	100	2000
Catchment CC							
5% CL	12.80	31.10	45.60	67.00	87.40	116.00	187.47
95% CL	155.00	377.00	552.00	811.00	1060.00	1400.00	2266.18
Recommended	44.40	108.00	159.00	233.00	304.00	403.00	651.70
Catchment CC Upper							
5% CL	*Arid region temporarily unavailable* (ARR, 2016)						
95% CL							
Recommended							
Catchment CC Lower							
5% CL	8.48	20.60	30.20	44.40	58.00	76.80	124.22
95% CL	104.00	253.00	371.00	545.00	711.00	943.00	1524.47
Recommended	29.70	72.20	106.00	156.00	203.00	269.00	435.13

The ARR1987 regional rational and index flood methods will be adopted for this project, and will also be used for all the Stage 2 work.

Although the topographic data used are insufficiently accurate for hydraulic calculations, a preliminary estimate was made of the likely flood along the main Clayhole Creek channel. The width of flow could extend up to about 100 m wide in a 1-in-100 year flood, and about 200 m wide in a Probable Maximum Flood (PMF). An indicative 1-in-100 year flood extent in the main channel of Clayhole Creek is presented in Figure 3 for planning purposes. This estimate should be taken as a rough indication, and not relied upon in detailed design. Any risk of impact on major infrastructure from such floods could be minimised by the usual 1+ m perimeter bunds.

The outcome of Mining Lease M74/245 Stage 2 assessment showed that flows from the smaller local catchments are relatively low and in most cases can be managed without requiring significant changes to proposed layout plans.

3. PROPOSED EASTERN ACCESS ROAD

Based on the findings of this Stage 1 hydrological assessment, the preliminary proposed Eastern Access Road (EAR) alignment is not ideal as it travels within a tributary creek bed just east of the main channel of Clayhole Creek. Two alternative conceptual route options are proposed based on the indicative flood extents and the topographic contours. These options are shown in Figure 4 and are based on the following preliminary design concepts:

- Option 1 EAR North: This option is proposed assuming the current preliminary Eastern Access Road alignment is preferred. The principle of this option is to move the road alignment from the creek bed to higher ground. The road still crosses over Clayhole Creek at approximately the same narrow channel point.
- Option 2: EAR South: It is difficult to estimate the depth of the Clayhole Creek channels from 5 m contours, but typically the narrow channel width also means it is a deeper crossing. Assuming the Eastern Access Corridor is mainly for light vehicle road use it is likely a floodway crossing is preferred. The EAR South option is aligned to cross a shallow and wide section of the creek which is more suitable for a low-lying floodway.

The recommended option prior to confirmation of detailed topography is EAR South. It is expected that this option will be more feasible to construct as the likely requirement of a large bank of culverts or a bridge to span the deeper channel section Clayhole Creek can be avoided.

4. CONCLUSIONS AND COMMENTS

The following are the conclusions and comments based on the Stage 1 hydrology desktop assessment:

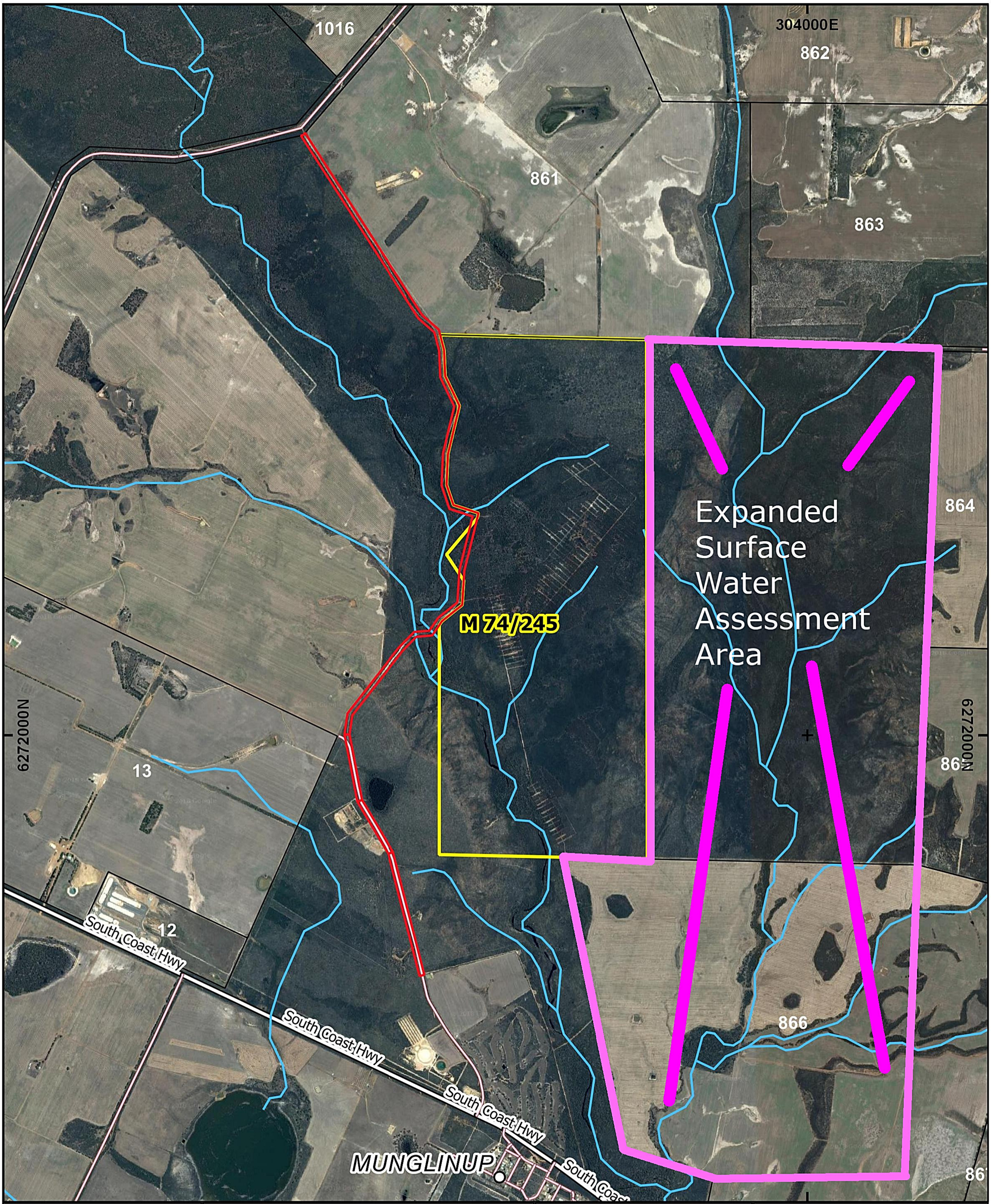
- The study domain area within mining tenement E74/565 is directly in a main flow path of the Clayhole Creek catchment system and will be impacted by flooding.
- Satellite imagery and 5 m interval contours have been used to estimate theoretical flow paths (in Figure 2) of the Clayhole Creek and contributing watercourses. These lines are indicative paths only and require confirmation in the Stage 2 assessment.
- The characteristics of Catchments CC, CC Upper and CC Lower were used to assess the most suitable method for flood peak flow estimation for the project area.
- The ARR1987 regional rational and index flood methods were selected and these are recommended for Stage 2 to estimate peak flows from local sub-catchments within the project area.
- Although the topographic data are insufficiently accurate for detailed hydraulic calculations, a preliminary estimate was made of the likely flood width along the main Clayhole Creek channel. The width of flow could be about 100 m wide in a 1-in-100 year flood, and about 200 m wide in a Probable Maximum Flood (PMF). This estimate should be taken as an indicative order of magnitude, and not relied upon in mine and infrastructure design.
- It is recommended that a different, more southerly alignment (EAR South) be adopted for the planned access road, so that the road does not lie within a creek channel, and it crosses the main drainage in an area where the drainage is probably shallow.

Dated: **4 September 2018** **Rockwater Pty Ltd**

J Goh
Senior Hydrologist

PH Wharton
Principal Hydrogeologist

FIGURES



Munglinup Graphite Project

Figure 1:
Project Area

Legend

Tenure

Reserves

Road Reserve

WA Road Network (MRWA 514)

Local Road

State Road

Water Features

Google Satellite

500 0 500 m

N

1:40,000

GDA94 / MGA Zone 51

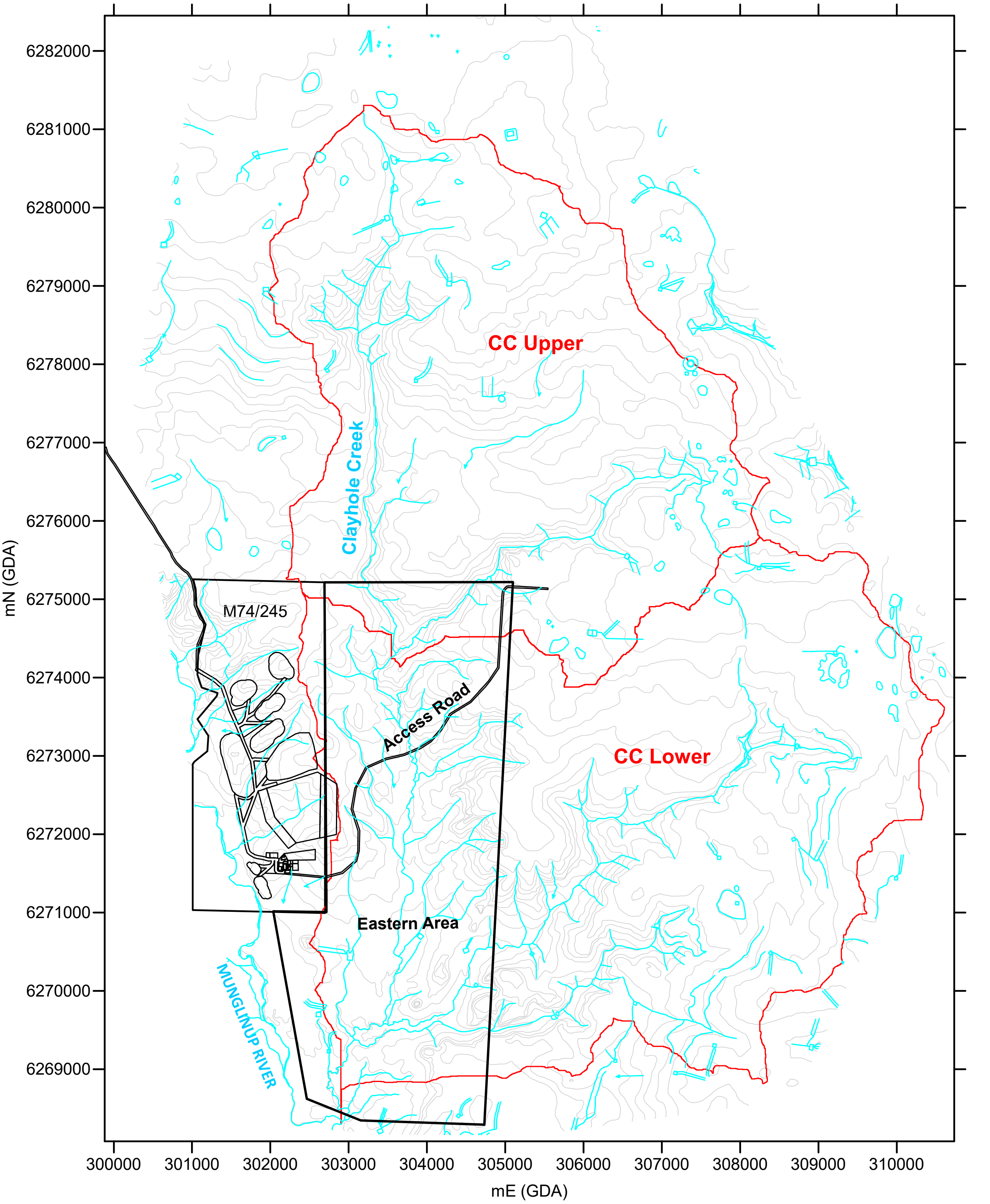
MRC

Rev 1

Feb 2018

"The information on this map was derived from various sources. Care was taken in its creation, however, Integrate Sustainability cannot accept any responsibility for errors, omissions, or positional accuracy. There are no warranties, expressed or implied, including the fitness for a particular purpose, accompanying this product. However, notification of any errors will be appreciated."

Figure 2



LEGEND

- Proposed Mining Infrastructure
- Hydrology
- Catchment CC

65-5/Surfer/18-05/Figure 2.srf

CLIENT: MRC Graphite

PROJECT: Munglinup

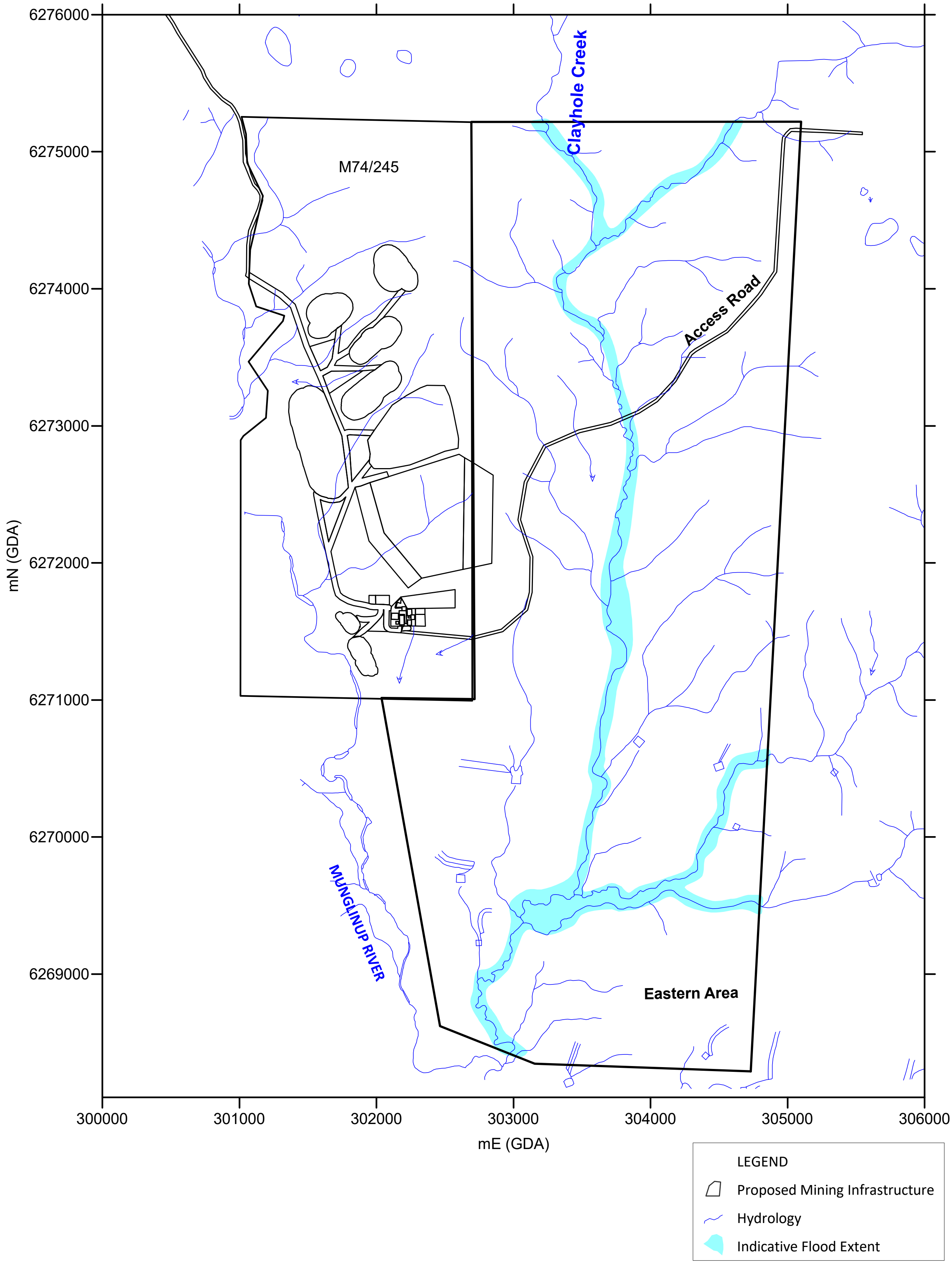
DATE: August 2018

Dwg. No: 65-5/18/5-2

MINE LOCATION WITH CATCHMENT CC OUTLINE

Rockwater PROPRIETARY LIMITED

Figure 3



65-5/Surfer/18-05/Figure 3.srf

CLIENT: MRC Graphite

PROJECT: Munglinup

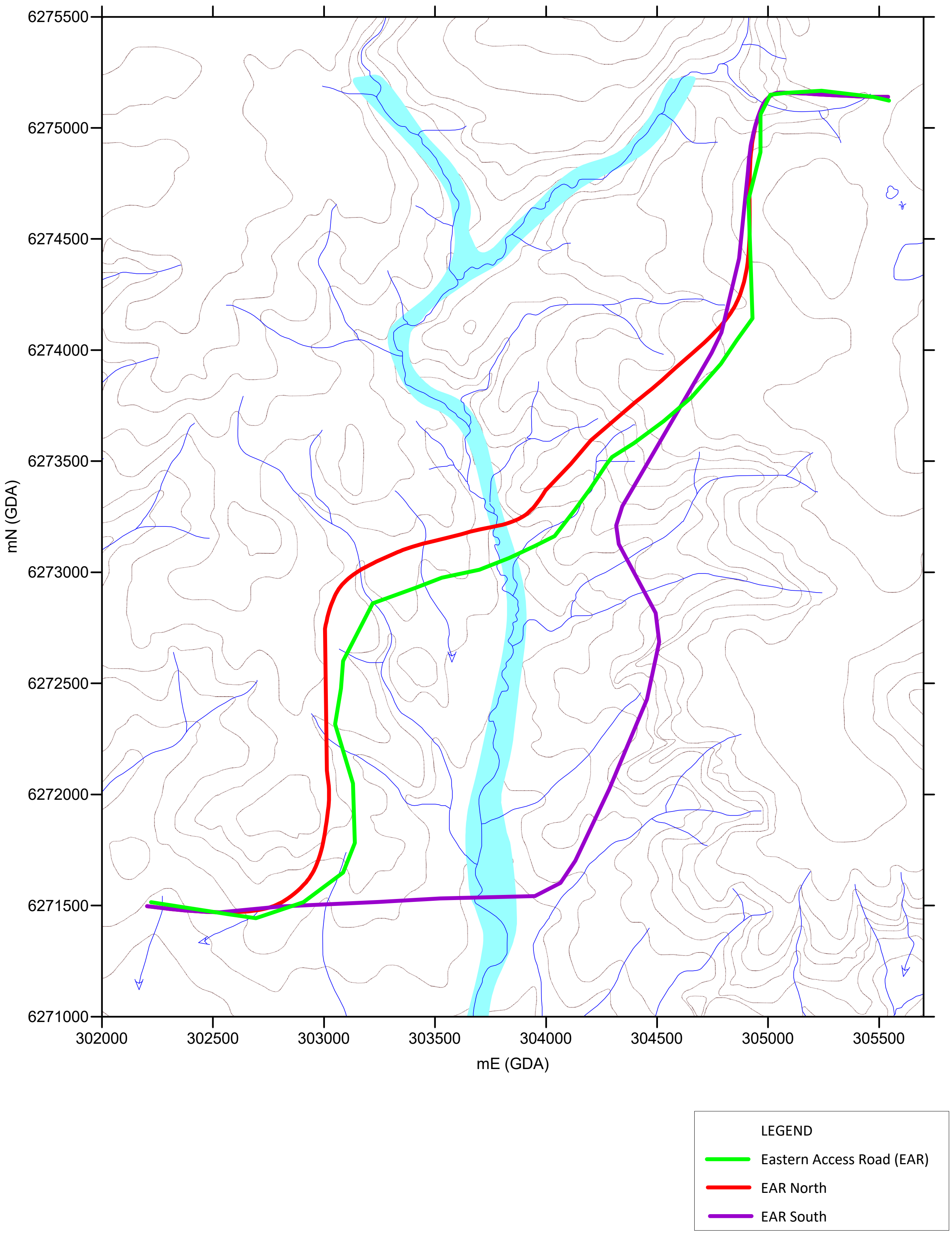
DATE: August 2018

Dwg. No: 65-5/18/5-3

INDICATIVE 100-YEAR FLOOD EXTENT

Rockwater PROPRIETARY LIMITED

Figure 4



65-5/Surfer/18-05/Figure 4.srf

CLIENT:	MRC Graphite
PROJECT:	Munglinup
DATE:	August 2018
Dwg. No:	65-5/18/5-4

ALTERNATIVE LOCATIONS, ACCESS ROAD

Rockwater PROPRIETARY LIMITED