SOILWATER CONSULTANTS

KUNDIP SURFACE HYDROLOGY ASSESSMENT

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Revision Code*

A - Report issued for internal review

B - Draft report issued for client review

C - Final report issued to client

LIMITATIONS

The sole purpose of this report and the associated services performed by Soil Water Consultants (SWC) was to undertake a surface water hydrological study for the proposed Ravensthorpe Gold Project. This work was conducted in accordance with the Scope of Work presented to ACH Minerals ('the Client'). SWC performed the services in a manner consistent with the normal level of care and expertise exercised by members of the earth sciences profession. Subject to the Scope of Work, the hydrological study was confined to the Kundip Project Area and power/water corridor (geographical extent). No extrapolation of the results and recommendations reported in this study should be made to areas external to this Project Area. In preparing this study, SWC has relied on relevant published reports and guidelines, and information provided by the Client. All information is presumed accurate and SWC has not attempted to verify the accuracy or completeness of such information. While normal assessments of data reliability have been made, SWC assumes no responsibility or liability for errors in this information. All conclusions and recommendations are the professional opinions of SWC personnel. SWC is not engaged in reporting for the purpose of advertising, sales, promoting or endorsement of any client interests. No warranties, expressed or implied, are made with respect to the data reported or to the findings, observations and conclusions expressed in this report. All data, findings, observations and conclusions are based solely upon site conditions at the time of the investigation and information provided by the Client. This report has been prepared on behalf of and for the exclusive use of the Client, its representatives and advisors. SWC accepts no liability or responsibility for the use of this report by any third party.

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1 INTRODUCTION

ACH Minerals (ACH) engaged Soilwater Consultants (SWC) to undertake a hydrological assessment for the Kundip Project Area of the Ravensthorpe Gold Project (RGP). This document will form part of an Environmental Review Document and an eventual mining proposal for the Project and was in part informed by previous surface water studies carried out for the RGP by other parties (Coffey, 2011).

The Kundip Project Area is located between Ravensthorpe and Hopetoun within the Shire of Ravensthorpe. Kundip will consist of open cut and underground mining using standard techniques with ore processing and associated tailings disposal taking place on site.

2 OBJECTIVES AND SCOPE

The study objectives included:

- Desktop review of previous reports;
- Identification of existing surface water flows and establish the baseline hydrological environment of the study area;
- Peak flow estimation;
- Floodplain mapping;
- Impact assessment (flows and quality); and
- Identification of areas requiring drainage control structures to minimise impacts on key infrastructure and the surrounding environment.

3 HYDROLOGICAL CHARACTERISATION

The Kundip Project Area is largely located within the Steere River catchment (Figure 3.1). The total catchment within the Steere includes the Phillips, West and Steere rivers and is 3,658 km^2 in area. All three rivers discharge to the same point at the Culham Inlet. The Steere River portion of this catchment makes up only 360 km^2 (approximately 10%) of the larger catchment area. A small proportion on the eastern side of the proposed development lies within the Jerdacuttup River catchment which is 1,467 km^2 in area and discharges to the Jerdacuttup Lakes located close to the coast south of Ravensthorpe. The Steere River catchment tributaries which take runoff from the Project Area flow west from the upper limits of the catchment to the Steere River, with the main river channel crossing under the Ravensthorpe-Hopetoun Road approximately 200 m south of the Project Area.

3.1 CLIMATE

The climate within the region is characterised by consistent rainfall throughout the year with slightly heavier falls in the winter months. The wider region receives approximately 430 mm annually. Pan evaporation for the wider area is approximately 1950 mm annually.

Table 3.1: Climate data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Daily Temp (max)	29.0	28.3	26.6	23.7	20.0	17.3	16.3	17.3	19.5	22.5	25.1	27.2
Mean Daily Temp (min)	14.1	14.6	13.6	11.8	9.6	6.7	6.7	6.7	7.4	11.1	11.1	12.8
Mean Monthly Rainfall (mm)	24.9	26.5	32.8	32.8	44.1	43.6	45.1	45.1	42.3	30.6	30.6	24.2

BOM, (2018)

3.2 LOCAL HYDROLOGY

The drainage morphology and associated hydrological responses across the Project Area are characterised by ephemeral stream, creek and drainage networks consisting of a mixture of steep and incised hillslopes with well-defined streamlines; broad and wide valleys with clear alluvial channel bed forms that are well vegetated; interspersed with comparatively flat damp lands which have poorly defined drainage. The local surface water drainage paths and catchments are presented in Figure 3.2. As discussed the proposed site layout is contained largely within the upper eastern Steere River catchment. Specifically this catchment contains the Flag, Harbour View and Kaolin mine developments, process plant, offices, site support buildings, water transfer infrastructure and two waste rock landforms (WRL) along with the majority of the linking mine roads. The Jerdacuttup River catchment directly to the east contains the magazine storage area and tailings storage facility (TSF) along with a small portion of the mine roads to provide access to these facilities.

3.3 SURFACE WATER FLOWS & QUALITY

There are no gauging stations and therefore no long-term water flow or quality data available for the Jerdacuttup River or any of its tributaries (DOW, 2017). Massenbauer (2006) reports the annual discharge from the Jerdacuttup River to be 8.8 GL a^{-1}, whilst Chapman estimates the annual discharge from the Steere River to be 1.4 GL a^{-1} though it is not clear as to the source of this information. With a potential evaporation rate of 1950 mm a-1 and mean rainfall of 430 mm a^{-1}, the mean annual flows from these landscapes are expected to be of the order of 5 - 50 mm a-1, with large inter-annual variability (DOW, 2007; McGrath et al., 2007). The flows estimated by Massenbauer and Chapman are at the low end of the estimates, between to 6 and 10.0 mm a^{-1}. Surface water flows are generally intermittent in both rivers whilst the minor tributaries which lie within the Project Area are usually dry between rainfall events.

Similar to the Jerdacuttup River there is no permanent gauging station installed along the Steere River or any of its tributaries (DOW, 2018). Two water quality grab samples were taken and recorded in 2010 at the Jones road crossing which is located approximately 25 km south and downstream of the Kundip Project Area (see Figure 3.1). The data was supplied by the Department of Water online database and is summarised in Table 3.2.

Table 3.2: Surface water quality data for lower reaches of the Steere River (DOW, 2018)

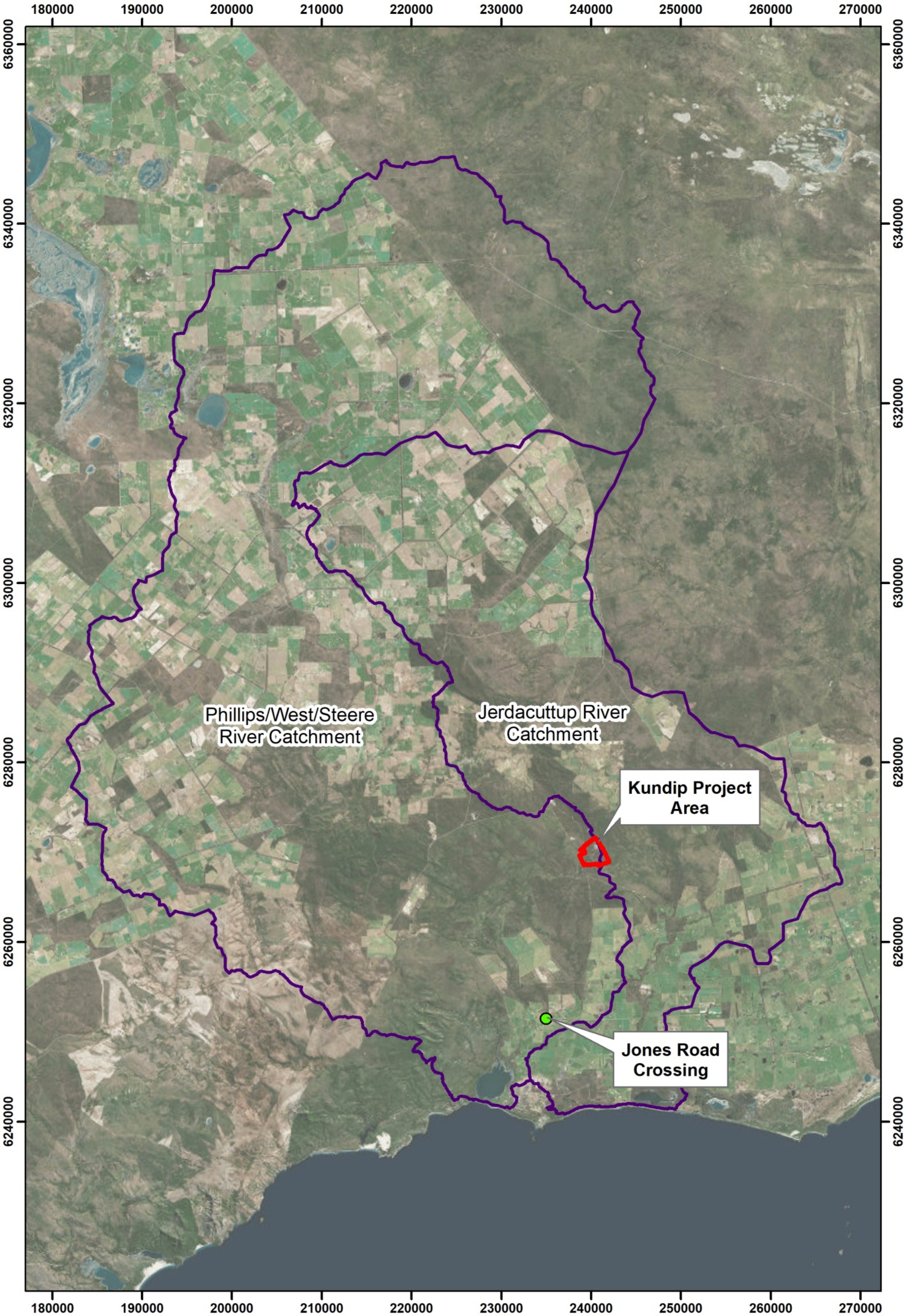
Site ID	Date	NH_3/NH_4	NO_2	N (kjel)	N (total)	P (total)	TSS	EC (µS/cm)	pH
Jones Rd Crossing	16/05/10	0.23	0.024	1.6	2.3	0.047	15	21,900	7.6
	10/10/10	0.03	<0.01	0.37	0.39	0.01	4	19,200	7.8

Data supplied in mg/L unless otherwise noted

3.4 ADJACENT LAND & WATER USES

The local catchment is almost entirely covered with native vegetation with small areas impacted by previous mining activity. The wider catchment area contains a mixture of agricultural land, native vegetation and transportation routes to the south of the Project Area. The agricultural land to the south has been mostly cleared of native vegetation, with shrubs and trees delineating drainage lines. There is no irrigated agriculture or use of surface water in the immediate vicinity of the site. Local town and farm water supplies in the area are primarily from surface dams, rainwater tanks or desalination of piped water from Esperance (Massenbauer, 2006).

The Jerdacuttup and Steere Rivers lie within the Fitzgerald Biosphere Reserve a part tenured land management concept supported by the State and Commonwealth Governments and UNESCO. Various regions of each river's foreshore vegetation are rated to be in a pristine condition (WRC, 2004). The UNESCO International Advisory Committee for Biosphere Reserves recommended the renomination for examination and endorsement to the Man and the Biosphere Programme governing body, the International Co-ordinating Council on scientific and technical matters concerning the nomination of new sites, and changes and periodic reviews of sites already included in the World Network of Biosphere Reserves (SOJ, 2017).



ACH MINERALS	Figure 3.1: Regional catchments	soilwater GROUP
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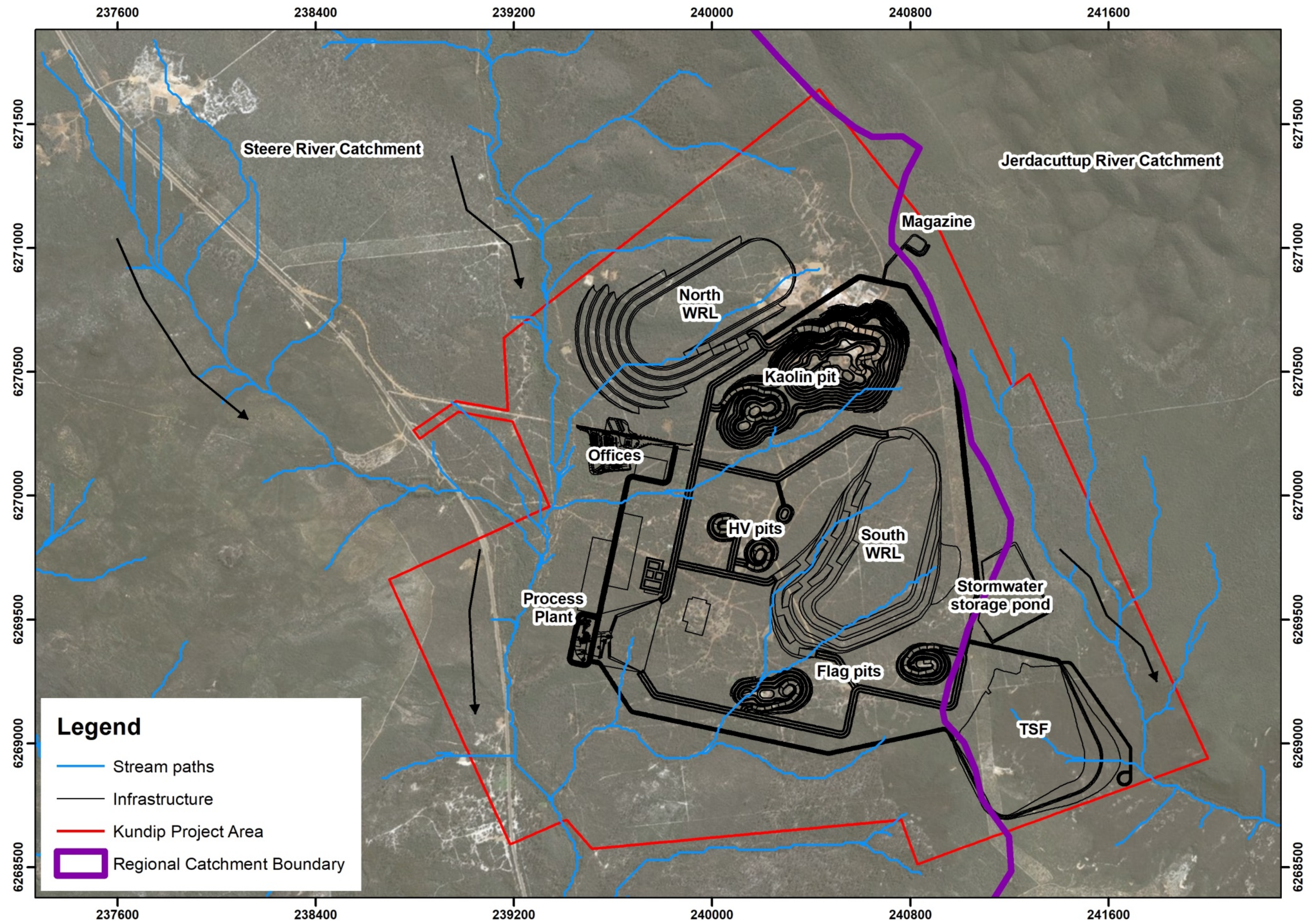

ACH MINERALS	Figure 3.2: Proposed Kundip Site infrastructure
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4 APPROACH TO STUDY

4.1 BASELINE CATCHMENT DELINEATION

Surface water drainage systems and associated sub-catchments surrounding and upstream of the broader study area have been delineated to determine which catchments are likely to impact on the proposed developments (Figure 4.1). For this purpose 2 m contour data supplied by ACH was utilised. Surface water catchments were further delineated using Topographic Paramaterization (TOPAZ) modelling program, embedded in the Watershed Modelling Software (WMS) software. TOPAZ uses a steepest descent, D8, flow direction routing algorithm, combined with pit filling and depression outlet breaching to assign flow directions and surface water contributing areas (Gabrecht and Martz, 1999).

The displayed catchments were limited to those which were likely to impact the proposed developments and were above 5 ha in overall size. The derived drainage paths have been validated against aerial photography, where possible, to ensure they closely match with visible drainage morphology.

Catchments C01, C02 and C03

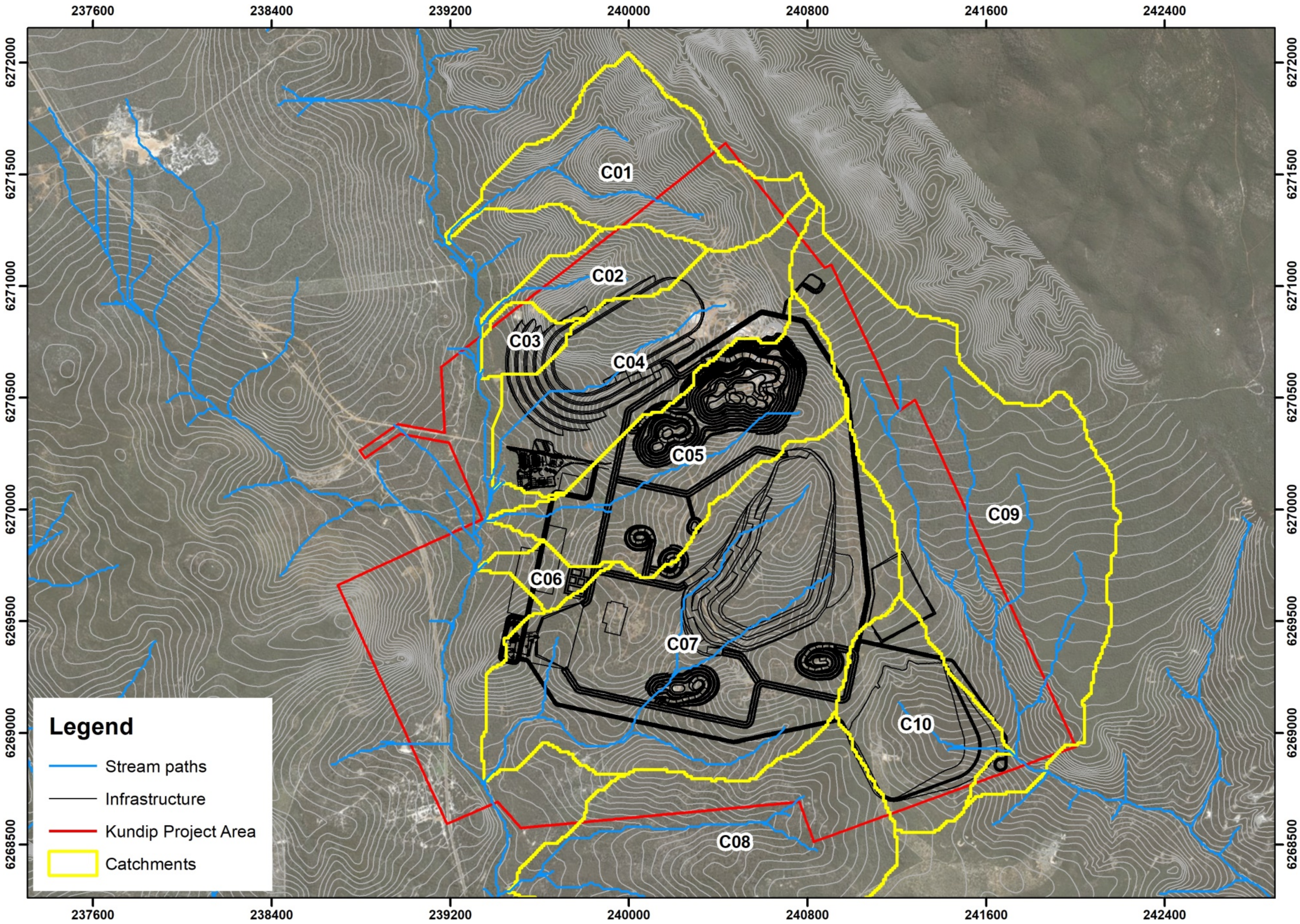
These catchments occur largely to the north of the proposed infrastructure development, with C02 and C03 encroaching on the northern boundary of the North WRL. They are largely covered by native vegetation across the entire length of each catchment. Both C01 and C02 have a fairly well-defined channel system that is evident from thicker native vegetation distribution oriented in a south-westerly direction along the main channels. C03 occupies a small relatively regularly sloping area adjacent to the south flowing main stream line and has no defined channels.

Catchments C04, C05, C06, C07 and C08

These catchments are co-incident with the proposed infrastructure development within the Steere River catchment. They have seen some clearance from previous mining activity which is mainly confined to catchments C04 and C05 along with minor roads and tracks. They have similar topography as the catchments to the north, with the larger catchments of C04, C05, C07 and C08 having fairly well defined channels whilst C06 occupies relatively uniform sloping ground with no well-defined channel system.

Catchment C09 and C10

These catchments occur beneath the proposed infrastructure development within the Jerdacuttup River catchment. It has better defined topography in areas than the catchments to west, with well-defined channel systems within steep valleys in its lower reaches. It is largely covered by native vegetation with some minor tracks and a development corridor.



ACH MINERALS	Figure 4.1: Modelled catchments intersecting the Kundip Project Area
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4.2 EXTREME RAINFALL INTENSITIES

Rainfall intensity-frequency-duration (IFD) estimates for the study area near Ravensthorpe were derived using BOM's CDIRS (Computerised Design IFD Rainfall System), which allows automatic determination of a full set of IFD curves and associated data for any location in Australia. This approach is compatible with the manual procedures described in Australian Rainfall & Runoff (ARR): A Guide to Flood Estimation (IEAust, 2016), recommended as appropriate in regions where reliable stream gauging information is unavailable. A selection of rainfall depths for various storm durations from 5 minutes to 72 hours for 1 to 100 Average Recurrence Intervals (ARI's) are presented in Table 4.1.

Table 4.1: Intensity Duration Frequency Rainfall Intensities

Duration	Average Recurrence Interval Rainfall Intensity (mm hr-1)						
	1 yr	2 yr	5 yr	10 yr	20 yr	50 yr	100 yr
5 minute	40.9	56.0	80.6	99.5	125	165	201
10 minute	38.0	52.0	74.8	92.3	116	153	186
30 minute	30.3	41.2	58.4	71.4	89	116	140
1 hour	21.1	28.3	39.0	46.8	57.5	73.7	87.9
2 hour	16.7	22.2	30.1	35.9	43.7	55.5	65.6
3 hour	10.8	14.4	19.1	22.5	27.1	34.0	39.9
6 hour	6.95	9.18	12.1	14.2	17.0	21.3	24.8
12 hour	5.35	7.06	9.31	10.9	13.1	16.3	19.0
24 hour	3.42	4.52	5.97	6.98	8.4	10.5	12.3
48 hour	2.17	2.87	3.80	4.46	5.38	6.72	7.88
72 hour	1.34	1.79	2.37	2.79	3.37	4.22	4.96

4.3 FLOOD ESTIMATION – PEAK DISCHARGE

As there are no hydrometric stations operating in the Project Area, historical records were not available to derive estimates of peak runoff rates. The Regional Rational Method (Rational Method) was applied to estimate peak flow rates in accordance with the procedures set out in the Australian Rainfall and Runoff (ARR) (IEAust, 2016) national guideline document. The parameters for the Southwest region with lateritic soils were used as the basis for peak flow estimation. The catchment characteristics used in estimating the peak flow using the Rational Method are presented in Table 4.2. To allow for comparison with other modelling methods, peak flow estimates were also performed using the Index Flood Method (IFM). However, within the Study Area the regional IFM data tends to underestimate peak flows. The IFM is therefore supplied for information only and should not be used for design purposes. The rational method is considered a more conservative estimate for use in the current study.

For the rational method in the southern Wheatbelt region for areas with loamy and lateritic soil catchments, discharge (Q) is based on the relationship:

$$Q_y = 0.278 \times C_{10} \times (C_y/C_{10}) \times I \times A$$

Where:

- Q_y = peak discharge ($m^3 s^{-1}$) for defined ARI;

- C_y / C_{10} = frequency factor for defined ARI;
- I = rainfall intensity (mm hr^{-1}) for catchment's time of concentration (t_c)
- A = catchment area (km^2); and
- t_c = $0.76\ A^{0.38}$

The frequency factors for the 1, 2, 5, 10, 20, 50 and 100 year ARI's are 0.0016, 0.43, 0.67, 1, 1.45, 1.98 and 2.37.

4.4 DESIGN DISCHARGES

For all catchments the critical peak discharges for the 100-year storm event were associated with various storm durations. The critical storm duration, t_c, is a function of the catchment area in this region. The critical duration of rainfall for peak flow estimation depends upon the catchment characteristics defining the time of concentration of surface water flows to the catchment's outlet. The key catchment characteristics for those catchments intersecting the Kundip Project Area are provided in Table 4.2.

Table 4.2: Modelled Catchment characteristics

Catchment ID	Catchment Area (km^2)	Stream Length (km)	Equal Area Slope (m/km)	% Cleared	Outflow
C01	0.63	1.62	11.5	5	Steere River
C02	0.22	1.05	9.7	5	Steere River
C03	0.10	0.53	9.2	10	Steere River
C04	0.68	1.93	7.6	15	Steere River
C05	0.76	1.72	7.5	10	Steere River
C06	0.08	0.60	4.2	5	Steere River
C07	1.77	2.35	5.4	5	Steere River
C08	1.30	1.76	4.2	5	Steere River
C09	1.71	2.70	4.2	5	Jerdacattup River
C10	0.50	0.92	5.4	5	Jerdacattup River

4.5 HYDROLOGIC MODELLING

To assess the potential scale and extent of flooding impacts on key infrastructure areas across the entire Study Area a one dimensional steady flow model was developed using the hydraulic software package HEC-RAS. This software is used to simulate rainfall runoff processes and surface water hydraulics via the diffusive wave equation. HEC-RAS requires the creation of stream channel cross-sections derived from available topographic data. Therefore a series of these were constructed from overlays of channel cross sections mapped over the created digital elevation model (DEM) at intervals of between 100 – 300 m along the main stream network. The floodplain extent and flood depth of the pre-mine landscape was derived by interpolation of flood elevations estimated by HEC-RAS over the surface of the DEM.

Flood extent modelling under different rainfall event intensities requires an estimate of catchment surface roughness to accurately derive peak discharges. This roughness factor is primarily determined by the vegetation and degree of rock cover and is termed Manning's 'n', a dimensionless coefficient within Manning's uniform flow equation. Aerial images of the study area were assessed to estimate the roughness of the various channels and adjacent hillslopes. A Manning's roughness assessment of all modelled channels found the majority of ground cover to be well vegetated with a mixture of native shrubs and grasses. Based on this assessment a Manning roughness of 0.04 was adopted for all channels in the catchments modelled, with the surrounding areas contributing to run-off modelled with a Manning roughness of 0.08.

4.6 HYDRAULIC ANALYSIS

4.6.1 CULVERT ANALYSIS

Estimates of peak flows at both 20 and 100 yr ARI intervals are provided to assist with the required culvert design. The culverts should be designed to convey the design flows and not result in unacceptably high headwaters levels in the culvert inlets and flow velocities at the inlets and outlets. The Austroads guidelines (Austroads, 2013) should be followed to assist with the estimates. The tail water elevation estimation using the channel and adjacent hillslope geometry extracted from the supplied DEM, together with Manning's equation to ascertain flood depths within the channel downstream of culverts can be used to assist with basic design.

4.6.2 DIVERSION DRAIN ANALYSIS

The drainage design has been based on the conveyance of non-impacted runoff around disturbed mining areas and conveyance of all impacted runoff through a sediment pond/detention storage basin before either being reused or released off site. Ultimately the purpose of the diversion channels is to prevent potentially impacted runoff flowing directly into the downstream catchments, without being treated or having the sediment removed.

The diversion channels from within the Project Area should all be sized according to Manning's equation below:

$$Q_y = n^{-1} A R^{2/3} S^{1/2}$$

Where:

- Q = flow rate ($m^3 s^{-1}$)
- n = roughness coefficient ($s\ m^{-4/3}$), assumed to be 0.03 for unlined channel
- A = cross sectional area (m^2)
- R = hydraulic radius (m)
- S = channel slope ($m\ m^{-1}$)

5 RESULTS OF FLOOD ANALYSIS

5.1 PRE-MINE PEAK FLOOD ESTIMATION

Estimated peak discharges for all contributing upslope catchments which will impact on proposed mine infrastructure and their respective catchment characteristics for the pre-operations Project are provided within Appendix A. The modelled flood depth and extents under a 1:100 yr ARI event of those catchments which interact with the proposed infrastructure are shown in Figure 5.1 and discussed below for each catchment. Those areas of the Steere River catchment which flow into the main river line upstream of the project area were not considered in the modelling as these are managed by existing drainage infrastructure (i.e. council managed road crossings).

Catchment C03 (Figure 5.1)

This catchment area and slope profile was modelled to be insufficient for appreciable flooding to develop using the HEC-RAS software during the ARI intervals assessed. No defined channels are present.

Catchment C04 (Figure 5.1)

Flood depths along this catchment appear to be well constrained by the topography. Flood depths are generally less than 2 m, with minor areas in the upper catchment centred on the tributary channel reaching 3 m in depth.

Catchment C05 (Figure 5.1)

Flood depths along this catchment are well constrained by the topography. Maximum depths are generally less than 3 m and the majority of the flooded area less than 2 m in depth.

Catchment C06 (Figure 5.1)

This catchment area and slope profile was modelled to be insufficient for appreciable flooding to develop using the HEC-RAS software during the ARI intervals assessed. No defined channels are present.

Catchment C07 (Figure 5.1)

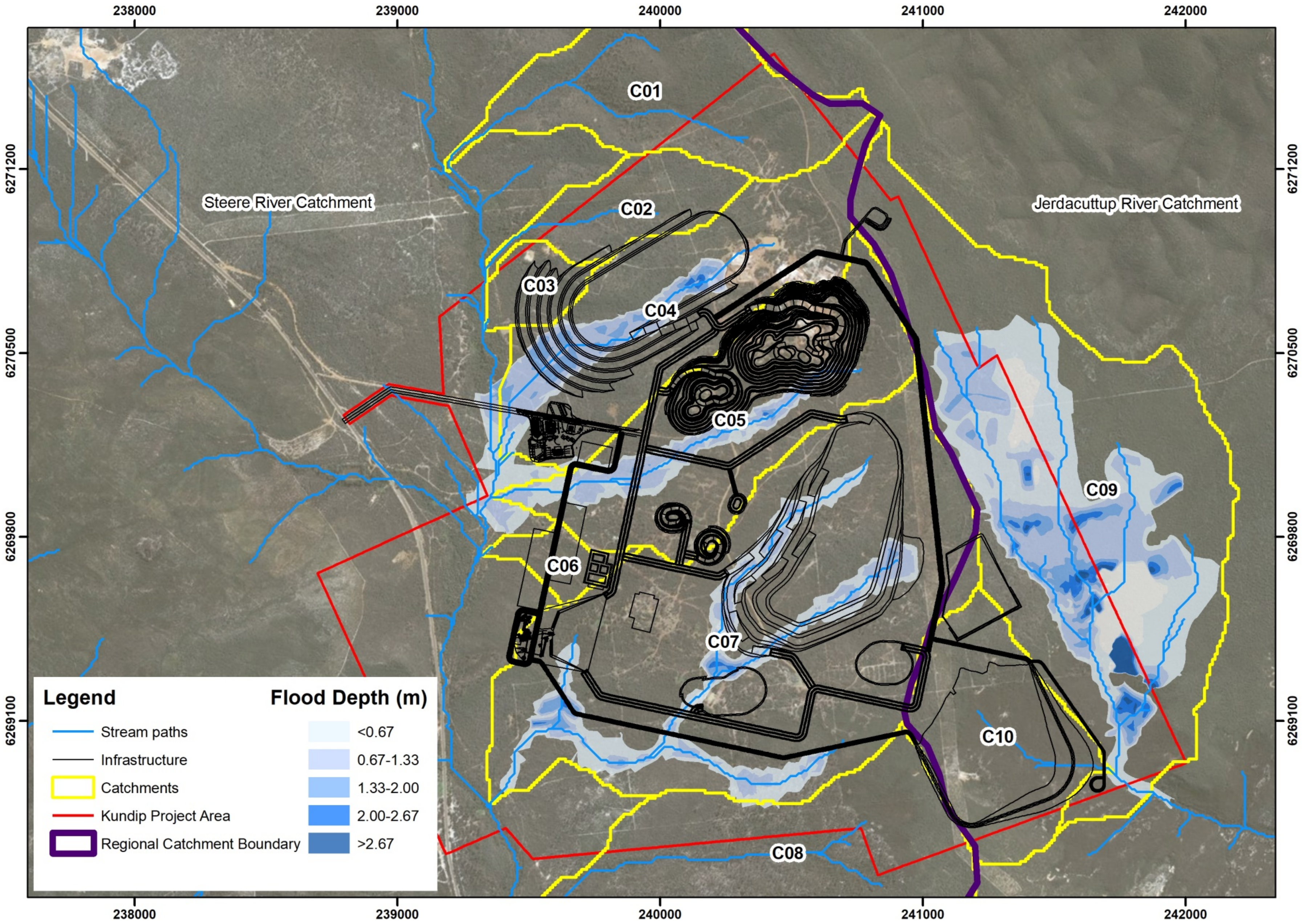
The flood extent within this catchment is well constrained by the topography, and flooding is generally less than 2 m in depth. Minor areas generally occurring at the confluence of tributaries in the centre and lower reaches of the catchment show estimated flood depths reaching 3.5 m in depth.

Catchment C09 (Figure 5.1)

This catchment is the largest of those which may impact on the proposed infrastructure both in terms of catchment area and maximum stream length. The topography within this catchment is also significantly different to those catchments within the Steere River area, with several steep stream paths adjacent to a large moderately sloped runoff area. In response to these factors there are both larger areas with shallow flooding less than 1 m which cover the flatter sloped areas along with smaller areas within the steeper small valleys which have flooding at deeper depths, with several areas exceeding 3 m in depth and a maximum estimated at 6 m at the lower end of the catchment.

Catchment C10 (Figure 5.1)

Flood depths along this small sub-catchment are well constrained by the topography, with all of the flooded area less than 1 m in depth.



ACH MINERALS	Figure 5.1: 1:100 yr ARI modelled flood extent for pre-mine topography
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5.2 MINE SURFACE WATER MANAGEMENT

5.3 CULVERT REQUIREMENTS

In order to manage the estimated water flows during a 1:100 year event, those catchments which are affected by the proposed mine infrastructure were adjusted based on the proposed infrastructure provided by ACH as dxf's and their parameters recalculated to provide the required input to design appropriate surface water management infrastructure. The revised catchment configurations are shown in Figure 5.2 whilst their key characteristics are summarised in Table 5.1. The estimated peak discharges for these revised catchments and their respective catchment characteristics are provided within Appendix A.

Table 5.1: Revised catchment characteristics during operations

Catchment ID	Catchment Area (km^2)	Stream Length (km)	Equal Area Slope (m/km)	% Cleared
C02-A	0.20	0.65	8.1	5
C03-A	0.05	0.22	6.2	10
C04-A	0.19	0.59	8.0	35
C04-B	0.03	0.48	7.6	50
C04-C	0.02	0.33	5.8	5
C04-D	0.13	0.64	5.6	5
C05-A	0.19	0.95	7.1	5
C05-B	0.04	0.43	6.8	5
C05-C	0.12	0.41	6.1	10
C05-D	0.08	0.26	4.5	10
C06-A	0.04	0.25	4.4	5
C07-A	0.17	1.41	6.8	10
C07-B	0.07	0.79	7.1	5
C07-C	0.03	0.28	5.2	10
C07-D	0.12	0.54	5.5	35
C07-E	0.15	0.66	6.2	25
C07-F	0.03	0.31	6.1	10
C07-G	0.16	0.72	6.7	10
C07-H	0.35	1.11	6.1	5
C08-A	0.04	0.42	6.4	5
C08-B	1.22	1.67	4.4	5
C09-A	1.92	2.75	4.2	5
C10-A	0.02	0.25	6.1	10

The locations of proposed topsoil stockpiles were not included within the assessment of surface water flood analysis against mine site infrastructure as these stockpiles will be limited to discrete linear shaped dumps in sections a maximum of 200 m long, with a gap of 20 m between each topsoil stockpile. This placement will prevent excessive ponding of water against the stockpile and allow relatively unimpeded sheet flow to continue in areas outside of stream flow paths.

The proposed mine site road designs intercept stream flow concentration from catchments greater than 5 ha in size at several points within the project, as do several pits and the WRLs. Where these catchments intersect the proposed designs the estimated peak flood volumes using the rational and index flood methods for both a 20 and 100 yr ARI event, equivalent to an annual 5 and 1 % chance flood respectively, were calculated. The data obtained from these calculations are summarised in Appendix A, whilst the locations of the proposed drainage structures is shown in Figure 5.3.

The following sections discuss an assessment of culvert requirements for the Project Area. Table 5.2 summarise proposed culvert design requirements.

Table 5.2: Proposed culvert designs for 1 in 100 year ARI event

Culvert ID	Diameter (mm)	Number of Barrels	Design Flow (m^3/s)	Design Capacity (m^3/s)	Roughness (n)
CU01	675	1	0.52	0.9	0.012
CU02	825	1	1.05	1.3	0.012
CU03	450	1	0.42	0.5	0.012
CU04	675	1	0.77	0.9	0.012
CU05	825	1	1.19	1.3	0.012
CU06	900	1	1.32	1.5	0.012
CU07	750	2	1.60	2.1	0.012
CU08	675	1	0.79	0.9	0.012
CU09	900	1	1.29	1.5	0.012
CU10	750	2	1.55	2.1	0.012
CU11	675	1	0.47	0.9	0.012
CU12	675	1	0.52	0.9	0.012
CU13	750	2	1.94	2.1	0.012
CU14	675	1	0.47	0.9	0.012
CU15	750	2	1.95	2.1	0.012
CU16	750	1	0.87	1.1	0.012
CU17	675	1	0.52	0.9	0.012
CU18	675	1	0.77	0.9	0.012
CU19	450	1	0.42	0.5	0.012
CU20	450	1	0.40	0.5	0.012

*Assumes inlet control using HDPE pipes

5.4 DIVERSION DRAIN CONTROL STRUCTURES

Diversion drains around the upstream borders of the Kaolin pit, Harbour View pit TSF and WRLs may be desirable to both limit ingress of water and limit scour erosion of the abandonment bund and landforms during high rainfall events. Additional diversion drains will be required upstream of the mine road within sub-catchments C04-D and C07-G (Figure 5.3). These drains will act to divert water parallel to the proposed mine roads until they intercept one of the proposed culvert locations. Table 5.3 sets out the estimated required open drain dimensions for each location based on modelled flow rates in a 1:100 yr ARI event.

Table 5.3: Estimated open drain dimensions required

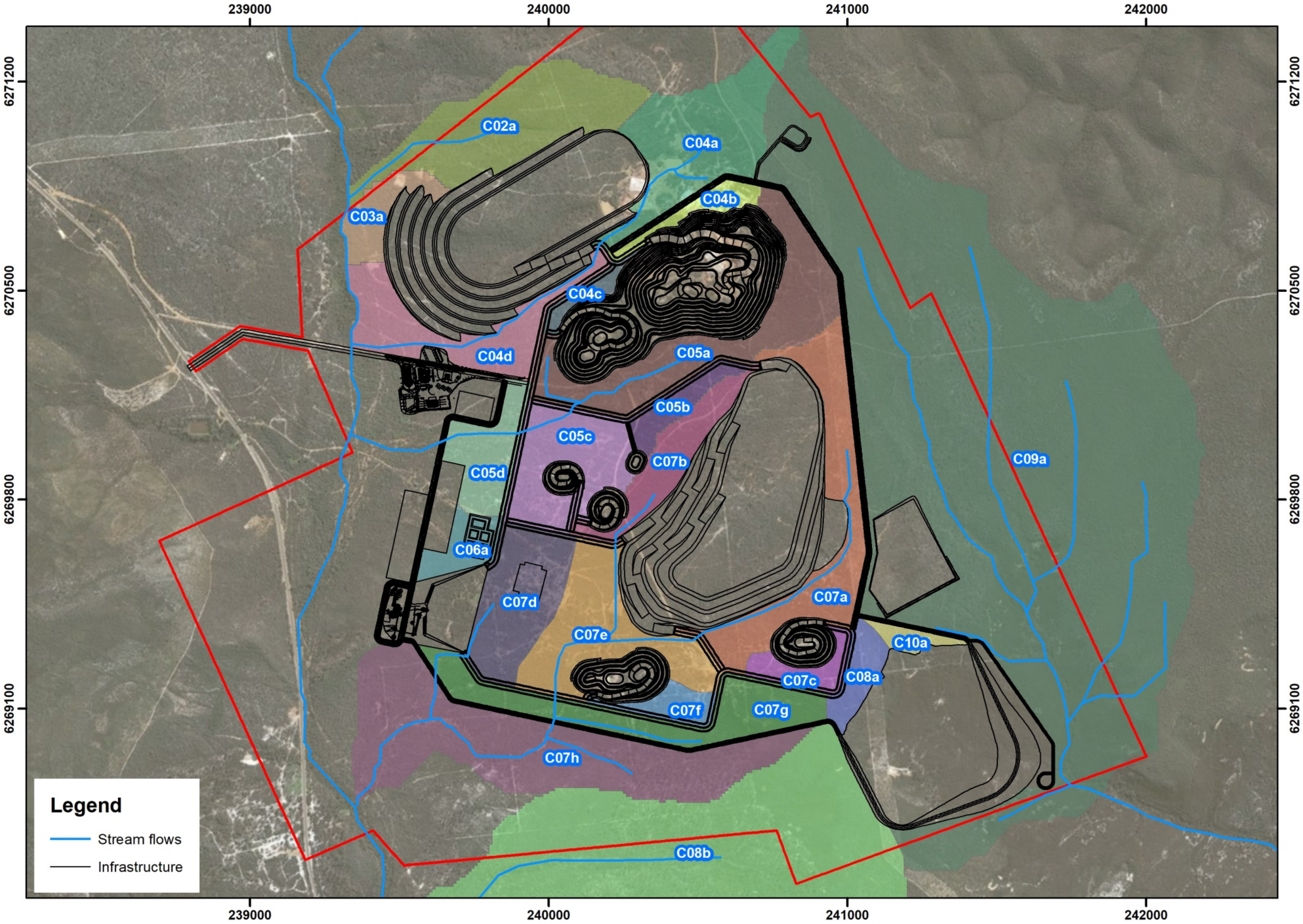
Open Drain ID	Base width (m)	Side batter (v:d)	Design Flow (m^3/s)	Stream grade (v:d)	Roughness (n)	Flow depth (m)
OD01	0	1:3	0.4	1:17	0.06	0.3
OD02	0.5	1:3	1.0	1:18	0.06	0.4
OD03	0	1:3	0.2	1:18	0.06	0.2
OD04	0	1:3	0.2	1:19	0.06	0.2
OD05	0	1:3	0.3	1:17	0.06	0.3
OD06	0	1:3	0.3	1:18	0.06	0.3
OD07	0.5	1:3	1.0	1:24	0.06	0.4
OD08	0.5	1:3	1.8	1:22	0.06	0.5
OD09	1.0	1:3	2.0	1:20	0.06	0.5
OD10	0	1:3	0.4	1:20	0.06	0.3
OD11	0	1:3	0.4	1:24	0.06	0.3
OD12	0	1:3	0.3	1:25	0.06	0.3
OD13	0	1:3	0.4	1:26	0.06	0.3
OD14	0	1:3	0.4	1:18	0.06	0.3

A portion of the proposed open drain 08 will be required to cut through approximately 2 m of the crest of a small rise on the eastern side of the southern WRL to overcome a natural depression which is present in this area and prevent water from sub-catchment C07-A from ponding against the WRL and/or flowing into the eastern Flag mine pit during storm events (Figure 5.3). Previous work conducted by Coffey also identified this need and proposed a pond design to overcome this issue (specifications in Coffey, 2011).

In addition to these identified locations, consideration should be given to drainage management (e.g. scour protection) alongside the down catchment sides of all proposed mine roads, mine pits and WRLs which have not been identified by the modelling due to the generally flat nature of the topography and hence the potential for surface water accumulation to occur along these roads which may not be apparent from the modelling carried out.

In order to prevent increased sediment loads from being released from disturbance areas into the surrounding and downstream surface water features a series of sediment settling or retention ponds should be constructed to reduce sediment loads from surface water runoff which passes through the proposed development area prior to entering the downstream catchments. The proposed positions of these ponds are shown in Figure 5.3. The final design of these structures should take into account both anticipated flood water flow rates and the need to position them downstream of disturbance areas.

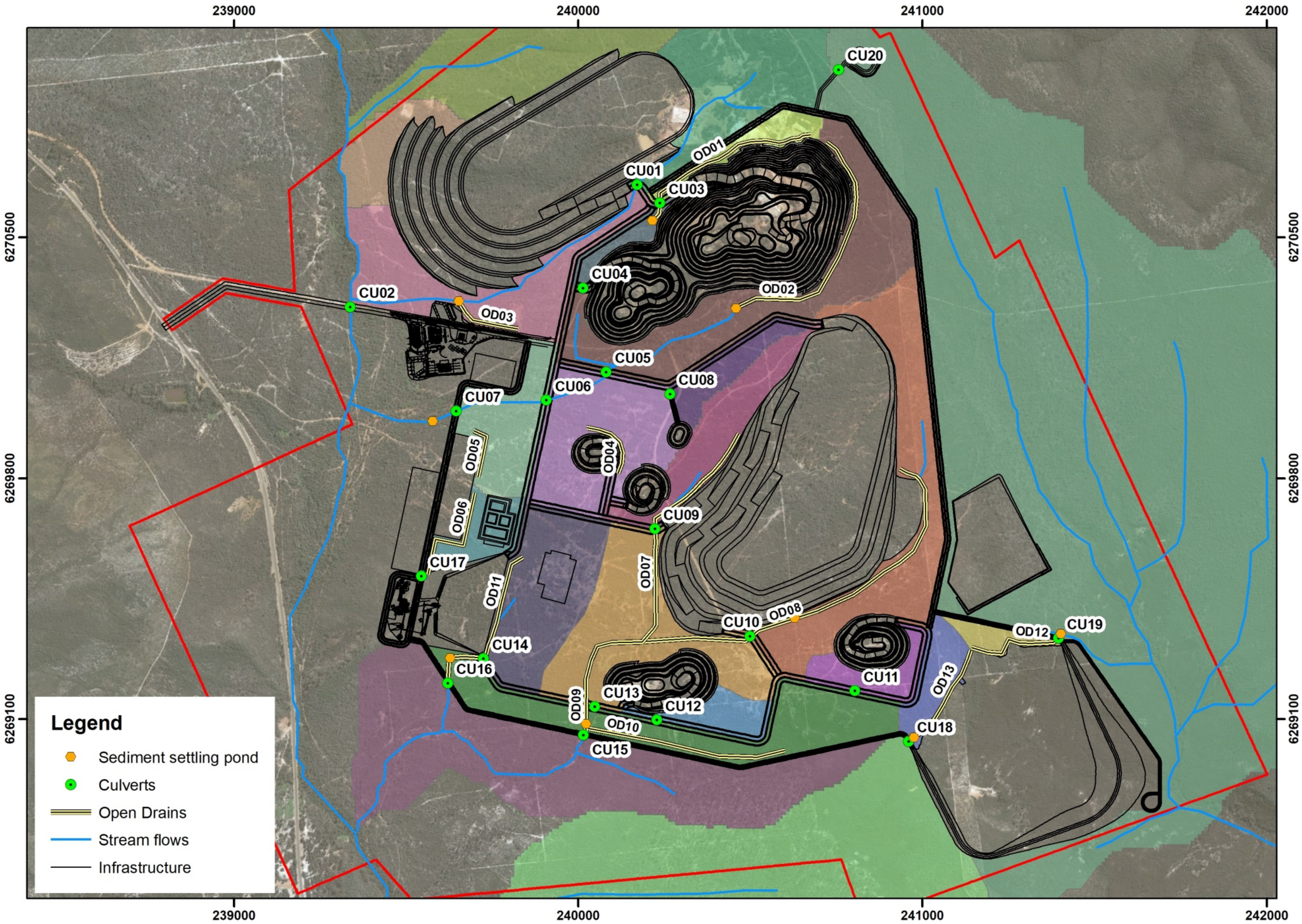
The topography surrounding the remaining proposed pits in the Kundip Project Area generally slopes away from the edge of the pits. Whilst surface water flow towards these pits is judged unlikely, the nature of the soils and the lack of obvious channelisation in this area means there is the potential that sediments might erode into the pits during rain events, potentially inducing gullying and impacting on pit wall stability. An appropriately sized bund surrounding the pit walls in these areas will minimise the potential for this to occur.



ACH MINERALS	Figure 5.2: Catchments during operation
KUNDIP SURFACE HYDROLOGY ASSESSMENT	

soilwater GROUP

PN: ACH-18-001 Prepared by: SC Date: 07/27/18 Reviewed by: ASP Date: 07/30/18 Revision: 3



ACH MINERALS	Figure 5.3: Identified culvert and open drain diversion structure locations	soilwater GROUP
KUNDIP SURFACE HYDROLOGY ASSESSMENT		

6 IMPACT ASSESSMENT

An impact assessment was undertaken to establish potential risks to downstream receptors, as a result of changes to water volume and quality. The results of this impact assessment inform additional recommendations made here to management off-site impacts and drainage controls.

6.1 POST MINE FLOOD MODELLING

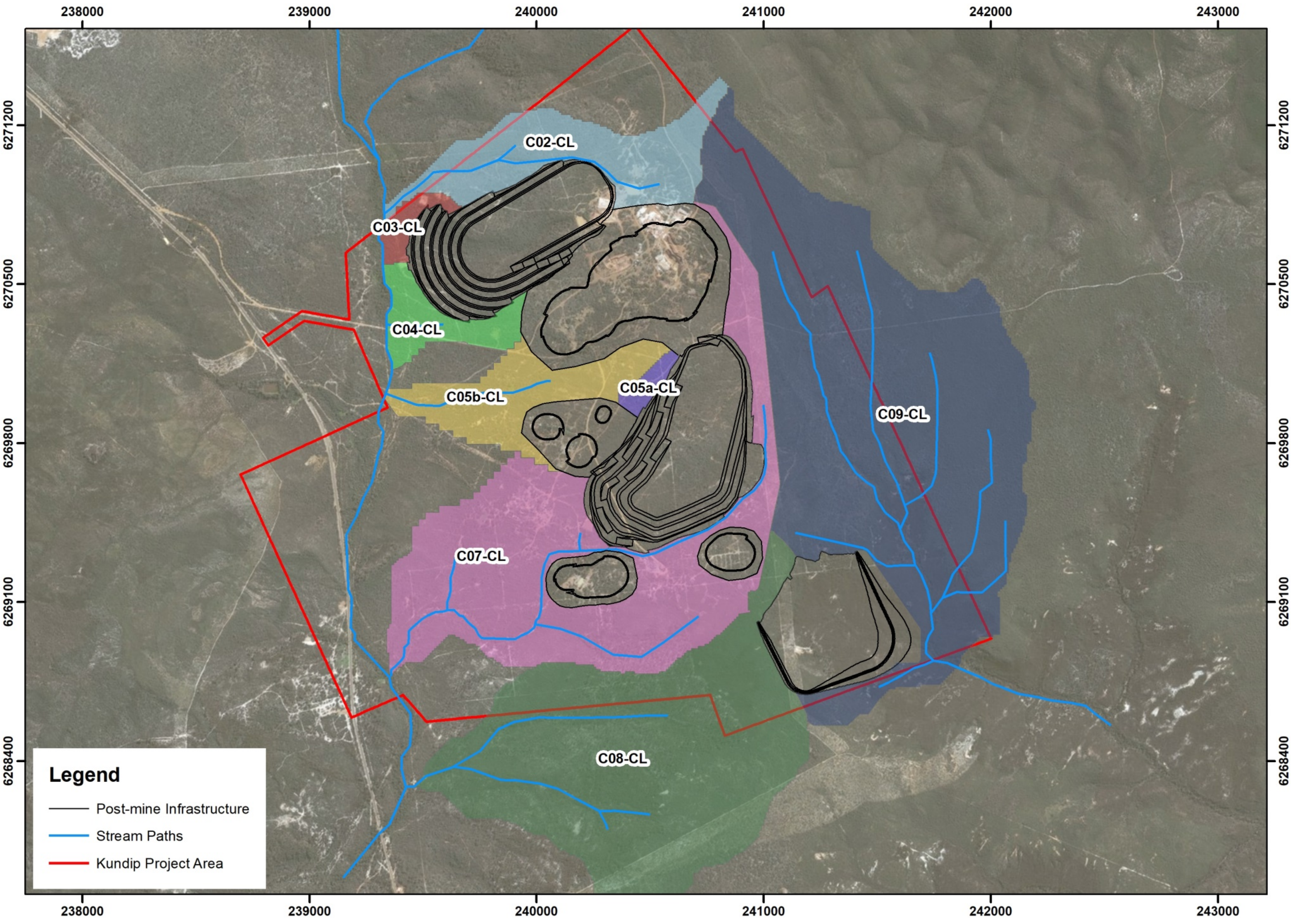
Estimated peak discharges for all contributing upslope catchments which will impact on the post mine landforms and infrastructure, along with their respective catchment characteristics are provided in Appendix A and shown in Figure 6.1. The modelled flood depth and extents under a 1:100 yr ARI event of those catchments which interact with the infrastructure which will remain after mine closure are shown in Figure 6.2.

The flood modelling illustrates that in most cases the extent and depth of flooding decreases with respect to pre-mine conditions, due to increased infiltration from clearing and areas within the pit boundaries and waste rock landforms where drainage has been assumed to be internal. These areas constitute a large fraction of the catchments they are within, between 10 and 50%, which results in a proportional reduction in flood volumes downstream.

Due to the requirement for abandonment bunds to be constructed at specific setback distances around the mine pits, several areas of the pre-mine catchments are either diverted (upper catchments areas of C02 and C07), or effectively isolated. The areas within the abandonment bunds generally flow towards the mine pits, with modelling showing that rainfall accumulation against the internal perimeter of the abandonment bunds within these areas is insignificant. The majority of the rainfall which falls within the abandonment bund areas will flow into the mine pits.

In contrast, the outside perimeter of the abandonment bunds were modelled to be exposed to significant flooding in several areas. The required bund locations cause several low lying areas to become isolated, causing a back-up of water and flooding to exceed 4 m in localised areas. These areas are located to the north of the Kaolin Pit, directly east of the North WRL, and at two locations on the northern boundaries of the abandonment bunds surrounding the two Flag Pits. In these three locations the combination of waste rock landforms and abandonment bund infrastructure cause accumulation of surface water runoff which is likely to impact on abandonment bund stability in the long term.

A surface water diversion construct which simulated the effect of a channel required to be constructed between the two Flag Pit abandonment bunds was included in the flood modelling. Careful consideration will need to be given to flood protection of the abandonment bunds and lower sections of the WRLs to prevent excessive scouring or bund degradation occurring following extreme rainfall events in these locations.



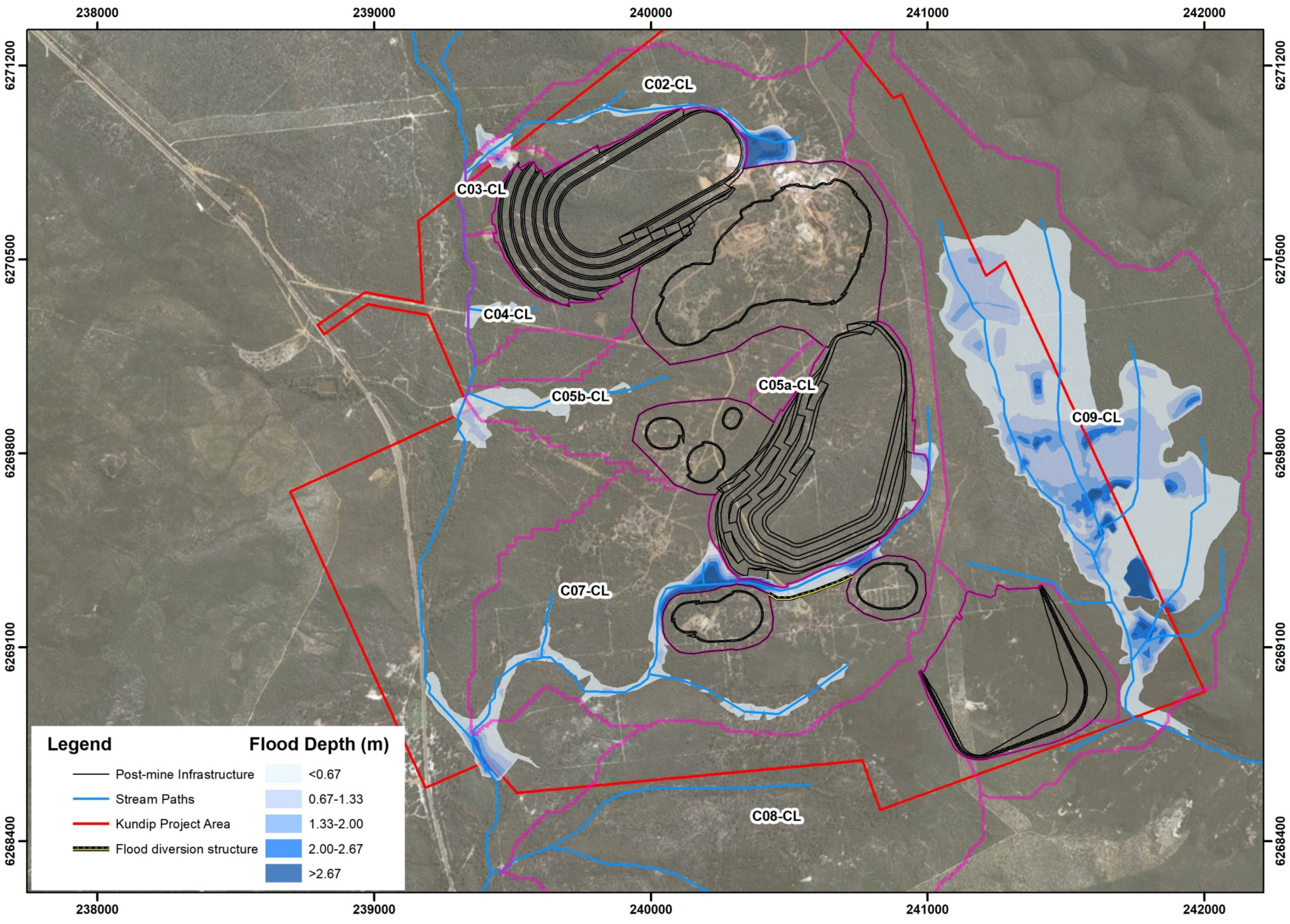
ACH MINERALS

KUNDIP SURFACE HYDROLOGY ASSESSMENT

Figure 6.1: Post mine catchments

soilwater GROUP

PN: ACH-18-001 Prepared by: SC Date: 09/03/18 Reviewed by: ASP Date: 09/04/18 Revision: 3



ACH MINERALS	Figure 6.2: 1:100 yr ARI modelled flood extent for post-mine topography	soilwater GROUP
KUNDIP SURFACE HYDROLOGY ASSESSMENT		

PN: ACH-18-001 Prepared by: SC Date: 09/03/18 Reviewed by: ASP Date: 09/04/18 Revision: 3

6.2 CHANGES TO FLOW PATHWAYS, FLOW VARIABILITY & VOLUMES

The catchments which drain to culverts include the entire area within the ring road surrounding the site, the catchments impacted by the Northern Waste Dump and the small catchment area north of the magazine. The percentage of each catchment which will be affected, either through water diversion into drains and culverts or isolated to internal drainage within the boundary of proposed site infrastructure such as a mine pit are summarised in Table 6.1.

Table 6.1: Summary of catchments affected by proposed infrastructure

Catchment ID	Total size (km^2)	% diverted	% isolated	% unaffected
C02	0.22	11.0	9.1	79.9
C03	0.10	0.0	49.2	50.8
C04	0.68	8.8	44.5	36.7
C05	0.76	68.8	31.2	0.0
C07	1.77	44.9	35.0	20.1
C08	1.30	0.9	5.2	93.9
C09	2.21	7.2	13.5	79.3

The total amount of catchment area which will be affected by the proposed development is approximately 3.17 km^2. This constitutes just 0.9% of the wider Steere River catchment area.

The construction of culverts at those points indicated will ensure that for the majority of the affected catchment areas surface water flows will largely maintain connectivity with their current downstream course. The impact of the culverts may be to reduce peak flows slightly downstream of the proposed infrastructure. The net impact on flows is anticipated to constitute a loss of flow volume less than the one third of each small catchments annual flow as most runoff is expected to be generated close to creek lines which are generally not overly affected by the proposed infrastructure placements. Surface flows will be partially compensated by the construction of diversion channels and the interception of increased flows.

Waste dumps are typically constructed with flat or inward-sloping tops, and consist primarily of coarse-grained material with high-permeability. Therefore, the majority of rain falling directly onto the proposed dumps at Kundip is expected to infiltrate, rather than run along the surface, and will not need to be managed as stormwater. Small drains may be warranted along the base of the waste dump in order to capture any runoff that occurs off the outer slopes of the landforms. If the dumps are properly designed and constructed, the volume of runoff should only be minor; however, it is likely to be sediment-laden. Thus, sediment traps may also be warranted at locations where the drains discharge off-tenement or into a natural creek line.

There is not anticipated to be significant flow volume reductions in the broader catchment as a result of the proposed development given the small fraction of the wider catchment area within the development area. Following decommissioning of the mine and rehabilitation of creeks no long term impacts to hydrological processes are expected.

6.3 SURFACE WATER QUALITY

Some site activities may result in an increase in sediment-laden runoff, thereby potentially increasing the sediment load in surface waters. As the majority of sediment that is eroded from disturbed areas is likely to be highest during more intense rainfall events, the largest releases of sediment from site are likely to be in proportion to the natural sediment discharge from undisturbed catchments. As noted above there may be a need to intercept minor surface runoff from the base of waste dumps at Kundip in the short term whilst vegetation establishment is proceeding to prevent excessive sediment from being released into downstream catchments via surface water.

During operation dust management along haul roads will assist in minimising the transport of mobile sediments into surface water channels. Small piles of soil and organic matter along the edge of haul roads on slopes leading to creek lines can be used to control erosion and sedimentation.

Detention ponds have the potential to partly fill with sediment, reducing storage capacity and necessitating activities to empty and deal with the accumulated material. To mitigate sediment accumulation and reduced storage capacity documented inspections of on-site detention ponds is recommended following major rainfall events. Inspections need to be undertaken to ensure:

- There are no low points in detention structures that could overtop in a large storm event
- Design capacity and minimum freeboard of sediment control ponds and drains are maintained
- Drains and sediment control ponds are operating as intended; and
- There are no active areas of erosion

A maintenance program for the sediment and erosion control structures should be implemented. The following maintenance or remediation works are suggested for sediment control structures:

- Removal of accumulated sediment should be considered when sediment levels reach 30% of the total depth. If this does not occur premature filling of the pond could result; and
- Silt and salts removed from sediment traps that have had dust suppression water applied should be disposed of within the tailings storage facility.

The points listed above can be captured within a management plan for all detention or sediment ponds detailing:

- Utilisation of captured surface water;
- Maintenance;
- Storage management; and
- A risk assessment of the management strategy.

Management of access roads to such facilities will be required to minimise erosion. Furthermore, these locations are also susceptible to flooding and detention pond facilities should be designed to withstand the modelled expected design flood conditions.

6.3.1 CURRENT SURFACE WATER QUALITY MONITORING

Current surface water quality monitoring is conducted biannually at a number of water storage dams and water bores which exist throughout the project area. The surface water sampling conducted provides an indication of the baseline condition of upstream catchment runoff which represents an important database resource for future monitoring of downstream impacts. The surface water monitoring locations are listed below;

- Kaolin dam,
- Kundip tailings dam,
- Harbour View dam,
- Flag dam; and
- H/Railway dam.

The water samples taken are tested for general water quality, with the list of analyses conducted on each water sample taken including the following;

- pH
- Electrical conductivity
- Total dissolved solids (TDS)
- Total Hardness (CaCO3)
- Total Alkalinity
- Ammonia
- Nitrite & Nitrate
- Total Nitrogen
- Fluoride
- Dissolved metals (Al, As, Be, Ba, Cd, Cr, Co, Cu, Pb, Li, Mn, Mo, Ni, Se, Sn, U, V, Zn, B and Fe)
- Dissolved Hg
- Weak acid dissociable (WAD) Cyanide
- Major cations (Ca, Mg, Na and K)
- Chloride
- Sulfate
- Total Phosphorous
- Total anions
- Total cations
- Faecal coliforms

In addition to this a number of water bores across the area are also tested for pH, electrical conductivity and faecal coliforms. The results of this testing are summarised in Appendix B. This procedure should form the basis of site wide water monitoring procedures during construction, operation and closure activities.

The results of monitoring show the surface water quality within the storage dams is generally good, with water existing in a circum-neutral pH between 6.5 and 8, with low salinity, TDS and major cation/anion contents. The exception to this is samples taken from the Kundip Tailings Dam which reported high TDS and associated salinity. The reported levels of dissolved metals were uniformly low across all samples taken from surface water storage locations. The levels of nitrogen within the samples are low, however the phosphorous levels can be considered elevated, likely as a result of runoff from upstream fertiliser application.

A comparison of these results with sampling undertaken at the Jones Road crossing in the lower reaches of the Steere River shows the values are all within 2 standard deviations, with the exception of the measured phosphorous levels which are elevated within the Site surface water samples in comparison to the Jones Road crossing samples.

Measurement of biological parameters through faecal coliforms shows that elevated levels of colony forming units (cfus) exist in several of the dams, principally the Kaolin Dam and Flag Dam 2, at 2400 and 1200 cfu/100 mL respectively. These levels exceed the limit for being used to generate pasture and fodder for dairy and grazing animals. This is likely a result of animal usage of the dam water as a drinking source introducing faecal matter coupled with extended holding times within the dams allowing for microorganism growth.

6.4 CONSIDERATION FOR SITE CLOSURE

The following surface water management aspects should be considered with respect to site closure:

- Significant proportions of catchments C04, C05 and C07 will be removed from the surface runoff system via the development of pit voids and waste rock landforms at Kundip.
- Following removal of the ring roads around the Project Area the natural topographic surface should be re-established and creek lines rehabilitated. This will largely restore the natural surface water hydrological conditions existing prior to the mine development.
- Infrastructure (roads, buildings, stockpiles, etc.) will likely be removed from the infrastructure area, and the land surface sought to be rehabilitated back to its pre-mine condition. Surface water management in this area will therefore no longer be required, and the existing drains and sediment traps in the infrastructure area should be removed or filled in and reshaped along with the remainder of the area.
- It may be warranted to leave the proposed drains and sediment traps associated with the waste dump in place to manage infrequent sediment releases after site closure. The sediment traps will lose their effectiveness as they fill with sediment over time, however, sediment releases should also be reduced with time, as the waste dump rehabilitation progresses and surface stability increases.

7 CONCLUSIONS & RECOMMENDATIONS

This hydrological assessment studied the proposed development of the Kundip Project Area which is part of the Ravensthorpe Gold Project. Peak flows were estimated for each sub-catchment area based on both the rational and index flood methods described in the Australian Rainfall and Runoff Guidelines. In light of the findings from this assessment the following recommendations are made:

- The surface water control infrastructure designs developed here should be reviewed and refined prior to commencing the development to ensure they align with updated requirements, and
- Consideration should be given to abandonment bund design and locations to prevent modelled flooding from negatively impacting on closure infrastructure.

The development is likely to have the following impacts to hydrological processes after appropriate surface water management:

- Minimal impact to annual flow volumes and the hydrological regime in most of the sub-catchments which cross the development areas following the installation of culverts and drain diversion structures,
- Minor reduction in surface water flow volumes and altered hydrologic variability downstream of the development; and
- Minimal impacts to flows and water quality within either the Steere or Jerdacuttup Rivers as a result of the development.

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APPENDIX A

FLOOD MODELLING DATA

Table A: Flood modelling data obtained for pre-mine catchments

Catchment ID (Pre-Mine)	Catchment Area (km^2)	Stream Length (km)	Equal Area Slope (m/km)	% Cleared	Time of Concentration t_c (hours)	Discharge Q (m^3 s^{-1})									
						Q1		Q5		Q20		Q50		Q100	
						RM	IFM	RM	IFM	RM	IFM	RM	IFM	RM	IFM
C01	0.63	1.62	11.5	5	0.64	0.00	0.07	0.30	0.24	0.94	0.72	1.62	1.33	2.29	2.34
C02	0.22	1.05	9.7	5	0.43	0.00	0.04	0.15	0.12	0.49	0.38	0.85	0.70	1.21	1.23
C03	0.10	0.53	9.2	10	0.31	0.00	0.02	0.11	0.08	0.35	0.23	0.61	0.43	0.88	0.76
C04	0.68	1.93	7.6	15	0.65	0.00	0.07	0.33	0.25	1.04	0.75	1.80	1.39	2.54	2.44
C05	0.76	1.72	7.5	10	0.68	0.00	0.08	0.39	0.26	1.22	0.80	2.10	1.49	2.97	2.62
C06	0.08	0.60	4.2	5	0.29	0.00	0.02	0.10	0.07	0.33	0.2	0.58	0.37	0.84	0.66
C07	1.77	2.35	5.4	5	0.94	0.00	0.13	0.57	0.44	1.76	1.34	3.02	2.49	4.25	4.38
C08	1.30	1.76	4.2	5	0.84	0.00	0.11	0.50	0.36	1.54	1.11	2.64	2.05	3.72	3.61
C09	1.92	2.75	4.2	5	0.93	0.00	0.14	0.59	0.46	1.82	1.42	3.12	2.63	4.38	4.62
C10	0.50	0.92	5.4	5	0.57	0.00	0.06	0.30	0.19	0.95	0.59	1.65	1.10	2.33	1.93

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Table B: Flood modelling data obtained for revised catchments (during operations)

Catchment ID (Operations)	Catchment Area (km^2)	Stream Length (km)	Equal Area Slope (m/km)	% Cleared	Time of Concentration t_c (hours)	Discharge Q ($m^3\ s^{-1}$)									
						Q1		Q5		Q20		Q50		Q100	
						RM	IFM	RM	IFM	RM	IFM	RM	IFM	RM	IFM
C02-A	0.20	0.65	8.1	5	0.65	0.00	0.04	0.12	0.12	0.30	0.36	0.55	0.67	1.06	1.17
C03-A	0.05	0.22	6.2	10	0.43	0.00	0.01	0.04	0.05	0.10	0.15	0.19	0.27	0.37	0.48
C04-A	0.19	0.59	8.0	35	0.62	0.00	0.03	0.06	0.11	0.15	0.34	0.27	0.63	0.52	1.11
C04-B	0.03	0.48	7.6	50	0.58	0.00	0.01	0.05	0.04	0.12	0.12	0.22	0.22	0.42	0.39
C04-C	0.02	0.33	5.8	5	0.50	0.00	0.01	0.08	0.03	0.19	0.09	0.35	0.16	0.69	0.28
C04-D	0.13	0.64	5.6	5	0.64	0.00	0.03	0.12	0.09	0.30	0.27	0.54	0.50	1.05	0.89
C05-A	0.19	0.95	7.1	5	0.75	0.00	0.03	0.16	0.11	0.40	0.35	0.73	0.64	1.41	1.13
C05-B	0.04	0.43	6.8	5	0.55	0.00	0.01	0.09	0.04	0.22	0.13	0.41	0.24	0.79	0.43
C05-C	0.12	0.41	6.1	10	0.54	0.00	0.03	0.07	0.09	0.17	0.27	0.31	0.49	0.60	0.86
C05-D	0.08	0.26	4.5	10	0.46	0.00	0.02	0.05	0.07	0.12	0.20	0.22	0.37	0.43	0.65
C06-A	0.04	0.25	4.4	5	0.45	0.00	0.01	0.06	0.04	0.15	0.13	0.27	0.25	0.52	0.44
C07-A	0.17	1.41	6.8	10	0.87	0.00	0.03	0.17	0.11	0.44	0.33	0.80	0.61	1.55	1.08
C07-B	0.07	0.79	7.1	5	0.69	0.00	0.02	0.15	0.06	0.37	0.20	0.67	0.37	1.29	0.64
C07-C	0.03	0.28	5.2	10	0.47	0.00	0.01	0.05	0.04	0.13	0.12	0.24	0.22	0.47	0.39
C07-D	0.12	0.54	5.5	35	0.60	0.00	0.03	0.05	0.09	0.13	0.27	0.24	0.49	0.47	0.87
C07-E	0.15	0.66	6.2	25	0.65	0.00	0.03	0.07	0.10	0.18	0.30	0.33	0.55	0.65	0.97
C07-F	0.03	0.31	6.1	10	0.49	0.00	0.01	0.06	0.04	0.15	0.12	0.27	0.21	0.52	0.38
C07-G	0.16	0.72	6.7	10	0.67	0.00	0.03	0.11	0.10	0.27	0.31	0.49	0.57	0.94	1.00
C07-H	0.35	1.11	6.1	5	0.79	0.00	0.05	0.19	0.16	0.47	0.50	0.85	0.93	1.65	1.63
C08-A	0.04	0.42	6.4	5	0.55	0.00	0.01	0.09	0.04	0.22	0.13	0.40	0.25	0.77	0.43

Catchment ID	Catchment Area (km^2)	Stream Length	Equal Area Slope	% Cleared	Time of Concentration	Discharge Q (m^3 s^{-1})									
C08-B	1.22	1.67	4.4	5	0.92	0.00	0.10	0.24	0.35	0.60	1.07	1.09	1.98	2.12	3.48
C09-A	1.92	2.75	4.2	5	1.12	0.00	0.14	0.35	0.46	0.87	1.42	1.59	2.62	3.08	4.61
C10-A	0.02	0.25	6.1	10	0.45	0.00	0.01	0.05	0.03	0.12	0.09	0.22	0.16	0.42	0.28

Table C: Flood modelling data obtained for revised catchments (post mining)

Catchment ID (Closure)	Catchment Area (km²)	Stream Length (km)	Equal Area Slope (m/km)	% Cleared	Time of Concentration t_c (hours)	Discharge Q (m^3 s^{-1})									
						Q1		Q5		Q20		Q50		Q100	
						RM	IFM	RM	IFM	RM	IFM	RM	IFM	RM	IFM
C02-CL	0.36	1.26	7.4	15	0.83	0.00	0.05	0.14	0.17	0.34	0.51	0.63	0.94	1.21	1.66
C03-CL	0.04	0.16	5.7	10	0.38	0.00	0.01	0.03	0.04	0.08	0.13	0.15	0.25	0.30	0.44
C04-CL	0.13	0.56	5.6	5	0.61	0.00	0.03	0.10	0.09	0.26	0.27	0.47	0.51	0.92	0.89
C05a-CL	0.03	0.10	6.8	5	0.32	0.00	0.01	0.03	0.04	0.07	0.13	0.13	0.25	0.25	0.44
C05b-CL	0.27	0.94	7.0	5	0.74	0.00	0.04	0.16	0.14	0.39	0.43	0.72	0.79	1.40	1.39
C07-CL	1.04	1.81	5.9	5	0.95	0.00	0.09	0.26	0.32	0.65	0.97	1.19	1.80	2.30	3.16
C08-CL	1.33	1.70	4.4	5	0.93	0.00	0.11	0.24	0.37	0.61	1.12	1.11	2.08	2.16	3.66
C09-CL	1.93	2.75	4.2	5	1.12	0.00	0.14	0.35	0.47	0.87	1.42	1.59	2.63	3.08	4.63

APPENDIX B
SURFACE WATER MONITORING DATA

Analyte	Date	Unit	LOR	Kaolin Dam	Kundip Tailings Dam	Harbour View Dam	Flag Dam (01)	Flag Dam (02)	H/Railway Dam
pH	14/01/18	pH Unit	0.01	6.69	7.75	7.59	7.43	7.50	7.26
	17/05/18			6.79	7.11	7.56	7.56	7.40	7.23
Electrical conductivity	14/01/18	µS/cm	1	502	4790	435	830	470	420
	17/05/18			527	4500	552	1020	9120	481
TDS	14/01/18	mg/L	10	668	2800	518	793	549	636
	17/05/18			688	2600	618	1100	6650	739
Total Hardness	14/01/18	mg/L	1	50	524	46	106	44	55
	17/05/18			43	527	50	123	1200	52
Total alkalinity	14/01/18	mg/L	1	8	92	65	52	59	43
	17/05/18			8	15	68	52	73	40
Sulfate	14/01/18	mg/L	1	35	490	12	65	19	29
	17/05/18			30	447	14	80	642	30
Chloride	14/01/18	mg/L	1	121	1160	84	193	96	88
	17/05/18			137	1090	119	251	2760	102
Calcium	14/01/18	mg/L	1	5	63	7	16	6	12
	17/05/18			4	56	7	18	88	4
Magnesium	14/01/18	mg/L	1	9	89	7	16	7	6
	17/05/18			8	94	8	19	238	6
Sodium	14/01/18	mg/L	1	79	817	74	120	81	66
	17/05/18			76	692	85	128	1530	67
Potassium	14/01/18	mg/L	1	5	32	8	10	8	8
	17/05/18			6	28	9	12	58	9
Aluminium	14/01/18	mg/L	0.01	0.43	0.01	0.72	0.26	1.67	0.38
	17/05/18								
Arsenic	14/01/18	mg/L	0.001	0.001	0.001	0.001	0.002	0.003	0.004
	17/05/18								
Beryllium	14/01/18	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	17/05/18								
Barium	14/01/18	mg/L	0.001	0.014	0.122	0.016	0.044	0.008	0.010
	17/05/18								
Cadmium	14/01/18	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	17/05/18								
Chromium	14/01/18	mg/L	0.001	0.002	<0.001	0.005	0.002	0.007	0.003
	17/05/18								
Cobalt	14/01/18	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	0.011	0.001
	17/05/18								
Copper	14/01/18	mg/L	0.001	0.030	0.013	0.043	0.206	0.412	0.081
	17/05/18								

Analyte	Date	Unit	LOR	Kaolin Dam	Kundip Tailings Dam	Harbour View Dam	Flag Dam (01)	Flag Dam (02)	H/Railway Dam
Lead	14/01/18	mg/L	0.001	1.40	<0.001	0.006	0.044	0.006	0.004
	17/05/18								
Lithium	14/01/18	mg/L	0.001	<0.001	0.002	<0.001	0.004	0.002	<0.001
	17/05/18								
Manganese	14/01/18	mg/L	0.001	0.009	<0.001	0.042	0.061	0.074	0.054
	17/05/18								
Molybdenum	14/01/18	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	17/05/18								
Nickel	14/01/18	mg/L	0.001	0.003	0.001	0.006	0.005	0.009	0.004
	17/05/18								
Selenium	14/01/18	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	17/05/18								
Tin	14/01/18	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	17/05/18								
Uranium	14/01/18	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	17/05/18								
Vanadium	14/01/18	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	17/05/18								
Zinc	14/01/18	mg/L	0.005	0.008	<0.005	<0.005	<0.005	0.007	<0.005
	17/05/18								
Boron	14/01/18	mg/L	0.05	0.09	1.17	0.25	0.24	0.23	0.16
	17/05/18								
Iron	14/01/18	mg/L	0.05	0.45	<0.05	5.26	0.78	5.64	1.36
	17/05/18								
Mercury	14/01/18	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	17/05/18								
WAD Cyanide	14/01/18	mg/L	0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
	17/05/18			<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Fluoride	14/01/18	mg/L	0.1	0.1	0.5	0.1	0.3	0.2	0.1
	17/05/18			0.2	0.2	0.2	0.5	0.2	0.2
Ammonia as N	14/01/18	mg/L	0.01	0.05	0.02	0.02	<0.01	0.14	0.05
	17/05/18			0.09	0.01	0.11	0.02	0.76	0.10
Nitrite as N	14/01/18	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	17/05/18			<0.01	<0.01	0.01	<0.01	<0.01	<0.01
Nitrate as N	14/01/18	mg/L	0.01	0.19	<0.01	<0.01	<0.01	<0.01	0.02
	17/05/18			0.20	<0.01	0.02	<0.01	0.01	0.07
Total Nitrogen as N	14/01/18	mg/L	0.1	0.9	1.0	1.2	1.0	2.2	0.8
	17/05/18			0.9	0.5	2.2	1.6	2.8	1.7

Analyte	Date	Unit	LOR	Kaolin Dam	Kundip Tailings Dam	Harbour View Dam	Flag Dam (01)	Flag Dam (02)	H/Railway Dam
Total Phosphorus	14/01/18	mg/L	0.01	0.07	0.09	0.10	0.10	0.15	0.10
	17/05/18			<0.02	0.01	0.08	0.04	0.08	0.07
Total Anions	14/01/18	meq/L	0.01	4.30	44.8	3.92	7.84	4.28	3.94
	17/05/18			4.65	40.4	5.01	9.78	92.7	4.30
Total Cations	14/01/18	meq/L	0.01	4.55	46.8	4.35	7.59	4.60	4.17
	17/05/18			4.32	41.3	4.94	8.34	92.0	4.19
Faecal Coliforms	14/01/18	CFU/100mL	1	2400	~17	~320	~530	~1200	~2
	17/05/18			<10	23	~24	2300	130	<10